Before the
FEDERAL COMMUNICATIONS COMMISSION
Washington, D.C. 20554

In the Matter of	)	
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	)	
LightSquared Technical Working Group Report	)	IB Docket No. 11-109 DA 12-214
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	)	
and	)	
	)	
LightSquared Subsidiary LLC Request for Modification of its Authority for an Ancillary Terrestrial Component	)	File No. SAT-MOD-20101118-00239

COMMENTS IN OPPOSITION OF LIGHTSQUARED INC.

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EXECUTIVE SUMMARY

The Commission encouraged—and, indeed, *affirmatively required*—LightSquared to deploy a nationwide 4G LTE network by 2015 to aid the Commission in achieving its broadband policy goals. LightSquared committed fully to meeting the Commission's mandate, investing more than $4 billion to extend competitive broadband access to hundreds of millions of consumers. The basic legal framework that enabled this investment in America's future was established by a final Commission order almost seven years ago, after a four-year rulemaking process, and a licensing process in which the GPS industry provided support for the network that it now seeks to destroy.

In a precipitous turn of events, the Commission on February 15, 2012, released a *Public Notice* that proposes to vacate and suspend indefinitely the authorizations that sustain critical elements of LightSquared's 4G LTE network. The asserted basis for these actions is a letter provided by NTIA[1] about the purported impact of LightSquared's operations on certain GPS receivers that are not regulated by the Commission.

The LightSquared network promises to bring broadband to underserved areas, drive wireless competition, create new businesses, invigorate existing ones, and create tens of thousands of new jobs. The proposed actions would eviscerate these benefits and represent an astounding, unsupported, and unprecedented reversal of Commission policy. If taken, those actions would set back our nation's broadband initiative by many years.

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1 Letter to Julius Genachowski, Chairman, Federal Communications Commission from Lawrence E. Strickling, Assistant Secretary for Communications and Information, U.S. Dep't of Commerce, at 8 (Feb. 14, 2012) ("*NTIA Letter*").

The unfairness and inequity embodied in the *Public Notice* is beyond drastic. The sudden and dramatic proposal to preclude LightSquared from operating its licensed facilities is legally impermissible, arbitrary, and capricious for the following reasons:

<u>There is no legally cognizable interference</u>

Putting aside the small number of GPS receivers that may be affected, the *Public Notice* fails to acknowledge a critical threshold issue: Under the Communications Act and the Commission's implementing rules, regulations and policies, *no legal protection exists for GPS receivers that are incompatible with LightSquared's network because they "listen" for GPS signals in the portion of radio spectrum that is licensed to LightSquared.*

Significantly, LightSquared's network does not interfere with the portions of the radio spectrum in which GPS satellites transmit GPS signals. Both the Commission and NTIA already have determined that the LightSquared network satisfies the GPS protection criteria that the GPS industry advocated, to which LightSquared agreed, and that NTIA urged the Commission to impose over nine years ago. The sole concern now arises because manufacturers have constructed some GPS devices that may not work as intended when they attempt to detect GPS signals in portions of spectrum that are not allocated for GPS use, and have been licensed to LightSquared for other purposes for many years. In the words of the *Public Notice*, the adverse effect arises when "signals are received by GPS receivers outside the frequency bands allocated to GPS."[2] This effect is called "overload," and it arises because GPS manufacturers have failed to account for the operating environment surrounding LightSquared's network, which both NTIA

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2 *Public Notice*, International Bureau Invites Comment on NTIA Letter Regarding LightSquared Conditional Waiver, IB Docket No. 11-109, DA 12-214, at 2 n.6 (rel. Feb. 15, 2012) ("*Public Notice*").

and the Commission endorsed. Stated another way, some GPS manufacturers have made poor design choices and have sold defective product.

Any concerns about the incompatibility of a limited number of GPS receivers with LightSquared's long-planned ATC operations *simply do not constitute legally cognizable "harmful interference"* and thus cannot justify the actions proposed by the *Public Notice*.

<u>The Executive Agency testing is deeply flawed and fatally biased</u>

NTIA has relied upon flawed and biased tests that offer no meaningful insight into the feasibility of real-world co-existence between LightSquared's network and GPS receivers.

First, the Executive Agency testing and analysis contain many defects, including the following:

- The Executive Agency testing was not based on the operating parameters under which LightSquared plans to deploy its network, rather, the testing and analysis assumed power levels many times more than what LightSquared plans to use, and used "free space propagation" that failed to account for the obstructions present in virtually any actual deployment; consequently, the results significantly overstate any chance of overload effects;

- GPS manufacturers were allowed to select units to be tested without review of whether those units were fairly representative of the current market, with the result that some of the devices tested were manufactured as far back as 1998 and others were not production devices;

- In other respects as well, much of the testing and analysis failed to comply with basic scientific methods;

- The Executive Agencies rejected accommodation proposals before the relevant requirements were even established; and

- NTIA neither analyzed nor credited the ability of GPS manufacturers to build effective receivers that are compatible with LightSquared's network.

Second, the Executive Agency testing is inherently unreliable because it is infected by a potential conflict of interest. Indeed, recent press reports suggest that the tainted testing is but one manifestation of a broader effort by the commercial GPS industry and certain of NTIA's constituent agencies to "'synch up' . . . in order to defeat LightSquared's plans to build the nation's first wholesale broadband network."[3]

Third, viewed objectively, no scientifically valid evidence exists that even 1% of GPS receivers would experience adverse performance consequences as a result of LightSquared's operations, as currently proposed.

The Commission must critically evaluate NTIA's conclusions

The lack of analysis in the *Public Notice*, and the speed with which the Commission released it (the day after receiving the *NTIA Letter*), are powerful evidence of an arbitrary and capricious process.

As an independent agency, the Commission is charged by Congress to conduct its own independent analysis. The Commission could not possibly have reconciled the flawed NTIA conclusions with its own administrative record in one day. Nor has the Commission paused to consider how the precipitous actions proposed in the *Public Notice* can be squared with (i) the NTIA's prior evaluations of the LightSquared network, (ii) the adequacy of the GPS protection criteria that NTIA endorsed, (iii) the expectation for more than a decade that a hybrid satellite-terrestrial network would be deployed, (iv) the apparent failure of certain GPS device manufacturers to plan for that deployment, and (v) the technical reality that GPS receivers actually can coexist with such a network.

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[3] E. Krigman, *DoD Official Urged 'Synch Up' With GPS Lobby to Stop LightSquared*, POLITICO (Mar. 1, 2012).

The Commission must exhaust all reasonable alternatives

One of the most disturbing aspects of the *Public Notice* is the false choice presented between preserving LightSquared's ATC authority and maintaining GPS service. In fact, both goals can be achieved.

LightSquared already has offered good-faith solutions over and above the protections contained in the Commission's rules and the terms of LightSquared's authority. Those solutions would voluntarily constrain LightSquared's operations in various ways in order to "protect" GPS receivers while still allowing LightSquared to commence commercial ATC service. While these efforts have been met with stonewalling by the GPS industry, they are viable proposals that must be considered.

And should the Commission conclude (despite the overwhelming evidence to the contrary) that those solutions do not work, then the history and the equities, as well as LightSquared's significant investment and reasonable reliance, would mandate that the Commission and NTIA, working with LightSquared, identify and engineer a partial or total exchange of alternative terrestrial spectrum rights. Contrary to NTIA's assertion that no options exist, this approach clearly would offer a "mitigation strategy" that would "both solve the interference issues and provide LightSquared with an adequate commercial network deployment." This approach would be consistent with the advocacy of GPS interests that repeatedly have claimed that the *only* solution to the "overload problem" is for LightSquared to operate in alternative spectrum.

In short, there is no valid basis to require that LightSquared bear full responsibility for resolving an issue that it did not create. And it would be profoundly arbitrary for the Commission to use a flawed and incomplete process that was prematurely halted to strip

LightSquared of the right to operate under terms established seven years ago with the support—in repeated public legal proceedings—of the same interests that now oppose LightSquared's operation. That is not consistent with the Administrative Procedure Act.

<u>The proposed actions cannot be reconciled with the public interest or LightSquared's legal rights</u>

In the near term, vacating or suspending LightSquared's ATC authority would deprive hundreds of millions of consumers of access to critical mobile broadband service (particularly in rural areas), imperil the creation of tens of thousands of American jobs, and waste billions of investment dollars spent in fulfillment of the Commission's mandate to LightSquared and its investors.

In the longer term, such actions would undermine confidence in the integrity of the Commission's rules and policies, cast a long shadow on upcoming spectrum auctions, chill investment in our nation's telecommunications infrastructure, and stifle economic growth.

Just a few weeks ago, Chairman Genachowski explained how the Commission is focused on "strengthening incentives for investment in mobile infrastructure," and recognized that "[w]ireless infrastructure doesn't build by itself. It requires many billions of dollars in investment—overwhelmingly by private companies."[4] The Chairman declared: "*[W]e've recognized that regulatory certainty and predictability promote investment*."[5]

The *Public Notice* is diametrically opposed to the Chairman's observations, as service providers and their financing sources will recognize when they weigh the lesson of what would be one of the most disastrous "bait-and switch" episodes in the history of telecommunications regulation.

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4 Julius Genachowski, Chairman, Federal Communications Commission, Remarks as Prepared for Delivery, GSMA Mobile World Congress, at 3 (Feb. 27, 2012).

5 *Id*. at 4 (emphasis added).

The regulatory uncertainty created by the Commission's proposed action threatens serious public interest consequences. As Dr. Coleman Bazelon observes in his attached analysis, the *Public Notice* signals a willingness by the Commission to effectively revoke or suspend a license in the absence of licensee malfeasance and even after capital investments have been made on projects that promise substantial consumer and societal benefit. Through basic economic modeling, Dr. Bazelon shows that the net results of this uncertainty are lower spectrum values for the wireless industry, literally *billions* of dollars of lost value and decreased investment in the sector over time, and ultimately a serious threat to our national economy.

For these reasons, the harm to the public interest from the actions proposed in the *Public Notice* would be enormous and quantifiable, as would the damages to LightSquared resulting from the Commission's breach of its agreement with LightSquared and its violation of LightSquared's constitutional rights. The federal government—to achieve the laudable policy goals of enhancing broadband competition and extending service to millions of Americans—agreed that LightSquared could operate its new network and required it to spend billions at a breathtaking pace to bring service to hundreds of millions of Americans by 2015. The federal government may not now—on the basis of flawed evidence, a flawed process, and conspicuous political pressure—strip away the approval it granted and leave LightSquared and its investors holding the bag for billions of dollars of losses. Its contractual obligations will not permit this; its constitutional responsibilities will not allow it. Nor, finally, is this the course of action for a Commission and an Administration that seek to be reliable supporters of American business development.

The Commission should terminate this inquiry and focus instead on finding a solution that truly advances the public interest and helps bring LightSquared's network to fruition.

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COMMENTS IN OPPOSITION OF LIGHTSQUARED INC.

LightSquared Inc., together with its affiliates, including LightSquared Subsidiary LLC (collectively, "LightSquared"),[1] hereby responds to and opposes the actions proposed in the *Public Notice* released by the International Bureau on February 15, 2012, in the above-captioned proceedings ("*Public Notice*").[2] The *Public Notice* proposes to effectively terminate authority previously granted to LightSquared on the basis of a biased and flawed technical analysis submitted by the National Telecommunications and Information Administration ("NTIA") on the

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1 Throughout these Comments, unless otherwise indicated, "LightSquared" refers to LightSquared, Inc.; all of LightSquared's predecessors in interest, including SkyTerra Communications, Inc. ("SkyTerra"), Mobile Satellite Ventures ("MSV"), Motient Services Inc. and America Mobile Satellite Company ("AMSC"); where appropriate, the investors in LightSquared; and, where appropriate, all affiliates of the foregoing.

2 *Public Notice*: International Bureau Invites Comment on NTIA Letter Regarding LightSquared Conditional Waiver, IB Docket No. 11-109, DA 12-214 (rel. Feb. 15, 2012).

day before the *Public Notice* was issued (the "*NTIA Letter*").[3] Notwithstanding the manifest deficiencies in the *NTIA Letter*, which (at least as evidenced by the lack of discussion in the *Public Notice*) do not yet appear to have been analyzed, the *Public Notice* proposes the drastic measure of vacating LightSquared's waiver authority *and* suspending its underlying authorization to operate an ancillary terrestrial component ("ATC") in connection with its mobile-satellite service ("MSS") network. In doing so, the *Public Notice* would jettison decades of governing Commission precedent without justification, in a manner contrary to the public interest, without providing the "reasoned analysis" that is needed to justify a departure from established Commission policy, and in a manner that violates the Administrative Procedure Act, LightSquared's constitutional and contractual rights, and that raises significant policy concerns. Needless to say, LightSquared opposes these actions. In lieu of taking them, the Commission can and should work with all affected parties to develop appropriate solutions that facilitate the buildout of LightSquared's licensed fourth generation ("4G") Long Term Evolution ("LTE") network, and the co-existence of that network with Global Positioning System ("GPS") receivers.

I. BACKGROUND

A. LightSquared's MSS/ATC 4G LTE Broadband Network

1. LightSquared's Origins and Early Operations

LightSquared is a mobile communications company. Although its business plans have evolved over time to keep pace with the rapid development of mobile technology, the

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[3] Letter to Julius Genachowski, Chairman, Federal Communications Commission from Lawrence E. Strickling, Assistant Secretary for Communications and Information, U.S. Dep't of Commerce (Feb. 14, 2012).

company's fundamental business model has remained the same: the provision of reliable mobile communications services on a nationwide basis.

For many years, LightSquared has provided satellite-based communications services in the portions of the radio spectrum licensed to LightSquared at 1525-1544 MHz, 1545-1559 MHz, 1626.5-1645.5 MHz, and 1646.5-1660.5 MHz (the "MSS/ATC Band"). That in itself entailed substantial investment, requiring LightSquared to launch two geostationary satellites. Since its first satellite became operational in 1996, LightSquared has provided satellite communications services to federal, state, and local public safety agencies, as well as to the transportation and natural resources industries.[4]

In the late 1990s, LightSquared determined that adding a terrestrial (*i.e.*, land-based) component to its satellite system would optimize use of the MSS/ATC Band and provide a communications system with superior reliability and coverage. By combining a nationwide system of terrestrial base stations with two of the largest and most sophisticated commercial satellites ever built—the first of which, the state-of-the-art SkyTerra 1, was launched in November 2010—LightSquared can offer the nationwide coverage of a satellite system and the efficiencies of a terrestrial wireless network. LightSquared thus has developed plans to deploy an integrated satellite-terrestrial network that would provide next generation, high speed wireless services on a nationwide basis.

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4 *See LightSquared Subsidiary LLC*, 26 FCC Rcd 566, at ¶ 3 (2011) ("*Conditional Waiver Order*"). For the convenience of the reader, Exhibit 1 hereto contains a list of the various "short-form" citation references employed in this pleading, along with their "long-form" equivalents.

2. <u>LightSquared's 4G LTE Broadband Network Will Drive Innovation, Spur Competition, and Create Jobs</u>

LightSquared's network promises to unleash a new era in broadband services with important benefits for our nation's technological infrastructure and economic health. As the Commission has explained, 4G LTE broadband networks like LightSquared's "are poised to be a primary driver of innovation in the U.S. economy over the next decade."[5] LightSquared's network has the potential to accomplish the following:

Bringing Wireless Broadband to Underserved Areas. Using LTE technology, the most widely-adopted 4G standard in the world, the LightSquared network will support present-day and emerging wireless devices and will provide significantly higher data rates than many current technologies. In plain language, that means mobile broadband will become considerably faster. In addition, LightSquared's integrated satellite-terrestrial network will expand wireless broadband capacity and coverage to millions of underserved Americans at a time when the demand for wireless broadband services is increasing exponentially. Nearly 100 million Americans do not have broadband today, and the U.S. currently ranks 15th worldwide in providing broadband to its citizens.[6] As Chairman Genachowski has observed: "The costs of this broadband gap are measured in jobs not created, existing job openings not filled, and our nation's competitiveness not advanced."[7] Largely due to the explosion of Internet-enabled

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5 *SkyTerra Communications, Inc., Transferor and Harbinger Capital Partners Funds, Transferee*, 25 FCC Rcd 3059, at ¶ 57 (2010) ("*Harbinger Transfer Order*").

6 *See* Federal Communications Commission, CONNECTING AMERICA: THE NATIONAL BROADBAND PLAN, at xi, 3 (2010), *available at* http://www.broadband.gov/plan ("NATIONAL BROADBAND PLAN"); Organization for Economic Co-operation and Development, OECD BROADBAND PORTAL, at Tbl. 1d (2011) (ranking United States 15th worldwide in broadband penetration per 100 inhabitants.

7 Julius Genachowski, Chairman, Federal Communications Commission, Connecting America: A Plan To Reform and Modernize the Universal Service Fund and Intercarrier

mobile-computing devices (such as smartphones and tablet computers), wireless networks in North America are expected to experience a *forty-fold increase* in data usage over the next three years.[8]

LightSquared has made a particular commitment to serve those Americans in rural and underserved areas. LightSquared has committed to build out its network rapidly, promising coverage for at least 260 million people by 2015. LightSquared has also already signed several capacity agreements with customers who provide telecommunications services to rural communities in states such as Arizona, Kansas, Kentucky, Oklahoma, Mississippi, New Mexico, Tennessee, and Texas.[9]

Driving Competition. The LightSquared network also promises to enhance competition among wireless broadband providers, not only by adding a new competitor in an increasingly concentrated market, but also by enabling new entrants to provide retail broadband services. LightSquared has committed to open its network on a wholesale-only basis, thus

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Compensation System, Remarks as Prepared for Delivery, at 2 (Oct. 6, 2011), *available at* http://transition.fcc.gov/Daily_Releases/Daily_Business/2011/db1006/DOC-310252A1.pdf.

[8] NATIONAL BROADBAND PLAN at 77; *see also Beyond the PC*, THE ECONOMIST (Oct. 8, 2011) (describing rapid growth of smartphones and tablet computers), *available at* http://www.economist.com/node/21531109.

[9] These customers include YourTel America, a provider of telecommunications services in Illinois, Kansas, Maine, Missouri, Oklahoma, Rhode Island, and Washington State; ClearTalk Wireless, a provider of telecommunications services to rural communities in Arizona, California, Colorado, New Mexico, and Texas; SI Wireless, a partnership of rural independent telephone companies that delivers wireless connectivity to rural parts of Illinois, Kentucky, and Tennessee; C Spire Wireless (formerly known as Cellular South), a provider of wireless telecommunications services with operations in Mississippi, Alabama; and Aircado, a wireless broadband service provider for "micropolitan" towns and cities across the United States. *See LightSquared Partners*, *at* http://www.lightsquared.com/partners (last visited Mar. 16, 2012); *see also Press Release: LightSquared and Aircado to Bring Wireless Broadband to "Micropolitan" Markets Across the Country* (Oct. 12, 2011), *available at* http://www.lightsquared.com/press-room/press-releases/lightsquared-and-aircado-to-bring-wireless-broadband-to-micropolitan-markets-across-the-country.

lowering barriers to entry for a new and diverse group of competitors, including wireless operators, traditional wireline carriers, cable operators, device manufacturers, online-content providers, and others. By purchasing capacity on LightSquared's network, those entities will be able to offer competitive alternatives to the mere handful of 4G LTE providers that currently exist in the market. That will, in turn, result in lower prices and other benefits for consumers.

Creating Incentives for Developing New Business and Expanding Existing Ones. By providing open access to a state-of-the-art 4G LTE broadband network to those who previously lacked such access, LightSquared's network will spur innovation and investments in new consumer devices and applications. Even ten years ago, it was hard to imagine the degree to which mobile computing would revolutionize nearly every part of the economy. Devices not thought possible are now everyday items for business and personal use. Three-quarters of all mobile phones sold today are smartphones,[10] and Forrester Research forecasts sales of tablets in the U.S. will grow from 10.3 million in 2010 to 44 million by 2015.[11] These devices are more powerful than their predecessors, and enable the use of services such as streaming media, online games, social networking and video calling—all of which contribute to the vast expansion of wireless data consumption. According to Cisco Systems, smartphones, tablets and mobile-

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10 Leslie Kwoh, *Smartphones to Overtake Traditional Cell Phones, Become the New "Standard,"* STAR-LEDGER (Sept. 4, 2011) (quoting former Nielsen analyst Roger Entner), *available at* http://www.nj.com/business/index.ssf/2011/09/smartphones_overtake_feature_p.html.

11 Sarah Rotman Epps, *US Tablet Sales Will More Than Double This Year*, FORRESTER BLOGS (Jan. 4, 2011, 7:30 AM), http://blogs.forrester.com/sarah_rotman_epps/11-01-04-us_tablet_sales_will_more_than_double_this_year (announcing new Forrester Research report, "Tablets Will Grow as Fast as MP3 Players").

enabled laptops consume, respectively, 35 times, 121 times, and 498 times the data of a standard feature phone.[12]

The adoption and growth of new mobile devices and data-rich content are key catalysts for the acceleration of high-speed, high-bandwidth mobile Internet usage. End users are increasingly demanding mobile access to the same data-intensive services that they use in the home and office, at similarly high performance levels. If wireless access is faster, more available, and less expensive, there is no telling what new machines and uses can be conceived. And increased high-speed wireless access will enable existing businesses to work more efficiently and at the rapid pace demanded by today's society. As the Commission has succinctly summarized, "the growth of mobile broadband networks will "spawn[] new industries and allow[] existing industries to become more productive," and will enable "entrepreneurs, consumers, non-profit organizations, and government to interact and build better businesses and stronger communities."[13]

Creating Jobs. With so many opportunities for new business growth and increased consumer spending, LightSquared's network has the potential to create new jobs in a new economy. LightSquared's proposed network has the potential to create more than 15,000 new private-sector jobs in each of the next five years.

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12 Cisco Systems, CISCO VISUAL NETWORKING INDEX: GLOBAL MOBILE DATA TRAFFIC FORECAST UPDATE, 2011-2016, at 7-8 (2012), *available at* http://www.cisco.com/en/US/solutions/collateral/ns341/ns525/ns537/ns705/ns827/white_paper_c11-520862.pdf.

13 *Harbinger Transfer Order* ¶ 57; *see also* NATIONAL BROADBAND PLAN at xi ("Like electricity a century ago, broadband is a foundation for economic growth, job creation, global competitiveness and a better way of life.").

3. <u>LightSquared Has Invested Billions to Deploy Its Revolutionary 4G LTE Broadband Network</u>

For over a decade, and in reliance on its MSS/ATC authorizations, LightSquared has spent billions of dollars to develop and build out its state-of-the-art, nationwide 4G LTE broadband network. These investments have included:

- $1.1 billion to construct and launch two next-generation satellites.
- $490 million to implement a coordination agreement with another satellite operator in order to make the MSS/ATC Band usable for 4G LTE broadband services.
- Substantial sums to meet the Commission's aggressive build-out schedule for the LightSquared network, which requires coverage of "at least 100 million people by December 31, 2012, at least 145 million by December 31, 2013, and at least 260 million people by December 31, 2015."[14]
- The development of technology to enable the world's first integrated satellite-terrestrial wireless broadband network, including the filing or awarding of 65 U.S. patents over the past decade.

When all is said and done, LightSquared will have invested billions of dollars to deploy and activate its nationwide 4G LTE broadband network.[15] The actions proposed in the *Public Notice*, however, plainly put this investment, the network and its attendant public interest benefits at risk, based on alleged problems with this network co-existing with unlicensed and unregulated GPS receivers.

B. The Relative Rights of MSS/ATC Licensees and GPS Users of the MSS/ATC Band

An understanding of the history of LightSquared's ATC authorization, as well as any analysis of the relative rights and obligations of LightSquared and GPS users with respect to the issues presented by the *Public Notice*, must start with the foundation of all spectrum rights

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[14] *Harbinger Transfer Order* ¶ 56.

[15] LightSquared (along with its investors) has already invested $4 billion. *LightSquared Recommendation* at 16.

granted by the Commission: the United States Table of Frequency Allocations (the "U.S. Table").

Section 303(y) of the Communications Act of 1934, as amended (the "Act") confers upon the FCC "authority to allocate electromagnetic spectrum."[16] The U.S. Table, codified at Section 2.106 of the Commission's rules, compiles the various allocations of spectrum by the Commission for non-federal use (and by NTIA for federal use). The U.S. Table often is consistent with the international frequency allocations reflected in the International Table of Frequency Allocations and also codified at Section 2.106 (the "International Table").[17] However, a number of differences exist between the two tables. In the event of a discrepancy, the U.S. Table governs the relative rights of spectrum uses within the United States (or between U.S. licensees), and the International Table governs the rights of a U.S. spectrum user with respect to uses that occur under authority of a foreign jurisdiction.

Use of spectrum in the United States must be in accordance with the allocations in U.S. Table,[18] or a waiver of the U.S. Table.[19] Allocation status is band-specific. Thus, that a given use is specified in one band does not mean that the same use has the same (or any) priority rights with respect to an adjacent band that is designated for a different use. This is true even when (as in the case of some GPS receivers), a single device performs the same function in two different bands that are specified for two different uses *(e.g.*, the MSS/ATC Band and one of the GPS bands).

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16 47 U.S.C. § 303(y).

17 47 C.F.R. § 2.106.

18 *See* 47 C.F.R. §§ 2.102(a); 2.106.

19 *See, e.g.*, *QUALCOMM, Inc.*, 4 FCC Rcd 1543, at ¶ 11 (1989) ("*QUALCOMM Order*").

Under the U.S. Table and Commission precedent, three broad categories of spectrum "protection" exist, and the level of protection afforded to a given spectrum use defines the relative rights of that use vis-à-vis other uses of that same spectrum band:

Primary uses. Primary uses enjoy the right to use designated spectrum on a priority basis over other categories of spectrum uses.

Secondary uses. Secondary uses operate on a strict "non-interference" basis with respect to any primary use that is allocated to use the same band. This means that the secondary use: (i) must not cause harmful interference to primary uses, and (ii) must accept all harmful interference from primary uses.[20]

Non-conforming uses. Spectrum uses that are not specifically provided for in the U.S. Table must occur on a strict non-interference basis with respect to *all* other uses, both primary and secondary, allocated for the same spectrum band. In other words, non-conforming uses enjoy *no* allocation status, and are treated as effectively tertiary in all analyses of relative spectrum rights.

The next section applies these principles to the allocations under the U.S. Table for the uses of the separate spectrum bands that are (i) licensed to LightSquared and (ii) provided for GPS use.

1. <u>MSS/ATC Band and GPS (RNSS) Band Allocations</u>

As detailed below, the current dispute involves allegations of potential "interference" that arise from the reception by GPS receivers of electromagnetic energy that is contained within the MSS/ATC Band. In contrast, the relevant portion of the radio spectrum

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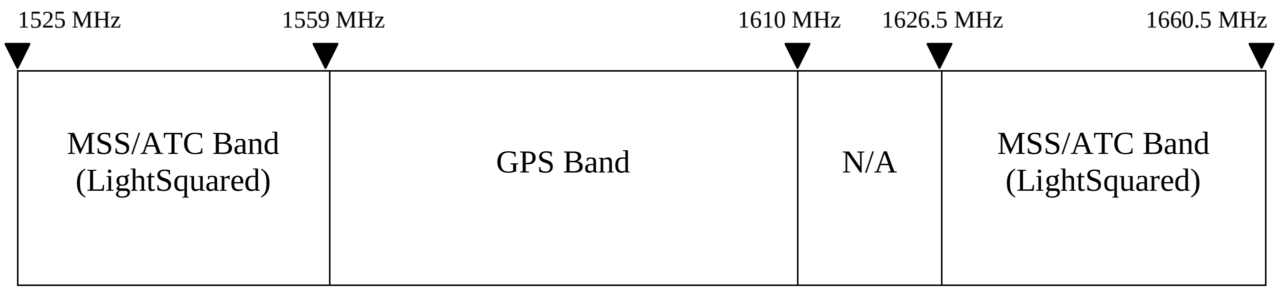
[20] *See* 47 C.F.R. § 2.105(c).

specified for GPS operations under the U.S. Table is 1559-1610 MHz (the "GPS Band").[21] The following graphic depicts these frequency bands:



a. MSS/ATC Allocation

Under the U.S. Table, the MSS/ATC Band is allocated for MSS/ATC use, which is designated as the "primary" service.[22] In authorizing ATC, the Commission carefully preserved the integrity of the U.S. Table as it applies to ATC in the MSS/ATC Band by adding a footnote to the U.S. Table regarding the already-existing primary MSS allocation for those band segments. That footnote (US380) provides that the primary MSS allocation includes ATC operations, subject to the Commission's ATC rules and the applicable conditions and provisions of a licensee's MSS authorization.[23]

As the Commission's 2001 Notice of Proposed Rulemaking on ATC reflects, the Commission amended the U.S. Table by adding that footnote simply "to clarify" that MSS/ATC Band providers operating in MSS/ATC Band "may also operate an ancillary terrestrial

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[21] *See* 47 C.F.R. § 2.106 (allocating this band for the Radionavigation–Satellite Service). Another band designated for GPS purposes is 960-1215 MHz.

[22] *See* 47 C.F.R. § 2.106. MSS is defined as a "radiocommunication service: (1) Between mobile earth stations and one or more space stations, or between space stations used by this service; or (2) Between mobile earth stations by means of one or more space stations." 47 C.F.R. § 2.1(c).

[23] 47 C.F.R. § 2.106 n.US380.

component reusing the assigned bands."[24] In so amplifying the existing language in the U.S. Table, the Commission acted in a manner consistent with at least one other case in which the Commission, by footnote (US309), has allowed portions of the MSS/ATC Band (again, otherwise allocated only for MSS) to be used to extend or supplement MSS service with (i) communications between terrestrial stations and aircraft, and (ii) communications between aircraft.[25]

Significantly, the Commission did not specify that ATC (or the other uses described above) must be provided on a non-interference/non-protected service, as the Commission has done in adopting other footnotes to the U.S. Table that so restrict the usage rights of other spectrum allocations.[26] Nor did the Commission authorize ATC on a non-conforming basis (and without amending the U.S. Table), as it has done in the case of authorizing other spectrum uses.[27]

b. GPS/RNSS Allocation

The GPS Band that is adjacent to the MSS/ATC Band has been allocated for two services, both on a primary basis: the Radionavigation-Satellite Service ("RNSS") (which is relevant to this matter) and the Aeronautical Radionavigation Service (which is not relevant to this matter). RNSS is defined as a "radiodetermination-satellite service used for the purpose of

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24 *Flexibility for Delivery of Communications by Mobile Satellite Providers in the 2 GHz Band, the L-Band, and the 1.6/2.4 GHz Band,* Notice of Proposed Rulemaking, 16 FCC Rcd 15532, at ¶ 35 (2001) ("*Flexibility Notice*"); *Flexibility for Delivery of Communications by Mobile Satellite Providers in the 2 GHz Band, the L-Band, and the 1.6/2.4 GHz Band*, 18 FCC Rcd 1962, at ¶ 235 (2003) ("*2003 ATC Order*").

25 *See* 47 C.F.R. §2.106 n.US309.

26 *See* 47 C.F.R. §2.106 n.US389, US390, US391.

27 *See e.g., QUALCOMM Order* ¶ 11; *see also* the Exhibit 2 hereto (containing additional FCC precedent demonstrating that nonconforming spectrum uses are not entitled to interference protection).

radionavigation." "Radiodetermination-Satellite Service" (or "RDSS") is defined as a "radiocommunication service for the purpose of radiodetermination involving the use or one of more space stations." "Radiodetermination" is defined as the "determination of the position, velocity and/or other characteristics of an object, or the obtaining of information relating to these parameters, by means of the propagation properties of radio waves."[28]

As detailed below, the Commission has ruled that RDSS (of which RNSS is a subset) and MSS are distinct from each other. Notably, no RNSS (or RDSS) allocation exists in the MSS/ATC Band in which MSS/ATC is primary, and in which MSS/ATC licensees enjoy the right to use their licensed spectrum on a priority basis vis-à-vis all other spectrum users (including GPS/RNSS).

2. <u>The Absence of any Interference from LightSquared Transmitters into the GPS Band</u>

The *Public Notice* indicates that the sole technical concern with respect to LightSquared's planned ATC operations involves the "overload" effects that a limited number of unregulated GPS receivers may experience when operated in close proximity to LightSquared transmitters. As the *Public Notice* correctly reflects, the potential for such "overload" arises only where "signals are received by GPS receivers *outside the frequency bands allocated to GPS*"[29]—*i.e.*, where GPS receivers engage in "out-of-band *reception*."

"Overload" should be distinguished from interference that may occur where a non-GPS transmitter emits too much energy into the band allocated for GPS—*i.e.*, where that transmitter produces high levels of "out-of-band *emissions*." The *Public Notice* does not allege any threat of interference from LightSquared transmitters emitting too much energy into the band

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[28] 47 C.F.R. § 2.1(c).

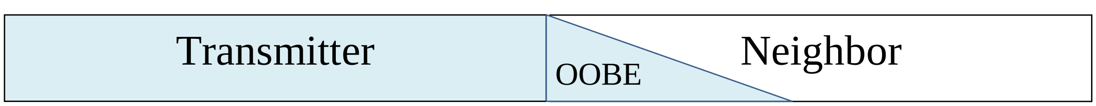
[29] *See Public Notice* at 2 n.6 (emphasis added).

allocated for GPS—*i.e.*, from LightSquared's "out-of-band *emissions*." Stated another way, the *Public Notice* does not allege that LightSquared would interfere with portions of the GPS spectrum in which GPS satellites transmit GPS signals. (Indeed, as discussed below, any theoretical potential for interference arising from such "out-of-band emissions" was resolved almost a decade ago in a series of long-final Commission decisions.)

Significantly different legal consequences extend from whether a given situation involves "out-of-band reception" as opposed to "out-of-band emissions." Therefore, a deeper understanding of the distinction between the two sets of circumstances is critical for purposes of assessing the "overload" concerns that exist today, and the potential impact on LightSquared's ATC authority.

The *potential* for "out-of-band emissions" is a result of the laws of physics: transmitted radio waves do not naturally stay within the boundaries shown on paper in the U.S. Table. Rather, as illustrated in Figure 1, transmitted radio waves slowly decrease in power over a range of frequencies, and, as such, they naturally will extend into those portions of the neighboring radio spectrum allocated for other spectrum uses.

Figure 1: Simplified Depiction of Out-of-Band Emissions ("OOBE")

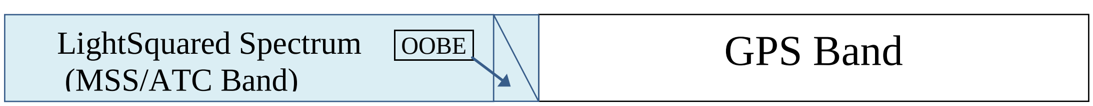


The power transmitted by an operator into the adjacent spectrum naturally falls off at a gradual rate.

Typically, the Commission's rules define the rate at which the energy emitted from a transmitter in one given band must decrease in strength as it enters spectrum that is assigned for the use by another service. For example, Section 25.253 of the Commission's rules specifies the permissible levels of such out-of-band-emissions from ATC into the frequency band allocated for GPS.[30] Even so, prior to obtaining its ATC authority LightSquared worked closely with both the GPS industry and NTIA and agreed to far more restrictive out-of-band emissions limits, which are reflected in LightSquared's ATC license.[31]

As shown in Figure 2 below, LightSquared achieves compliance with the agreed out-of-band emission limits that apply to its ATC service through sophisticated filtering in its equipment, and by allowing a 3.8 MHz buffer zone (*i.e.*, an implicit guard band) between its Upper 10 MHz channel, which ends at 1555.2 MHz, and the lower edge of the GPS Band. As a result, out-of-band emissions from LightSquared's proposed operations simply are not a concern; this issue is not raised in the *NTIA Letter*, or in the filings in this proceeding by the GPS interests.[32]

Figure 2: Simplified Depiction of LightSquared's Out-of-Band Emissions (OOBE)



LightSquared reached agreement with GPS industry and NTIA to significantly limit LightSquared transmissions so that they are restricted from entering the GPS Band

30 47 C.F.R. § 25.253.

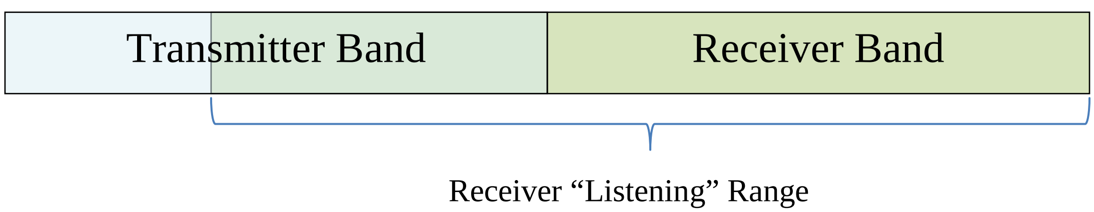
31 *See* Sections I.C and I.D, *infra*; *see also e.g.*, Letter to FCC from Mobile Satellite Ventures L.P. and the U.S. GPS Industry Council, IB Docket No. 01-185, at 4-5 (July 17, 2002) ("*2002 MSV-GPS Joint Letter*") attached as Exhibit 3 hereto; Reply to Comments of U.S. GPS Industry Council, IB Docket No. 01-185, at 2 (Sept. 4, 2003) ("*USGIC Reply to Comments*"); Letter to FCC from NTIA, IB Docket No. 01-185, at 2-3 (Jan. 24, 2003; rec'd Feb. 10, 2003) ("*January 2003 NTIA Letter*").

32 Any near term concerns about potential intermodulation effects would be fully addressed by LightSquared's proposal to forego use of the Upper 10 MHz channel pending further technical analysis.

3. The Potential for GPS Receiver "Overload" is Caused by GPS Receivers that "Listen" Outside of the GPS Band and in LightSquared's Licensed MSS/ATC Band

As discussed, "overload" is not a function of a radio transmitter emitting energy outside of its licensed spectrum. Rather, it is a function of a device: (i) receiving (*i.e.*, "listening" to) energy that is transmitted outside the spectrum band in which the receiver is expected to operate—whether as the result of a deliberate design decision or design flaw; and (ii) being unable to handle that energy. The figure below depicts how a receiver may "listen" in the authorized spectrum of its neighbor:

Figure 3: Simplified Depiction of "Overload"



Overload is very different from out-of-band emissions. The difference can be visualized by way of analogy. Out-of-band emissions are similar to the effect on a neighbor when an apartment resident plays loud music that can be heard next door. In contrast, "overload" is akin to a situation when music cannot be heard next door, but the neighbor chooses to walk into the resident's apartment, sit on the sofa, and then complain that he cannot read because of the volume of the music. The "problem" is caused by a combination of the neighbor's decision to enter the apartment and his personal sensitivity to the volume of the music in the resident's apartment—and not by any behavior that infringes on the neighbor's "rights."

And, to extend the analogy, the law has never protected the neighbor in this context, let alone provided standing for the neighbor to complain about it, or to seek redress by evicting the resident from his own apartment.

This example helps to highlight why the Commission has long recognized that "overload" is "basically a . . . receiver design problem."[33] From a policy perspective, the reason is clear: (i) the manufacturing and sale of radio receivers in largely unregulated and (ii) the solution to "overload" lies entirely within the control of the unregulated manufacturer of the receiver, which can solve the "problem" by making its receivers compatible with neighboring licensed uses of radio spectrum. Thus, while the Commission has afforded manufacturers flexibility to employ a variety of receiver designs, it has done so with the understanding that the users of those receivers must bear the risk of any resulting incompatibility with authorized transmitters in adjacent bands.

At the most fundamental level, the overload "problem" can be solved by making sure that the GPS receiver does not operate outside the spectrum bands that have been allocated for the receiver's intended use (*e.g.,* by ensuring that GPS devices listen only in the bands allocated for GPS). This can be accomplished by ensuring that the receiver has suitable radiofrequency selectivity capabilities. If the receiver nonetheless is designed to pick up signals from adjacent bands, a number of technical design techniques are available by which a receiver manufacturer can ensure that its device is able to tolerate the energy transmitted by others and received by the device in those adjacent bands. These techniques, which can be used singularly or in combination, include the use of: suitable low noise amplifiers (LNAs), suitable bandpass filters, suitable diode limiters in the preamplifier/filter assembly, an optimized distribution of

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33 *See Public Notice: Potential Interference to Television Reception from Operation of FM Broadcast Stations on Certain Frequencies,* FCC 65-130 (Feb. 19, 1965).

LNAs and bandpass filters in a multistage front end, suitable intermediate frequency (IF) filtering, high resolution A/D converters, and state-of-the-art digital signal processing. As LightSquared has explained, in many cases involving GPS, this type of solution may involve the addition of a small filter or the improvement of existing filters at minimal additional cost—indeed, for cellphones and devices with similar form factors, appropriate filtering would add about a nickel to the cost of the device, assuming any modification is necessary in the first place.[34] Exhibit C of the Technical Appendix elaborates on the practicality of GPS manufacturers producing ATC-compatible devices without sacrificing performance or materially increasing the production cost or size of the device.[35]

The relevance of the unregulated nature of radio receivers to the "overload" issue bears particular emphasis. One may manufacture, sell and import GPS receivers without reference to any performance standards and without any testing or certifications to ascertain compatibility with licensed uses of adjacent spectrum bands. Moreover, GPS receivers are operated on a non-licensed basis. In fact, there are no GPS-specific service rules—but GPS receivers are subject to generally applicable policies that govern unlicensed devices. These policies provide that the use of such devices must proceed on a strict non-interference basis (*i.e.*, one cannot complain about the interference he might receive while using the device, and the device may not cause interference to others).[36]

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34 *See* Technical Working Group (TWG) Final Report, IBFS File No. SAT-MOD-20101118-00239, at 55; and App. C.5, at 7-8 (June 30, 2011).

35 *See* Technical Appendix, Exhibit C.

36 *See 1979 Receive-Only Earth Station Order* ¶¶ 28 and 38; *see* 47 C.F.R. § 25.131; 47 C.F.R. §§ 15.5, 15.15, 15.17; U.S. Department of Commerce, NTIA, *Manual of Regulations and Procedures for Federal Radio Frequency Management*, §§ 7.8, 7.9 (2011) ("*NTIA Redbook*").

The logic of the non-interference legal framework under which GPS receivers operate is compelling. Providing interference protection to devices that are not subject to any of the Commission's standards or authorizations would wreak havoc on the Commission's spectrum management policies, and would undermine investment as well. Indeed, one cornerstone of the Commission's spectrum policy to date has been to delineate clearly spectrum users' rights and responsibilities, and to afford "exclusive use" licensees enough certainty to create a robust secondary market in licensed spectrum rights.[37] Such a market cannot develop with unlicensed and unregulated devices claiming and receiving equivalent protection.[38] To be sure, the Commission could set rules that define the parameters under which GPS receivers could be manufactured, sold, imported, and used. And in that context, the Commission could define a suitable level of performance, as it has done with many other types of satellite receive devices. But that has not happened.

As an example, under longstanding Commission precedent, licensed or registered receive-only satellite earth stations[39] are provided interference protection only to the extent

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[37] *See, e.g.*, *Promoting Efficient Use of Spectrum Through Elimination of Barriers to the Development of Secondary Markets*, 15 FCC Rcd 24203, 24213 (2000).

[38] For one thing, it is impossible for licensees to design around a myriad of devices whose performance specifications are not made public, and it would be unreasonable for the Commission to have an expectation that licensees could do so.

[39] On a few occasions, the Commission has treated certain GPS receivers as subject to the regulatory framework that governs unlicensed receive-only earth stations, which is codified in Section 25.131 of the Commission's rules. *See Public Notice: National Telecommunications and Information Administration Provides Information Concerning Executive Branch Recommendations for Waiver of Part 25 Rules Concerning Licensing of Receive-Only Earth Stations Operating with Non-U.S. Radionavigation Satellites*, DA 11-498 (Mar. 15, 2011) (noting that the FCC's rules require licensing of "receive-only earth stations operating with non-U.S. licensed [RNSS] satellites.") ("*Section 25.131 Waiver Notice*"); *see also* Inmarsat Hawaii Inc., IBFS File No. SES-MSC-20100415-00483 (Jul. 13, 2010) (granting waiver of Section 25.131(j) to permit unlicensed GPS (RNSS) terminals to receive transmissions from a U.K.-licensed Inmarsat satellite)

expressly specified in the Commission's rules.[40] No such protection criteria are specified at all for GPS receiver "overload" susceptibility, including with respect to "overload" experienced by such devices in the MSS/ATC Band. This is true for at least three reasons: (i) the interference protection specified in Part 25 for satellite receivers provides protection only inside a receiver's authorized band (and not with respect to any other band in which a satellite receiver may "listen");[41] (ii) GPS receivers historically have not been licensed, and, under longstanding precedent (and absent an express determination from the Commission to the contrary) unlicensed earth stations are not entitled to any interference protection whatsoever;[42] and (iii) to the extent

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("*Inmarsat Hawaii Order*"); *Amendment of Parts 2 and 25 to Implement the Global Mobile Personal Communications by Satellite (GMPCS) Memorandum of Understanding and Arrangements*, 18 FCC Rcd 24423, at ¶ 30 (2003) (GPS receivers among the list of receive-only earth stations exempt from compliance with equipment certification procedures because of the absence of applicable performance standards in the Commission's rules). NTIA has viewed GPS receivers in a similar fashion. *See* Letter to FCC from NTIA, attached to the *Section 25.131 Waiver Notice*, at 1 (observing that the FCC's rules "require licensing of . . . receive-only earth stations operating with non-U.S. licensed [RNSS] satellites," including GPS (RNSS) receivers, and citing Section 25.131).

40 *See* 47 C.F.R. §§ 25.138, 25.209, 25.224.

41 *See Deregulation of Domestic Receive-Only Satellite Earth Stations*, 104 FCC.2d 348, at ¶ 17 (1986) ("*1986 Receive-Only Earth Station Order*") ("[M]inimum parameters must, of course, be specified in order to define the interference protection afforded. . . ."). The antenna performance criteria specified in Sections 25.138, 25.209 and 25.224 of the Commission's rules protect against only "in-band" interference; they do not provide any protection whatsoever to a satellite receiver "listening" outside of its authorized band, or otherwise operating outside of specified parameters. *See* 47 C.F.R. §§ 25.138, 25.209, 25.224. Stated another way, a receive-only earth station that operates in the 17/24 GHz BSS band under 4 degree orbital spacing may be entitled to interference protection against "in-band" interference to the extent provided in Section 25.224, but a user certainly cannot complain about the level of signals that receiver also picks up from an adjacent spectrum band that operates under different orbital spacing rules. This is a fundamental premise that underlies all spectrum management at the Commission—if you venture outside the bands that you are supposed to use, you do so at your own risk.

42 *See* LightSquared Petition for Declaratory Ruling, IB Docket No. 11-109, at 11-18 (filed Dec. 20, 2011) ("*Petition for Declaratory Ruling*"); *Regulation of Domestic Receive-Only Satellite Earth Stations*, 74 FCC.2d 205, at ¶¶ 27-28 (1979) ("*1979 Receive-Only Earth Station Order*"). *Compare 1986 Receive-Only Earth Station Order* ¶ 12 (expressly

the radio receiver inside a GPS device does experience "overload," that particular electronic component is not subject to any Commission regulation about how it is designed, but it is subject to the express requirement that it cannot claim any interference protection.

This last point is key. The radio receiver inside a GPS device, like most radio receivers, fits within the definition of an "unintentional radiator."[43] As such, the radio receiver inside a GPS device is subject to the express requirements of Section 15.5 of the Commission's Rules, which provides that all operations of unintentional radiators are subject to the conditions that: (i) they "shall not be deemed to have any vested or recognizable right to continued use of any given frequency;" (ii) "no harmful interference is caused" by such operations; and (iii) "interference must be accepted that may be caused [to such operations] by the operation of an authorized radio station . . . ."[44] These basic requirements apply to GPS receivers even though they may be exempt from the equipment authorization requirements of Section 15.101 of the Commission's rules.[45]

Stated another way, different rules may govern different components of the equipment used in connection with a given service, and an unregulated component that is susceptible to "interference" cannot be used as the basis for obtaining protection for the rest of

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exempting 11.7-12.2 GHz band earth station antennas from general requirement that earth stations must be licensed or registered to receive interference protection).

43 *See Review of Part 15 and Other Parts of the Commission's Rules*, 17 FCC Rcd 14063, at ¶ 2 n. 3 (2002) ("An unintentional radiator is defined in Section 15.3(z) of the rules as a device that intentionally generates radio frequency energy for use within the device, or that sends radio frequency signals by conduction to associated equipment via connecting wiring, but which is not intended to emit RF energy by radiation or induction. Examples of unintentional radiators include radio receivers . . .").

44 47 C.F.R. § 15.5. This statement is included expressly in the owners' manuals for many GPS devices. *See Petition for Declaratory Ruling* at Exh. 1.

45 *See* 47 C.F.R. § 15.101(b) ("Receivers operating above 960 MHz, or below 30 MHz, except for radar detectors and CB receivers, are exempt from complying with the technical provisions of this part but are subject to § 15.5.")

the equipment in the chain. Consider, for example, a Ka Band FSS satellite television service (such as that provided by DIRECTV and DISH to supplement their DBS services), which involves the use of a Part 25 satellite antenna (outside the home) and a Part 15 radio receiver/decoder "box" (inside the home). That antenna may receive a wide range of radiofrequency signals outside of the portions of the Ka Band licensed to the satellite service provider, and pass those signals through to the receiver/decoder "box." But there are no Commission rules that ensure that the receiver/decoder necessarily will work as intended. And, in the event that the receiver/decoder fails because the antenna "listens" outside of licensed portions of the Ka Band (*e.g.*, to federal government radar devices or microwave facilities in neighboring portions of the Ka Band), the satellite service provider surely would not be entitled to claim interference protection from authorized licensed transmitters in neighboring bands. Affording such protection would be flatly inconsistent with the Part 15 rules (described above) under which the receiver/decoder operates—and flatly inconsistent with the policy determinations that led the Commission to deregulate receive-only satellite earth station facilities more generally.

In the early days of satellite service, the Commission regulated heavily the technical characteristics of receive-only satellite earth stations, based on "the premise of assuring the high quality of service . . . provided to the general public and consistent with our spectrum regulation policies."[46] After gaining "real-world" experience, the Commission decided to deregulate the technical characteristics of receive-only earth station facilities: (i) in order to facilitate innovation; and (ii) with the express understanding that the Commission would not consider "the nature of services provided over unregulated receiving earth stations" when

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[46] *See 1979 Receive-Only Earth Station Order* ¶ 24.

exercising its "spectrum management responsibilities"—*i.e.*, would not aim to "protect" unlicensed receive-only earth stations.[47] Thus, interference protection of satellite receive-only facilities is provided, as a general matter, only to the extent the earth station is licensed (or registered) and only to the extent the antenna meets certain performance requirements. And, even though the Commission has created a limited exception to the licensing requirement in one specific frequency band (which is irrelevant here),[48] interference protection still extends only to other users of the exact same frequency band in which the satellite service is primary, and the Commission has made clear that scope of such protection is expressly defined by the Commission's rules.[49]

C. NTIA's Intimate Involvement in Reviewing LightSquared's Deployment Plans for Nearly a Decade

The record reflects that, since 2001, NTIA (and the agencies it represents) has been intimately and actively involved in the development of ATC policy generally, and the evolution of LightSquared's network specifically. In particular, during this time NTIA has had access to all relevant information about LightSquared's 4G LTE network and ample opportunity to voice any objections to the Commission's decision to license LightSquared's network. Tellingly, during this entire period NTIA focused its objections solely on limiting "out-of-band" emissions from LightSquared's MSS spectrum into the GPS Band at 1559-1610 MHz (*i.e.*, interference into the GPS Band designated for GPS satellites to transmit GPS signals). At no time during the authorization process has NTIA or any federal spectrum user raised concerns

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47 *Id.*

48 This is the 11.7-12.2 GHz band allocated solely to the Fixed Satellite Service.

49 *See, e.g.*, 47 C.F.R. §§ 25.138, 25.209, 25.224; *see also 1986 Receive-Only Earth Station Order* ¶ 17 ("[M]inimum parameters must, of course, be specified in order to define the interference protection afforded").

about the potential "overload" of GPS receivers that lack adequate filtering and thus "listen" in LightSquared's licensed MSS spectrum for GPS signals, despite other parties having raised this as a possibility as far back as 2001.[50]

More specifically, the record reflects that in the late 1990s LightSquared determined that adding a terrestrial component to its satellite system would optimize use of its authorized MSS/ATC Band frequencies and facilitate the introduction of a communications network with superior reliability and coverage. In 2001, LightSquared sought Commission authority to deploy such a system.[51] In response, the Commission initiated a rulemaking proceeding, seeking public comment.[52] In 2003, the Commission concluded that an MSS

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[50] In April 2001, Inmarsat filed a Partial Petition to Deny the initial application that LightSquared's predecessor had filed seeking ATC authority. *See* Inmarsat Ventures plc, Partial Petition to Deny, IBFS File No. SAT-ASG-20010302-00017 (Apr. 18, 2001) ("*Inmarsat Petition to Deny*"). Inmarsat had a particular interest in the impact of ATC "overload" on GPS receivers because its satellites contain transponders that could transmit GPS signals on GPS frequencies. In its petition, Inmarsat stated that "the level of transmitted power from [ATC] terrestrial base-stations also will be sufficient to block reception of the satellite navigation signals in the adjacent GPS band . . . because the [GPS] receivers have only a limited amount of filtering to reduce the adjacent band signal to a level that will not overload the receiving amplifiers." *Id.* at 10. Inmarsat further asserted that granting the authorization "could prevent operation of mobile earth stations in the MSS operating near to any base-station, due to overloading of the front-end receiver by the high-level signals coming from the base stations" and that such "base stations will interfere with the operation of nearby GPS receivers in the adjacent band in the same way." *Id.* at 12. A few weeks later, Deere & Company reiterated the same points, citing Inmarsat's petition and agreeing that "the level of transmitted power from [the proposed ATC] base stations may be sufficient to block reception of the satellite navigation signals in the adjacent [GPS] band by overloading the sensitive receiving amplifiers of the GPS terminals." *See* Comments of Deere & Company, IBFS File Nos. SAT-ASG-20010302-00017, at 6 (May 7, 2011) ("*Deere Comments*"). To this extent, the *Public Notice* errs in describing the issue of overload associated with LightSquared's terrestrial transmitter deployment as "newly expressed." *See Public Notice* at 3. Rather, the issue was known long ago, but the GPS industry nonetheless repeatedly supported LightSquared's ATC authority, as explained below.

[51] *See* IBFS File No. SAT-ASG-20010302-00017 (Mar. 2, 2001).

[52] *See generally Flexibility Notice*.

operator should be permitted to operate ATC in any portion of its authorized satellite frequencies.[53] In 2004, the Commission granted LightSquared a license for ATC authority.[54] The Commission revised a number of its ATC rules in 2005, including by permitting the operation of an unlimited number of ATC base stations and mobile user terminals and higher power operations than previously permitted.[55] Subsequently, LightSquared sought and received additional Commission approvals regarding its ATC authorization, including a March 2010 authorization allowing LightSquared to operate in a manner consistent with the higher power levels approved in the 2005 rules and the LightSquared 2007 satellite coordination agreement with Inmarsat.[56]

Twice during these proceedings, LightSquared entered into and concluded negotiations with the GPS industry through the United States GPS Industry Council ("USGIC"), which was chaired by a founder of Trimble Navigation (a leading GPS manufacturer).[57] As a result of these negotiations, LightSquared addressed the USGIC's concerns by agreeing to accept more restrictive limitations on its out-of-band emissions into the GPS Band than are required by

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53 *See generally 2003 ATC Order* (subsequent history omitted and discussed below).

54 *See generally Mobile Satellite Ventures Subsidiary* LLC, 19 FCC Rcd 22144 (2004) ("*MSV ATC Order*").

55 *Flexibility for Delivery of Communications by Mobile Satellite Service Providers in the 2 GHz Band, the L Band, and the 1.6/2.4 GHz Bands*, Memorandum Opinion and Order and Second Order on Reconsideration, 20 FCC Rcd 4616, at ¶¶ 49-50 (2005) ("*2005 ATC Order*").

56 *SkyTerra Subsidiary LLC*, 25 FCC Rcd 3043 (2010) ("*SkyTerra Modification Order*"); *Harbinger Transfer Order* ¶¶ 56, 74-75 (approving the transfer of control of LightSquared to Harbinger and imposing milestone deadlines for ATC deployment.) *See also 2010 SkyTerra Subsidiary LLC*, 25 FCC Rcd 2022, at ¶ 14 (2010) (authorizing for MSS and ATC the reuse of frequencies used on the Mexican MSS satellite network) ("*SkyTerra Re-Use Order*").

57 The resulting agreements are attached as Exhibits 3 and 4.

the Commission's ATC rules.[58] NTIA supported this process fully, and subsequently endorsed the limits agreed upon by the parties.[59] Likewise, the Commission approved the agreed-upon limits, and reflected those limits in its orders and in the terms of LightSquared's ATC authorizations.[60]

As is standard practice for Commission decisions that involve spectrum (such as the MSS/ATC Band) that is allocated to both government and commercial use and that could impact government operations in adjacent bands,[61] NTIA reviewed drafts of and provided comments on the Commission's 2003 and 2005 ATC orders and the Commission's 2004 and 2010 ATC licensing decisions.[62] Moreover, the Commission's decisions reflect both that NTIA provided substantive feedback in these proceedings, and that this feedback was factored into the Commission's ultimate decisions in establishing the ATC technical rules and authorizing LightSquared to conduct ATC operations.[63]

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58 *See 2002 MSV-GPS Letter* at 1; *See also Letter* to FCC from USGIC and SkyTerra Subsidiary LLC, IBFS File Nos. SAT- MOD-20090429-00046 at 1 (Aug. 13, 2009) ("*2009 SkyTerra-GPS Joint Letter*"), attached as Exhibit 4 hereto.

59 *See January 2003 NTIA Letter* at 3 (identifying the agreement between LightSquared and the commercial GPS industry as evidence that effective technical solutions "are attainable by the MSS ATC communities and agreeable with the GPS community.") *See* Letter to FCC from NTIA, IBFS File No. SAT-MOD-20031118-00333, at 2 (Apr. 21, 2004) ("*2004 NTIA Letter*"); Letter to FCC from NTIA, IBFS File Nos. SAT-AMD-20031118-00332 and SAT-MOD-20031118-00033, at 2-6 (May 25, 2005) ("*2005 NTIA Letter*")

60 *See, e.g., 2003 ATC Order* ¶ 180 n.478, ¶¶197-200; *MSV ATC Order* ¶ 11 n.23, and ¶¶ 35, 36, 95(c); *SkyTerra Modification Order* ¶ 4 n.15 and ¶¶ 45, 46(d).

61 *See NTIA Redbook §* 2.4 (2011).

62 *See* nn.67-69, *infra*.

63 *See 2003 ATC Order* ¶¶ 103, 124, 125, 132, 133, 171, 172, 174, 180, 181, 182, 197, 198, 199, App. C2 §§ 2.1, 2.2.2, 2.2.3, 3.3 (citing and addressing NTIA comments); *2005 ATC Order*, at ¶¶ 16, 69, 70, 71 (citing and addressing NTIA comments filed in ATC rulemaking and licensing proceedings); MSV *ATC Order* ¶¶ 10, 54, 61, 70, 77, 79, 83 (citing and addressing NTIA comments regarding application); *SkyTerra Modification Order* ¶¶ 33, 39, 43 (citing and addressing NTIA comments regarding application).

Throughout these proceedings, LightSquared met with NTIA many times to discuss LightSquared's proposed operations.[64] At every stage, NTIA was fully aware of the scope of LightSquared's planned deployment. For example, the record shows specifically that, prior to the release of the 2005 ATC order—which authorized ATC operators to employ an unlimited number of base stations at essentially the power levels LightSquared is now proposing to operate (and an unlimited number of mobile user terminals, as well)—NTIA participated in an *ex parte* meeting with the DoD, the Commission, Inmarsat, and LightSquared. Following this meeting, the scope of LightSquared's deployment plans was readily apparent (if it was not beforehand); Inmarsat distributed a handout noting that LightSquared "has stated that it desires to employ as many existing cellular base station sites as possible" and LightSquared will have potentially "tens of thousands of ATC base stations."[65] Two years earlier, the GPS industry had acknowledged the same thing.[66]

Furthermore, the record in the Commission's proceedings shows both NTIA's active engagement with respect to GPS-related issues, and that the sole GPS-related concern raised by NTIA involved out-of-band emissions from the MSS/ATC Band into the GPS Band. In November 2002, in response to the Commission's ATC rulemaking proceeding, NTIA filed a

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[64] *See, e.g.*, Letter to FCC from DoD, IB Docket No. 01-185, at 1 (Jan. 5, 2005) (providing notice of an ex parte meeting between DoD, NTIA, FCC, Inmarsat, and LightSquared); Letter to Marlene H. Dortch, Secretary, FCC from Richard B. Engelman, Chief Engineer, International Bureau, FCC, IB Docket No. 01-185, at 1 (Feb. 3, 2005) (providing notice of a meeting between DoD, NTIA, FCC, Inmarsat, and LightSquared) ("*Engelman Letter*'); *see also* Letter to NTIA from DoD, IBFS File No. SAT-MOD-20090429-00046, at 1 (Mar. 19, 2010) ("The DoD met with SkyTerra and Inmarsat many times over the last several months. . . .").

[65] *Engelman Letter,* App. B at 26, 27.

[66] *See USGIC Reply to Comments* at 2 (acknowledging that LightSquared's proposed operations would result in "potentially millions of MSS mobile terminals operating in ATC mode" and "transmit[ting] back to potentially tens of thousands of ATC wireless base stations").

68-page technical document addressing potential interference issues and providing recommendations, including specifically the adoption of certain out-of-band emissions limits to protect the GPS Band.[67] Subsequently, NTIA filed two letters encouraging the Commission's adoption of the out-of-band emissions limits agreed to by LightSquared and USGIC.[68] NTIA also filed a similar letter supporting those out-of-band emissions limits in the Commission proceeding that resulted in the grant of LightSquared's ATC authorization.[69] In all cases, the sole concern raised was to limit out-of-band emissions from the MSS/ATC Band into the GPS Band; NTIA never raised any concern with respect to "overload" of GPS receivers.

At one point in the process leading up to the Commission's 2010 ATC licensing decision, LightSquared was effectively required by NTIA and the DoD to pay more than $100,000 for a study by the Department of Defense ("DoD") Joint Spectrum Center ("JSC") to analyze certain issues regarding the potential impact of LightSquared's planned deployment on DoD users. As part of this study, LightSquared provided detailed information regarding its deployment plans, including a scenario with 520 base stations in the Baltimore-Washington area alone. Neither DoD, which had dozens of personnel participating, nor NTIA raised any concern regarding the proposed widespread deployment of LightSquared's 4G LTE network or the possibility that GPS receivers used by federal users might experience "overload" in the vicinity of LightSquared transmitters.

Finally, Chairman Genachowski noted in May of last year that the Commission's March 2010 orders involving LightSquared—which imposed rigorous buildout requirements—

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67 *See* Letter to FCC from NTIA, IB Docket No. 01-185 at 3 (Nov. 12, 2002; rec'd Feb. 10, 2003) ("*November 2002 NTIA Letter*").

68 *See January 2003 NTIA Letter* at 1-2 (discussing OOBE limits intended to protect the GPS "L1" band); *2005 NTIA Letter* at 2-6.

69 *See 2004 NTIA Letter* at 2, 13.

were coordinated with other federal spectrum users, through NTIA, and the underlying applications were open for review and comment by any member of the public.[70]

The absence of concern by NTIA with the "overload" of GPS receivers is consistent with the relative rights of MSS/ATC licensees and GPS users in the spectrum where the potential for overload exists, and the resulting absence of legally cognizable interference. It is also mirrored by a similar lack of concern manifested by the GPS industry, discussed below.

D. The Commercial GPS Community's Involvement in LightSquared's Deployment Plans, and the Consideration and Adoption of Specific Protection for GPS Receivers

The concept of using MSS spectrum for combined satellite and terrestrial purposes, and LightSquared's authority to conduct such operations, have evolved with the active participation *and support* of the GPS industry for almost a decade. Indeed, LightSquared has worked with the GPS industry to ensure that GPS receivers would remain compatible with LightSquared's forthcoming terrestrial broadband network in the MSS/ATC Band. During this time, the GPS industry *repeatedly* supported the evolving technical parameters of LightSquared's network—and, in particular, supported LightSquared in proceedings in which the Commission relaxed the numerical limits applicable to LightSquared's terrestrial transmitters and significantly increased the power level at which LightSquared's terrestrial base stations may transmit within its authorized MSS spectrum.

For example, LightSquared's initial application for ATC authority prompted discussions between LightSquared and the GPS industry to resolve objections that commercial GPS receivers might not work properly in the presence of terrestrial transmitters in the adjacent

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70 *See* Letter to Senator Charles E. Grassley from Julius Genachowski, Chairman, FCC, IBFS File No. SAT-MOD-20101118-00239, at 2 (May 31, 2011).

MSS/ATC Band.[71] In fact, the commercial GPS industry drove the adoption of out-of-band power limits in the Commission's ATC rulemaking[72] as well as those that have always applied to LightSquared's authorization for its terrestrial network.[73] Those terrestrial power limits were intended to minimize the impact of LightSquared's ATC operations on commercial GPS receivers,[74] after taking into account the "increased user density from *potentially millions of MSS mobile terminals operating in ATC mode*" and "*tens of thousands of ATC wireless base stations* . . . ."[75]

A 2002 joint industry agreement memorialized those technical limits in order to "protect the GPS service's present and future operations and to provide a stable environment for the development and operation of [LightSquared's] proposed system."[76] The analysis that led to that agreement "considered all relevant issues concerning potential interference to GPS," and reflected the agreement of "[a]ll relevant stakeholders," as identified by the GPS industry.[77] In particular, those limits were adopted with the express expectation of "GPS receivers operating in

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[71] Other commenters expressly raised "overload" in their comments. *See Deere Comments* (stating that power from base stations could be sufficient to overload the "sensitive receiving amplifiers of the GPS terminals"); *Inmarsat Petition to Deny,* at 9-10 (stating that power from base stations could "overload" Inmarsat METs and GPS receivers); Comments of Inmarsat Ventures plc, IB Docket No. 01-185, at 17-18 and Technical Annex at 8-9 (Oct. 22, 2001) ("*Inmarsat Comments*") (asserting that base station operations could overload GPS receivers).

[72] *2005 ATC Order* ¶ 53.

[73] *See MSV ATC Order* ¶ 80 (subsequent history omitted).

[74] *See 2002 MSV-GPS Joint Letter* at 1.

[75] *See USGIC Reply to Comments* at 2 (emphasis added). NTIA subsequently identified the agreement with the commercial GPS industry as evidence that effective technical solutions "are attainable by the MSS ATC communities and agreeable with the GPS community." *See January 2003 NTIA Letter* at 3.

[76] *See* Petition for Reconsideration of the U.S. GPS Industry Council, IB Docket No. 01-185, at 2 (June 11, 2003) ("*2003 USGIC Petition for Reconsideration*").

[77] *Id.* at 4.

the vicinity of [LightSquared terrestrial base] stations."[78] The limits, which are far more stringent than the limits contained in the Commission's rules, also have formed the basis for the out-of-band power limits imposed on Globalstar and TerreStar as conditions to their ATC authorizations.[79] The GPS industry also endorsed the LightSquared network in the very same proceedings in which the Commission relaxed, and then eliminated, limits on the number of terrestrial transmitters in the MSS/ATC Band, and in which the Commission authorized a substantial increase in the power level that could be emitted by terrestrial base stations within the MSS/ATC Band.[80]

A similar pattern emerged following LightSquared's 2009 request that the Commission modify the application of certain of its technical rules following the execution of the LightSquared-Inmarsat Cooperation Agreement to facilitate the deployment of 4G LTE wireless service, including another increase in the power level that could be emitted by terrestrial base stations within the MSS/ATC Band.[81] In response to that license modification request, the GPS industry questioned whether the planned operation of LightSquared's "femtocells" and

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78 *See* Letter to FCC from U.S. GPS Industry Council, IBFS File No. SAT-MOD-20031118-00333, at 1 (Mar. 24, 2004) ("*2004 USGIC Letter*").

79 *See Globalstar LLC*, 21 FCC Rcd 398, at ¶¶ 23-24 (2006); *TerreStar Networks Inc.*, 25 FCC Rcd 228, at ¶ 28 (2010).

80 *See MSV ATC Order* ¶ 90 (relaxing numerical limit on MSS/ATC Band base stations); *2005 ATC Order* ¶¶ 46-48, 55 (eliminating the numerical limit on MSS/ATC Band base stations and increasing permitted base station EIRP from 23.9 dBW per sector to 31.9 dBW per sector).

81 *See SkyTerra Modification Order* ¶¶ 10, 46 (increasing permitted base station EIRP from 31.9 dBW per sector to 42 dBW per sector).

"microcells" would be compatible with GPS receivers.[82] Those concerns similarly were resolved through the adoption of negotiated out-of-band power limits.[83]

Although LightSquared's 2009 modification application would have allowed it to increase the power of its base stations *by a factor of 10*, the GPS industry did not comment on that aspect of the application. Nor did the GPS industry comment in any way with respect to the issue of GPS receiver "overload." Rather, the industry complained that the *2005 ATC Order* allowed ATC operators to deploy any number of base stations and did not contemplate either: (i) the type of indoor base station use or outdoor microcell and femtocell technology that the modification application proposed; or (ii) the "hundreds of thousands of units operating in the band adjacent to the GPS L-1 signal."[84] The GPS industry thus argued that the 2005 decision (by then, a long-final rulemaking order), as well as LightSquared's new proposal to use microcell and femtocell technology, "effectively and significantly changed the operational scenario" on which the 2002 joint industry agreement with LightSquared was based.[85] But in making these arguments, the GPS industry never raised what now would seem to have been the obvious point that LightSquared's planned operations, including an increase in base station power of *10 times*, would cause receiver "overload." The GPS industry only asked that the Commission impose additional out of band emission limits with respect to "indoor femtocell and microcell operations."[86] Just one month later, the GPS industry notified the Commission that it had

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[82] *See* Comments of the U.S. GPS Industry Council, IBFS File No. SAT-MOD-20090429-00047, at 2-3 (Jul. 10, 2009) ("2009 GPS Comments").

[83] *See 2009 SkyTerra-GPS Joint Letter* at 1.

[84] *2009 GPS Comments.* at 3.

[85] *Id.* at 2.

[86] *Id.* at 3, 5.

reached an agreement with LightSquared "addressing the concerns expressed by the Council in its Comments," and that it therefore was withdrawing its objection to the application.[87]

In short, the GPS industry participated actively in the rulemaking and licensing proceedings that underlie LightSquared's existing authority, and the industry supported the development of LightSquared's network. In particular, the GPS industry worked with LightSquared to develop mutually-acceptable power limits that would ensure, according to the GPS industry itself, a suitable level of protection for GPS devices. Moreover, the GPS industry described the Commission's initial grant of LightSquared's ATC authority as validation of LightSquared's "adherence to best commercial practices" with respect to protecting GPS interests.[88]

E. The *Conditional Waiver Order*, the Testing Process and LightSquared's Proposed Accommodations

In 2011, the Commission granted LightSquared a waiver to afford LightSquared's customers additional flexibility to provide retail ATC service through "terrestrial-only" mobile handsets. Significantly, the grant of that waiver did not effect any change in the number of LightSquared's terrestrial base stations, or the power that would be emitted by those base stations.[89] Notwithstanding these facts, certain members of the commercial GPS industry used that proceeding to raise concerns that the power levels emitted by LightSquared's licensed terrestrial base stations within the MSS/ATC Band could "overload" GPS receivers—concerns entirely unrelated to the waiver relief sought by LightSquared (which did not affect those power levels in any manner whatsoever).

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87 *2009 SkyTerra-GPS Joint Letter*; Letter to FCC from USGIC, IBFS File No. SAT-MOD-20090429-00046 (Aug. 17, 2009).

88 *See 2004 USGIC* Letter at 1.

89 *See generally Conditional Waiver Order*.

In the spirit of cooperation and to facilitate grant of the requested waiver, LightSquared volunteered to participate in a process intended to examine the concerns raised by the GPS industry that was conducted through a technical working group promoted by the *Conditional Waiver Order* ("TWG").[90] Critically, however, nothing in the *Conditional Waiver Order* altered the relative substantive rights and obligations of the parties. In other words, the *Order* did not in any way alter the interference protection or status of GPS receivers under Commission rules and precedent, and it did not alter the fundamental parameters of LightSquared's ATC license.

The actual results of the TWG testing demonstrated several points and are discussed in further detail below. First, there was no problem identified in the TWG testing with respect to the 1626.5 to 1660.5 MHz uplink portion of the MSS/ATC Band that is licensed to LightSquared.[91] Second, the testing showed that more work was required to establish compatibility between GPS receivers and LightSquared's planned ATC base station transmissions in the 10 MHz channel at the top of the 1525-1559 MHz band licensed to LightSquared,[92] *i.e.*, the portion of that band nearest to the GPS Band.[93]

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90 Letter to FCC from LightSquared Subsidiary LLC, IBFS File No. SAT-MOD-20101118-00239, at 2 (Jan. 21, 2011).

91 *See* Sections I.A and IB, *infra*, for a complete explanation of the spectrum licensed to LightSquared and its relationship to the GPS Band.

92 This is a 10 MHz channel at 1545.2-1555.2 MHz ("Upper 10 MHz channel").

93 Once again, the reason for the problem was and is not improper transmission by LightSquared into the GPS Band, but rather that certain legacy GPS receivers do not adequately reject transmissions from base stations operating in the adjacent frequency band because the GPS receivers have been deliberately or, sometimes, inadvertently, designed or manufactured with the assumption that there would be no adjacent-band terrestrial transmissions.

Third, the test results demonstrated that that base station transmissions in the 10 MHz channel at the bottom of the 1525-1559 MHz band licensed to LightSquared[94]—the portion of that band farthest away from the GPS Band—will not adversely affect the performance of *over 99 percent* of GPS receivers (including 100 percent of GPS-enabled mobile phones and general location and navigation devices). The exceptions were limited mostly to certain precision measurement devices used primarily in agriculture, survey, mining and construction that have been designed, in effect, to receive MSS augmentation signals transmitted on LightSquared and Inmarsat frequencies in order to improve the accuracy of GPS signals and whose use is subject to the terms of satellite coordination agreements and commercial contracts.[95] Additional data submitted into the record by LightSquared demonstrates unequivocally that those compatibility concerns regarding base station transmissions in the Lower 10 MHz channel can be readily resolved.[96]

As the TWG testing process unfolded, however, it became apparent that a number of potential solutions would address GPS concerns while allowing LightSquared to begin deployment of its network in some form.

As a result, LightSquared proposed to implement its network in the Lower 10 MHz channel and in the 1626.5-1660.5 MHz uplink frequencies, while deferring deployment in its Upper 10 MHz channel in order to provide more time for the resolution of concerns there. LightSquared also proposed to operate its ATC base stations at the power levels that the Commission adopted generally in the *2005 ATC Order*, which are reflected in the Commission's

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94 This 10 MHz band refers specifically to the 1526-1536 MHz channel ("Lower 10 MHz channel").

95 *See* Part III, *infra*.

96 *See, e.g.* Letter to FCC from LightSquared, IB Docket No. 11-109 (Jan. 20, 2012) ("*January 20 LightSquared Letter*").

rules, instead of the higher power levels authorized in LightSquared's 2010 ATC license modification.[97]

In addition, LightSquared has offered to limit the "power on the ground" that results from the operation of its base stations in the Lower 10 MHz channel in order to provide greater certainty to GPS users about the ATC operating environment they actually will experience.[98] LightSquared also has proposed that, subject to LightSquared operating in a manner consistent with those parameters, the Commission should find the condition set forth in the *Conditional Waiver Order*[99] satisfied as it applies to the Lower 10 MHz channel and LightSquared's entire 1.6 GHz uplink band (1626.5–1645.5 MHz and 1646.5-1660.5 MHz), while deferring resolution of the continued applicability of that condition with respect to the Upper 10 MHz channel.[100]

In sum, the TWG testing validated that co-existence between LightSquared ATC operations and GPS devices is an issue of receiver overload only, as well as the fundamental fact that it is feasible for LightSquared to deploy under its modified proposals.

In early 2011, the National Space-Based PNT Systems Engineering Forum ("NPEF") conducted certain assessments of the compatibility of GPS receivers with LightSquared's network. That assessment did not reflect the proposals LightSquared had made in July 2011. As a result, on October 12, 2011, the National Executive Committee ("EXCOM") for Space-Based Positioning, Navigation, and Timing ("PNT") tasked NPEF with conducting a

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97 *See LightSquared Recommendation* at 13 n.17, 24-25.

98 *See* Letter to FCC from LightSquared, IB Docket No. 11-109, at 2 (Dec. 12, 2011) ("*December 12 LightSquared Letter*").

99 *See Conditional Waiver Order* ¶ 48.

100 *See December 12 LightSquared Letter* at 1.

further assessment of the compatibility of GPS receivers based on the modified LightSquared parameters. The FAA conducted a similar analysis starting in August 2011.

As summarized in the following section and as further detailed in the Technical Appendix, the entire process was flawed from the start. LightSquared began discussions with the constituent agencies in an effort to address their concerns. LightSquared continued to develop modified network implementation proposals.[101] Unfortunately, each positive effort initiated by LightSquared ultimately met resistance somewhere within the Executive Agencies. Throughout the process, leaks about negative NPEF work results occurred, and ultimately the assessment process by Executive Agencies was abruptly shut down.

F. The Deeply Flawed Executive Agency Testing

As described in the NTIA Letter, NTIA has relied upon testing conducted by the NPEF and an analysis by FAA/DOT to reach its conclusions. The attached Technical Appendix evaluates their reports, which NTIA has proffered as support for its adverse determinations regarding the compatibility of GPS receivers with LightSquared's MSS/ATC operations, and the feasibility of various accommodation plans.

As discussed in more detail below and in Exhibit A to the Technical Appendix, the evidence is overwhelming that NPEF's testing and analysis of personal/general navigation devices failed to comply with scientific standards or reflect LightSquared's stated ATC deployment plans, with the result that the tests cannot be used to support any rational conclusion regarding the general population of such devices. Among other things, the testing and analysis was based on an obsolete model of LightSquared's ATC deployment plan.

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[101] *See* Letter to FCC from LightSquared, IB Docket No. 11-109 (Dec. 7, 2011) ("*December 7 LightSquared Letter*"); *December 12 LightSquared Letter* at 1-2.

Had NTIA given proper consideration to LightSquared current plan, it would have concluded that more than 80 percent of personal general navigation devices tested in fact passed even the unreasonable 1 dB C/N_0 test that NTIA imposed, and if other flaws were corrected, all of the devices would have "passed." At the time the NPEF report was issued, LightSquared had already agreed both to reduce the maximum power of its base stations as a function of their height and to guarantee not to exceed a given power on the ground at practically any GPS receiver. The guarantee to a limited power on the ground would be provided either by: (i) designing and deploying the network based on the use of a light-clutter propagation model; or (ii) using a post-deployment measurement program with sufficient spatial resolution to identify any hotspots that would be eliminated by further modification of base station power. NPEF failed to credit these commitments in its tests and the *NTIA Letter* fails to either acknowledge LightSquared's proposals or address them in its consideration of mitigation options.

Similarly, with respect to aviation devices, as discussed below and in more detail in Exhibit B, the evidence shows that accommodation proposals were rejected even before FAA determined its evaluation criteria or considered the feasibility of accommodation proposals.

Exhibit C of the Technical Appendix discusses a key technical issue that NTIA neglects to analyze or credit, despite its importance: the ability of GPS manufacturers to build receivers that are compatible with LightSquared operations without any loss in performance or material increase in cost or size. NTIA fails to note that all classes of GPS devices include at least some devices that, as manufactured and without modification, pass even the flawed process by which NTIA judges them. Exhibit C rebuts the various technical arguments that commercial GPS manufacturers have made that "high performance" renders GPS devices incompatible with LightSquared's operation and shows that there is no reason why all GPS devices in the past decade could not have been designed and built to be compatible with LightSquared's ATC operations.

G. The MSS/ATC Band Operating Environment Was Firmly Established Almost Seven Years Ago

A false refrain often heard is that LightSquared's ATC plans represent a "new interference environment" that could not have been anticipated by the GPS industry during the ATC rulemaking process, which started in 2001 and ended in 2005.[102] As a result, the incompatibility of certain GPS receivers with ATC operations—*i.e.*, the potential for "overload"—is (unfairly) blamed on LightSquared. As detailed in this section, the environment presented by LightSquared's currently planned ATC operations actually is far more favorable to GPS receivers than the environment that NTIA expressly considered in evaluating LightSquared's ATC application almost eight years ago, in 2004.

The following are the salient parameters for assessing the potential for "overload" when a GPS receiver "listens" for GPS signals within the MSS/ATC Band:

- the expected power levels GPS units will encounter from ATC base stations and mobile user terminals;
- the expected number of ATC base stations and mobile user terminals to be deployed;
- the expected proximity of GPS receivers to ATC base stations and mobile user terminals.[103]

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102 *See* Letter to FCC from NTIA, IBFS File No. SAT-MOD-20101118-00239, at 1 (Jan. 12, 2011) ("*January 2011 NTIA Letter*"); *see also, e.g.,* Letter to FCC from Trimble Navigation Limited, IBFS File No. SAT-MOD-20101118-00239, at 3-11 (June 14, 2011) (suggesting that the nature of LightSquared's operations have materially changed so as to alter the interference environment).

103 Receiver "overload," also referred to as desensitization or blocking, occurs because of the reaction of electronic components inside a receiver to strong radiofrequency signal voltages that are received from outside the receiver's intended band of operation (in this case, from the reception of RF energy outside the GPS Band). The strength of the

- the "sensitivity" of the GPS receivers to power from outside their specified operating band.

The risk of "overload" in the presence of an "ATC-only" mobile user terminal is typically less than the risk presented by a dual-mode MSS/ATC terminal when it communicates with the satellite, and also is lower than the risk presented by a typical mobile satellite terminal. As discussed below, expectations with respect to the primary aspects of the ATC operating environment have not changed materially since 2005. In contrast, the "sensitivity" of GPS receivers to this operating environment has always been controlled by and known only to the manufacturer (because the performance of the GPS receiver is not subject to any Commission standards or authorization).

1. Power Levels and Numerical Limits

The Commission's ATC rules, and the terms of LightSquared's ATC authorizations, define the maximum power levels at which LightSquared's ATC base stations and mobile user terminals may transmit, and the number of ATC base stations and mobile user terminals that LightSquared may deploy. These ATC rules and authorizations also define reasonable expectations as to the environment in which such operations will occur.

The Commission finalized its ATC rules in 2005, after resolving numerous petitions for reconsideration of the earlier *2003 ATC Order*. Reconsideration was sought by, among others, the GPS industry,[104] which asked that the Commission incorporate into the ATC rules and apply to all ATC licensees the same type of GPS protection criteria with which LightSquared had already agreed to comply (*i.e.*, stringent out-of-band emission limits).[105] The

received signal voltages is affected by both the transmitted power and proximity to the transmitter.

104 *See, e.g., 2003 USGIC Petition for Reconsideration* at 3.

105 *See, 2002 MSV-GPS Joint Letter* at 1.

2005 ATC Order expressed a clear preference for allowing market forces to determine where and to what extent ATC would be deployed. The Commission also modified certain of its technical rules to provide ATC operators with additional flexibility to design efficient networks in response to market dynamics. These changes were largely consistent with: (i) relief previously enjoyed by LightSquared alone, after the Commission granted applications for ATC authority that LightSquared had submitted following the adoption of the *2003 ATC Order*;[106] and (ii) LightSquared's petition for reconsideration of the *2003 ATC Order*, which sought additional flexibility similar to that sought in LightSquared's ATC applications (which were filed in parallel).[107]

Notably, NTIA conducted a detailed technical analysis of LightSquared's proposed ATC operations, including an analysis of the potential impact in the GPS Band. Following that review, NTIA expressed that it had no concern with the "*unlimited* reuse of [LightSquared's] satellite spectrum for ATC operations" as long as no other co-channel MSS network was affected.[108] Subsequently, and in light of the *2005 ATC Order*, which made generally applicable much of the relief that had previously been granted to LightSquared alone, NTIA reaffirmed that that the out-of-band emissions limits to which LightSquared had agreed were sufficient to protect GPS receivers from the emissions of ATC base stations and mobile user terminals.[109]

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106 *See* IBFS File Nos. SAT-MOD-20031118-00333; SAT-AMD-20031118-00332; SES-MOD-20031118-01879.

107 Petition for Partial Reconsideration and Clarification of Mobile Satellite Ventures Subsidiary LLC, IB Docket No. 01-185, at 8 (July 17, 2003).

108 *See 2004 NTIA Letter* at 2.

109 *See 2005 NTIA Letter* at 3.

The following table depicts the operating parameters salient to an analysis of GPS "overload" that are within LightSquared's control: (i) as assumed by the NTIA in 2004 in the course of evaluating LightSquared's ATC applications; (ii) as reflected in the final ATC rules adopted by the Commission in 2005; and (iii) as reflected in LightSquared's current operating plans.[110]

	NTIA (2004)	**FCC (2005)**	**LightSquared (2012)**
Maximum Base Station Power (aggregate EIRP per sector)	3890 Watts (35.9 dBW)	1549 Watts (31.9 dBW)	1585 Watts (32 dBW)[111]
Maximum Number of Base Stations[112]	Unlimited	Unlimited	36,000 estimated[113]
Maximum Mobile User Terminal Power	1 Watt	1 Watt	1 Watt
Maximum Number of Mobile User Terminals[114]	Unlimited	Unlimited	Based on demand

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110 *See, e.g., December 7 LightSquared Letter; December 12 LightSquared Letter;* Letter to FCC from LightSquared, IB Docket No. 11-109 (Dec. 20, 2011) ("*December 20 LightSquared Letter*").

111 This limit on base station power would be subject to additional constraints as the result of LightSquared's "power on the ground" proposals. *See December 20 LightSquared Letter* at 2.

112 The *2003 ATC Order* originally limited the number of base stations that could simultaneously operate on any one 200 kHz channel, but did not limit the number of base stations that could be deployed. The Commission eliminated the limit on simultaneous base station spectrum reuse in 2005, in favor of a rule that allowed reuse of MSS spectrum for ATC subject only to the terms of coordination with co-channel MSS networks and the substantial satellite service requirement. *See 2005 ATC Order* ¶¶ 42-50. The Commission took such action after the NTIA indicated that it had no concern with "unlimited reuse of [LightSquared's] satellite spectrum for ATC operations" as long as no other co-channel MSS network was affected. *See 2004 NTIA Letter* at 2.

113 This is an estimate of the number of base stations that will be needed to meet LightSquared's existing build-out obligations. *See HarbingerTransfer Order* ¶ 72.

114 The *2003 ATC Order* limited the number of simultaneously transmitting mobile user terminals in a single GSM time slot, yielding an effective limit of 14 million subscribers. *See MSV ATC Order* ¶ 67. The Commission eliminated that effective limit in 2005, in favor of a rule allowing reuse subject only to the terms of coordination with co-channel MSS networks and the substantial satellite service requirement. *See 2005 ATC Order* ¶¶ 42-50. The NTIA indicated it had no concern with this change, as no co-channel MSS network would be affected. *See 2004 NTIA Letter* at 2.

The table clearly shows that the expected operating environment in the MSS/ATC Band today essentially is the same as it was in 2005. If anything, LightSquared's current plans materially *decrease* that risk by proposing a deployment with reduced base station operating power.

2. Proximity of GPS Receivers to ATC Operations

The record underlying the ATC rulemaking proceeding demonstrates that expectations with respect to the likelihood that GPS receivers would be used in the vicinity of ATC base stations and mobile user terminals also have not changed materially.[115]

Since 2003, there has been no doubt that, once deployed, the use of ATC base stations and mobile user terminals would be concentrated in populated areas, where the MSS/ATC Band would be heavily used. For example, the *2003 ATC Order* noted that one of the key benefits of ATC operations would be to allow MSS spectrum to be used more intensively in "geographic areas that can be more efficiently served by ATC."[116] The *2003 ATC Order* also recognized explicitly that "[a]chieving optimal spectrum usage may require an MSS operator to use ATC even though a particular call might be served by satellite."[117] Indeed, the Commission anticipated that, in some cases, a MSS/ATC system could use "the large majority of its channels and time for ATC."[118]

Moreover, the agreement between LightSquared and the GPS industry reflected the likelihood that ATC base stations and mobile user terminals would be deployed ubiquitously.

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115 Notwithstanding the analysis presented below, in 2011 the NTIA expressed its "understanding" that "the original construct of MSS/ATC operations [was] that they would operate as 'satellite first/terrestrial second' systems." *See January 2011 NTIA Letter* at 5. As demonstrated above, this "understanding" is simply incorrect.

116 *See 2003 ATC Order* ¶ 99.

117 *Id.* at ¶ 101.

118 *See 2005 ATC Order* ¶ 20; *see also id.* at ¶ 21 ("[W]e cannot predict what eventualities may cause traffic loading to increase or decrease, or how such loads will be distributed between ATC transmitters and MSS handsets.")

Tellingly, in 2003 the U.S. GPS Industry Council observed that the agreement had been reached after taking into account the "increased user density from *potentially millions of MSS mobile terminals operating in ATC mode*" and "*tens of thousands of ATC wireless base stations* . . . ."[119]

The Commission confirmed in 2003 and again in 2005 that no requirement exists that an ATC service be "mostly satellite," or that mobile user terminals "look to the satellite first." In fact, the Commission considered and rejected proposals to require that MSS traffic be quantitatively "primary" or "predominant" in MSS/ATC systems: "The proposal to require 'predominant' satellite use would limit the MSS provider's flexibility and its concomitant spectrum efficiencies, *e.g.*, by requiring predominant satellite coverage in geographic areas that can be more efficiently served by ATC, such as large cities."[120] The Commission also rejected proposals that MSS/ATC operators first attempt to route a given call through a satellite before relying on ATC infrastructure.[121]

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119 *See USGIC Reply to Comments* at 2.

120 *2003 ATC Order* ¶ 99.

121 *Id.* ¶ 100 ("[R]equiring satellite-routing would defeat most of the benefits of authorizing ATC in the first instance. The disadvantages would increase markedly if we were to further restrict MSS operators to offering only dual-mode phones that defaulted to the satellite transmission path."); *see also 2005 ATC Order* ¶ 24 (rejecting the "requirement that any MSS/ATC handset first attempt to place a call through the MSS component of the service and only call through the ATC if the satellite signal is unavailable or unreliable" and noting that "the efficiencies of dynamic frequency assignment would be hampered by a firm rule that handsets must try to acquire the MSS communications path first," as a "satellite first-look" requirement "would involve the use of extra time and power in the handset, . . . increase the cost of providing service, hinder call completion, and ultimately reduce system efficiency" as well as "force a weaker satellite signal on consumers in areas where a stronger ATC signal was available, but a satellite signal was also available.") (footnotes omitted).

3. Irrelevance of the *Conditional Waiver Order*

The NTIA has suggested that the *Conditional Waiver Order* somehow altered the ATC operating environment in a way that would materially increase the risk of GPS receiver "overload."[122] This claim is entirely unfounded.

As the *Public Notice* acknowledges, the *Conditional Waiver Order* involved only a "limited waiver" that "narrowly addressed" the integrated service requirement in the Commission's ATC rules, and allowed LightSquared's wholesale customers to deploy "terrestrial-only" mobile user terminals. However, the *Conditional Waiver Order* did not alter any of the ATC operating parameters salient to an analysis of GPS "overload." Rather, the *Conditional Waiver Order* merely allows LightSquared's wholesale customers to offer "terrestrial-only" mobile user terminals to consumers—ensuring that these customers can choose from the widest possible range of chipset and terminal manufacturers, and provide consumers the benefits of competitive alternatives.

Contrary to the NTIA's suggestion, the *Conditional Waiver Order* had no bearing on the fundamental technical parameters of LightSquared's network,[123] and no conceivable impact whatsoever on the ATC operating parameters salient to an analysis of GPS "overload." In the words of the *Public Notice*, "the interference addressed by the *NTIA Letter* is associated with LightSquared's planned terrestrial base stations *rather than the mobile handsets at issue in the Conditional Waiver Order*."[124] Thus, the *Conditional Waiver Order* has done nothing to alter the operating environment that the NTIA and the GPS industry reasonably could have expected since at least 2005 when: (i) the ATC rules were finalized; and (ii) the NTIA reaffirmed

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122 *Public Notice* at 2.

123 *See id*.

124 *Id.* at 4 (emphasis added).

that the out-of-band emissions limits to which LightSquared had agreed were the salient "protection requirements of RNSS receivers" from the emissions of ATC base stations and mobile user terminals.[125]

II. THE STATED BASES FOR THE PROPOSED MODIFICATIONS OF LIGHTSQUARED'S ATC AUTHORITY ARE FUNDAMENTALLY INCONSISTENT WITH LIGHTSQUARED'S LICENSED STATUS IN THE MSS/ATC BAND AND THE UNPROTECTED STATUS OF GPS RECEIVERS IN THAT BAND

A. GPS Users and Manufacturers Are Not Entitled to Protection from "Overload" and Have No Standing to Complain When MSS ATC Licensees Operate Within Their Licensed Parameters

In an apparent attempt to distract attention from their legal vulnerabilities, GPS interests have conflated a number of critical technical issues and legal principles regarding the operation of GPS receivers. They essentially argue that "any impact on GPS regardless of the cause is prohibited and must be stopped at LightSquared's expense." However, that is not what the law requires or even allows. The potential incompatibility of a limited number of GPS receivers with LightSquared's planned ATC operations does not extend from legally cognizable "harmful interference," and does not justify the actions proposed in the *Public Notice*.

1. <u>GPS Receiver Overload Is a Self-Inflicted Wound for which LightSquared Has No Legal Responsibility</u>

As detailed above, unregulated receivers simply cannot be provided with broad, sweeping protection for their own reception of signals (i) from outside of the band allocated for a given purpose, and (ii) in portions of the radio spectrum allocated for other purposes and licensed to other users for such other purposes. This is particularly true where unregulated receivers are not subject to any technical standards, and where the susceptibility of such receivers to "overload" is entirely determined by the manufacturer. To be sure, the Commission can take the

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125 *2005 NTIA Letter* at 1, 4-5.

existence of such devices into account when it sets the rules for new services—but it must do so deliberately, and after weighing both the evidence presented and the impact on larger policy goals.

In the case of ATC operations in the MSS/ATC Band, that evaluation happened almost a decade ago. And, even though the possibility of GPS "overload" from ATC operations were raised initially, the Commission did not adopt—and the GPS industry did not insist upon—technical limits designed to prevent the "overload" of GPS receivers engaged in "out-of-band *reception*." Rather, the Commission specified a different set of rules designed to limit "out-of-band *emissions*" from ATC operations into the GPS Band. Those criteria were agreed to by the U.S. GPS Council (representing the GPS industry) and LightSquared after considering "all relevant issues concerning potential interference to GPS," and reflected the agreement or support of "[a]ll relevant stakeholders."[126] Those limits also were endorsed by NTIA[127] after an exhaustive analysis of the potential impact of ATC operations on a variety of spectrum uses, including GPS.[128]

In fact, the GPS industry argued at the reconsideration phase of the ATC rulemaking proceeding that "[n]othing in the record" supports the adoption of any other technical criteria to protect GPS.[129] All of this history is fully consistent with the Commission's longstanding encouragement of "receiver manufacturers to design receivers reflecting the state of the art" and its policy of considering "the installation of suitable receiver filters" an appropriate

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126 *2003 USGIC Petition for Reconsideration* at 4.

127 *See January 2003 NTIA Letter* at 3 (identifying the agreed-upon limits as evidence that effective technical solutions "are attainable by the MSS ATC communities and agreeable with the GPS community.").

128 *See November 2002 NTIA Letter*.

129 *2003 USGIC Petition for Reconsideration* at 3.

remedy "[w]here design inadequacies in various situations result in interference being received."[130]

Fortunately, the designs of most GPS receivers being marketed today are consistent with the Commission's direction, and thus are compatible with the operation of LightSquared's ATC network.[131] Yet, some GPS manufacturers have done nothing to modify their receiver designs to account for LightSquared's planned ATC operations and to avoid the potential for "overload," notwithstanding: (i) the GPS industry's agreement that the applicable out-of-band emissions limits, with which LightSquared will comply fully, are the only limits that are necessary to ensure that in-band GPS operations are protected; (ii) the Commission's warning to manufacturers that avoiding undesired "overload" effects and other incompatibilities may require appropriate modifications to their receiver designs;[132] and (iii) widespread recognition, for more than a decade, that ATC facilities would be deployed in the MSS/ATC Band. In fact, evidence submitted by GPS interests themselves demonstrates that some manufacturers actually have modified their receivers to make them *more* susceptible to "overload" effects. For example, Deere admits that is has "opened up" its GPS receivers so that they "listen" to an even broader range of frequencies in the MSS/ATC Band.[133]

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130 *See Public Notice: P*olicy *to Govern the Change of FM Channels to Avoid Interference to Television Reception*, 2 FCC.2d 462 (1966). The Commission generally has not codified these case-specific limits in its rules, although they are reflected in various licensing decisions.

131 This is illustrated, for example, by the TWG testing results. *See* Section III.A, *infra*, and Technical Appendix.

132 *See 2003 ATC Order* ¶ 120 (observing that "desensitization or overload from ATC operations . . . that may develop over time as ATC is deployed can be mitigated by future [receiver] design modifications and through a cooperative effort by . . . licensees to resolve these issues").

133 *See* Petition for Reconsideration of Deere & Company, IBFS File No. SAT-MOD-20101118-00239, at 6 (Feb. 25, 2011) ("*Deere Petition for Reconsideration*"). This is a

Those same GPS interests defend their blatant disregard for good engineering practices by claiming (wrongly) that the *Conditional Waiver Order* materially altered the technical parameters of LightSquared's planned network, and thus the degree to which GPS devices "listening" in the MSS/ATC Band might be incompatible with that network. As detailed above, that simply is not true. As the *Public Notice* acknowledges, the *Conditional Waiver Order* involved only a "limited waiver" that "narrowly addressed" the integrated service requirement in the Commission's ATC rules, and allowed LightSquared's wholesale customers to deploy "terrestrial-only" end user terminals. The *Conditional Waiver Order* had no bearing on the fundamental technical parameters of LightSquared's base stations that are the claimed source of overload.[134] In fact, the base station power limits at which LightSquared plans to operate are no higher than the levels established in 2005, when the Commission eliminated any numerical limits on the number of ATC base stations or mobile user terminals, and also eliminated the expectation that "self-interference" to an MSS spacecraft would constrain the scope of ATC deployment.[135] Thus, the *Conditional Waiver Order* in no way created an increased threat of "overload," and there is no credible basis to assert that the GPS industry was not aware of LightSquared's intentions until last year.[136]

For these reasons, the failure of GPS manufacturers to deploy receivers that are compatible with LightSquared's ATC authorization can be viewed only as a self-inflicted wound. Moreover, and as detailed in the following sections, neither GPS manufacturers nor

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particularly significant admission because Deere & Company first raised the overload issue in 2001, did not pursue it, and then chose to open up its receivers.

134 *See Public Notice* at 2.

135 *2005 ATC Order* ¶ 42.

136 *See* Sections I.D, I.E, and I.G, *infra*.

users of GPS receivers had any legitimate expectation that any incompatibility with LightSquared's network would receive protection under the law.

2. Under the Commission's Rules, GPS Receivers Operating in the MSS/ATC Band Are Not Entitled to Protection

a. LightSquared's pending Petition for Declaratory Ruling establishes that GPS receivers are not entitled to protection from "overload" effects they may experience in the MSS/ATC Band

The Commission's rules, policies, and precedent make clear that GPS receivers that "listen" in the MSS/ATC Band are not entitled to *any* interference protection with respect to those operations. As noted above, and as the *Public Notice* specifies, the "overload" at issue is caused by "signals . . . received by GPS receivers outside the frequency bands allocated to GPS"—*i.e.*, in the MSS/ATC Band.

LightSquared's pending Petition for Declaratory Ruling provides extensive support for these propositions. In particular, the Petition establishes that GPS receivers have no generalized right to "overload" protection in the MSS/ATC Band.

This is consistent with the Commission's non-regulation of GPS receivers and its policy of allowing manufacturers to market receivers without regard for any established technical specifications—provided that the manufacturers accept the resulting risk of "overload" and other adverse effects. Indeed, as explained in greater detail above, it would be infeasible to afford GPS receivers broader protection in the absence of Commission regulations or standards for GPS receivers: no one would know what technical parameters might require "protection."

More broadly, LightSquared's Petition demonstrates that LightSquared's planned operations in the MSS/ATC Band are fully consistent with its longstanding license, the U.S. Table, the Commission's service rules, and the technical standards developed over the past decade with the cooperation and support of the GPS industry itself (*and* NTIA). At the same time, the Petition establishes that the GPS receivers "listening" in the MSS/ATC Band are not licensed,[137] are not subject to any service rules that govern their operating parameters, and thus are not entitled to any interference protection whatsoever. On this basis alone, it should be clear that the GPS industry has *no* basis for claiming protection, or for asserting that any "overload" GPS receivers may experience in the MSS/ATC Band would constitute cognizable "harmful interference."

This conclusion is reinforced by that fact that, as detailed above, a GPS receiver that "listens" in the MSS/ATC Band represents a nonconforming use of spectrum that is inconsistent with the U.S. Table.[138] As is the case with respect to other uses of the radiofrequency spectrum in the United States, GPS "listening" activities that are not conducted in accordance with the U.S. Table are, at best, a "nonconforming" use.[139] When the Commission grants a waiver to allow a nonconforming use, that use must proceed on an unprotected basis with respect to all other services.[140] In other words, nonconforming uses enjoy *no* allocation status, and, like Part 15 uses, are treated as effectively tertiary in all analyses of relative spectrum rights.

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137 As the *Petition for Declaratory Ruling* observes, commercial GPS receivers that are not licensed could be characterized as unlicensed receive-only earth stations that operate under Part 25 of the Commission's rules (at least to the extent they communicate with U.S. GPS spacecraft), and/or treated as unlicensed devices that operate under Part 15 of the Commission's rules, a characterization that the commercial GPS industry itself has adopted. *See Petition for Declaratory Ruling* at 10 & n.29. Under either rubric, however, manufacturers and users of GPS receivers that are not licensed simply have no legal right to interference protection vis-à-vis LightSquared, or any other licensed user of radio spectrum, for that matter.

138 *See* Section I.B, *supra*; *see also Petition for Declaratory Ruling* at 18-22.

139 *See* 47 C.F.R. §§ 2.102(a); 2.106.

140 *See, e.g.*, *QUALCOMM Order* ¶ 11; *see also* cases listed in Exhibit 2 hereto.

As discussed above, the 1525-1559 MHz band is allocated in the United States for MSS on a primary basis, which includes ATC operations.[141] The adjacent 1559-1610 MHz band is allocated for RNSS/GPS on a primary basis. Commission precedent makes clear that radiodetermination-satellite service ("RDSS") (and the more-narrowly-defined RNSS) operations do not fall within the scope of the definition of MSS, as "MSS and RDSS are intended to serve different customer needs"[142] and "RDSS and MSS are sufficiently different that separate and distinct allocations are warranted."[143] The commercial GPS industry itself acknowledges the difference between MSS and RNSS, and in a recent letter to the Commission, the U.S. GPS Council went so far as to emphasize the widespread recognition that "radionavigation signals are different in kind from radiocommunication signals."[144] Given these distinctions, GPS receivers that "listen" in the MSS/ATC Band are nonconforming, such that they may operate only on an unprotected, non-interference basis. This would be the case even if the GPS receivers at issue were licensed to operate in the adjacent RNSS band—which they are not.

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141 *See Flexibility* Notice ¶ 35; *2003 ATC Order* ¶ 208 ("We do not adopt new allocations in the 2 GHz, L- and the Big LEO MSS/ATC Band, but rather indicate that ATC is permissible by footnote in the domestic table of allocations . . . .") and ¶ 236 (concluding that modification of the 1525-1559 MHz allocation is not necessary to implement ATC authority because "ATC networks are to be closely tied to a licensee's MSS network operations from a technical and operational standpoint . . . ."); *see also* 47 C.F.R. § 2.106 n.US309 (taking similar path to permit terrestrial use of AMS(R)S spectrum).

142 *Radiodetermination Satellite Service*, 104 FCC.2d 650, at ¶ 15 (1986).

143 *Radiodetermination Satellite Service*, 104 FCC.2d 637, at ¶ 8 n.4 (1986). Tellingly, the U.S. Table of Frequency Allocations includes a footnote permitting "differential GPS" operations in the 1559-1610 MHz RNSS band. *See* 47 C.F.R. § 2.106 n.US343. The Commission has explained that a "footnote of this kind is necessary" because these operations involve "data transmission [that] is not considered a radionavigation application," and "[r]adionavigation must be accomplished by obtaining information by means of the propagation properties of radiowaves." *Review of Part 87 of the Commission's Rules Concerning the Aviation Radio Service*, Notice of Proposed Rulemaking, 16 FCC Rcd 19005, at ¶ 39 n.90 (2001).

144 *See* Letter to FCC from U.S. GPS Industry Council, IB Docket No. 11-109, at 4 (Nov. 9, 2011).

b. GPS receivers that rely on augmented signals from the MSS/ATC Band have no greater rights than provided in MSS satellite coordination agreements

Certain "high-precision" GPS receivers rely on the use of a narrowband communications signal that is transmitted in the MSS/ATC Band, using satellite capacity that is leased from Inmarsat or LightSquared. These receivers could be designed in a manner that would ensure that they are not susceptible to "overload." For example, they could be designed to incorporate one RF front end that receives the designated narrowband signal from the MSS satellite, and another RF front end that receives the GPS signal (much like a car radio has different components to receive the AM radio band, the FM radio band, and the satellite radio band). However, some of these receivers instead have been designed with a wide-open front end that stretches across the GPS Band and MSS/ATC Band, leaving the receivers susceptible to "overload" from ATC operations in the MSS/ATC Band.

The existence of a limited number of these "augmentation" receivers does not change the analysis presented above. As an initial matter, such devices generally are either unlicensed (*e.g.,* certain Trimble devices) or are licensed to use, at most, only an extremely narrow range of frequencies in the MSS/ATC Band (*e.g.,* certain Deere devices). In the former case, and as discussed above, "augmentation" receivers do not enjoy any interference protection, whether regulated under Part 15 or Part 25. In the latter case, "augmentation" receivers do not enjoy any interference protection in any portion of the MSS/ATC Band in which they are not expressly licensed;[145] moreover, and, as discussed below, augmentation receivers do not enjoy any protection from ATC operations in any portion of the MSS/ATC Band in any event.

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[145] *See* LightSquared Petition for Reconsideration, IBFS File No. SES-RWL-20110908-01047, at 17-18 (Oct. 14, 2011), attached as Exhibit 5 hereto.

Under longstanding precedent, an earth station operator cannot claim "harmful interference" from MSS operations that are consistent with the terms of a coordination agreement to which its space segment provider is bound. In fact, the rights of any end user of an MSS/ATC Band satellite system are derivative of the rights of the satellite network from which it receives service, and the terms of its own contractual relationship with that service provider.

As the Commission is well-aware, an international L Band coordination agreement between LightSquared's predecessor and Inmarsat was entered into in 2007 and then was ratified by the United States, Canada, and the United Kingdom. That agreement resolved an eight-year-old coordination deadlock, and facilitated the resolution of dozens of controversies before the Commission involving the previously uncoordinated use of the MSS/ATC Band.[146] Today, that agreement continues to govern the current and future satellite networks of LightSquared and Inmarsat, as well as any ATC network that either party might deploy. Consistent with Commission policy,[147] that coordination agreement also allows for the deployment of an ATC network in the MSS/ATC Band at parameters other than those specified in the Commission's "default" ATC rules.

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146 *See Press Release: SkyTerra, Mobile Satellite Ventures and Inmarsat Sign Spectrum Coordination and Cooperation Agreement* (Dec. 21, 2007), *available at* http://www.issi-us.net/news/international-satellite-services-press-releases/bid/34255/SkyTerra-Mobile-Satellite-Ventures-and-Inmarsat-Sign-Spetrum-Coordination-and-Cooperation-Agreement. A multinational agreement entered into in 1996 provided for the MSS/ATC Band to be shared among satellite networks, including those operated by Inmarsat and LightSquared, through a spectrum sharing arrangement providing for each operator to use distinct band segments while serving the same geographic area (but providing for spectrum reuse across different geographic areas), and while ensuring that adjacent spectrum uses remain compatible with each other. *See* News Release: *International Action: FCC Hails Historic Agreement on International Satellite Coordination*, Report No. IN 96-16 (Jun. 25, 1996). A few years later, however, difficulties in the annual review of that arrangement led to a deadlock among the affected satellite operators, leaving great uncertainty about the services that could be provided in the MSS/ATC Band—whether by new, state-of-the-art spacecraft, or by complementary ATC facilities.

147 *2005 ATC Order* ¶¶ 43-47.

Because LightSquared's planned ATC operations are consistent with that agreement, those operations cannot be deemed to constitute "harmful interference" into the Inmarsat network. And, because GPS receivers with "augmentation" capabilities receive MSS signals either from Inmarsat or LightSquared, those receivers cannot claim protection from LightSquared's ATC operations in the MSS/ATC Band.

Conceptually, the agreement between LightSquared and Inmarsat is no different than the coordination agreements in the FSS industry that separate potentially "incompatible" single carrier per channel ("SCPC") VSAT traffic from higher-powered analog video traffic—agreements on which the Commission relied for decades. Longstanding precedent makes clear that the Commission: (i) relies on this coordination process to facilitate efficient use of the limited spectrum resource; (ii) allows satellite operators to make a variety of tradeoffs—including tradeoffs based on business considerations—in the course of coordination; and (iii) relies on satellite operators and their customers to honor those agreements.[148] Therefore, an earth station operator has no basis upon which to claim the existence of "harmful interference" from any operations that are consistent with the terms of a coordination agreement to which its space segment provider is bound. For this reason, the Commission routinely has required earth station licensees in the MSS/ATC Band to operate subject to the results of coordination, and on a non-interference basis in the absence of a coordination agreement.[149]

When the Commission established its rules for ATC operations in the MSS/ATC Band, it anticipated that MSS operators would enter into arrangements like the LightSquared-

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148 *See, e.g., Satellite Network Earth Stations*, 20 FCC Rcd 5666, at ¶ 51 (2005); *Fixed-Satellite Service (Reconsideration of 1988 Orbital Assignment Plan)*, 5 FCC Rcd 179, at ¶ 32 (1990); *Orion Satellite Corp.*, 5 FCC Rcd 4937, at ¶ 14 (1990); *GE American Communications*, 3 FCC Rcd 6871, at ¶ 2 (1988).

149 *See, e.g., Comsat Mobile* Communications, 16 FCC Rcd 21661, at ¶ 115(d) (2001).

Inmarsat coordination agreement to facilitate the "efficient and intensive use" of the MSS/ATC Band and "bring more options for high-quality communications at reasonable cost to all Americans."[150] Thus, while the Commission established certain "default" ATC technical rules, the Commission expressly encouraged and empowered MSS/ATC Band satellite operators to negotiate and agree to less restrictive ATC operational limits in order to promote more efficient use of the spectrum.[151] Two years later, when the Commission modified its ATC rules on reconsideration, it made clear that satellite coordination agreements would *automatically supersede* the default limits specified in its rules.[152] By way of example, Section 25.253(a)(2) provides that "[a]ny future coordination agreement between the [MSS operators] governing ATC operation will supersede" the "default" in-band and out-of-band emissions limitations specified in the rule.[153]

Thus, the Commission clearly intended that such negotiated coordination agreements would be used to define the rights of MSS operators vis-à-vis each other as well as the derivative rights of their respective customers (in this case, users of GPS receivers with MSS augmentation capabilities). Allowing the operation of a receive-only GPS device to effectively "veto" such an arrangement would undermine the value of such agreements, and moreover would be inconsistent with the satellite network coordination framework set forth in the ITU Radio Regulations.

The Commission already has concluded as much in its 2010 *SkyTerra Order*, which rejected claims that MSS/ATC Band earth station licensees are entitled to protection from

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150 *2005 ATC Order* ¶¶ 43-47, 95.

151 *2003 ATC Order* ¶ 143.

152 *2005 ATC Order* ¶¶ 43-47.

153 47 C.F.R. § 25.253(a).

"overload" when such protection is not provided under the LightSquared-Inmarsat coordination agreement. In the underlying pleadings, Amtech and Skywave made precisely the type of "protection" arguments now being advanced by the GPS industry.[154] In rejecting these arguments, the Commission noted that "[r]eliance on satellite-operator coordination agreements is an important aspect of a longstanding Commission policy of reliance on marketplace mechanisms to develop solutions to interference concerns, and of refraining from interfering unnecessarily with licensees' business negotiations,"[155] and that such agreements "serve[] the public interest by promoting overall spectrum efficiency and facilitating provision of valuable new services . . . ."[156]

Critically, the Commission acknowledged that giving effect to such agreements could "present challenges to earth station operators using the satellites involved, and *may require modification of operations, deployment of new equipment, or other adjustments*."[157] The Commission found that giving effect to such agreements would serve the public interest, notwithstanding these challenges, and that "[i]t would not serve the public interest for the Commission to assume the role of an arbiter of disputes between a satellite operator and its customers . . . ."[158] The same result is required here: As in the 2010 *SkyTerra Modification*

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154 *See* Petition to Deny of Amtech Systems, LLC, IBFS File No. SAT-MOD-20090429-00047, (Jul. 10, 2009); Comments of SkyWave Mobile Communications, Corp., IBFS File No. SAT-MOD-20090429-00047, (Jul. 10, 2009).

155 *SkyTerra Modification Order*; ¶ 29; *see also Principles for Promoting the Efficient Use of Radio Spectrum by Encouraging the Development of Secondary Markets*, 15 FCC Rcd 24178, at ¶ 8 (2000) ("[I]n general, the best way to realize the maximum benefits from the spectrum is to permit and promote the operation of market forces in determining how spectrum is used").

156 *SkyTerra Modification Order* ¶ 30.

157 *Id*. (emphasis added).

158 *Id*.

Order, users of GPS receivers with augmentation capabilities have no greater rights in the MSS/ATC Band than the rights provided under the LightSquared-Inmarsat coordination agreement, and the terms of their service contracts with their satellite operators.

3. Under NTIA's Rules, Federal GPS Receivers Operating in the MSS/ATC Band Similarly Are Not Entitled to Protection

Like commercial GPS devices, government GPS devices that fall within the category of "federal stations"[159] are not entitled to protection from any "overload" that they may experience when they "listen" in the MSS/ATC Band (all non-federal GPS devices are subject to the rules adopted by the Commission for "commercial" devices). This conclusion flows directly from NTIA's own rules, as reflected in its *Manual of Regulations and Procedures for Federal Radio Frequency Management* (the "Redbook").

As an initial matter, it bears repeating that the "overload" at issue does not stem from LightSquared's transmissions into the GPS Band or any interference into the spectrum used by government GPS satellites to transmit GPS signals. Rather, any potential "overload" of GPS receivers that are federal stations arises from the reception of signals "outside the frequency bands allocated to GPS," and would impact only GPS receivers that "listen" in the MSS/ATC Band. As in the commercial case, such "overload" is avoided easily through appropriate receiver design.

Nothing in NTIA's rules or policies establishes that GPS receivers that are federal stations have any generalized right to protection from "overload" when they operate in the MSS/ATC Band. To the contrary, the Redbook makes clear that GPS receivers that are federal stations are not protected where they operate *either*: (i) on an unlicensed basis; *or* (ii) outside of the spectrum designated for GPS use.

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159 *See NTIA Redbook* § 8.2.17.

First, Sections 7.8 and 7.9 of the Redbook specify that as non-licensed devices, GPS receivers "must accept any interference" from any federal or non-federal authorized radio station or system.[160] This requirement applies both to the substantial number of "off-the-shelf" units used by federal agencies that are manufactured for the general public and subject to regulation by the Commission,[161] as well as other non-licensed devices, which are subject to the technical rules in Annex K of the Redbook.[162] Thus, these GPS receivers are not entitled to *any* overload protection from LightSquared's licensed operations.

Moreover, the Redbook specifically advises government agencies using devices subject to Annex K to "consider the proximity and the high power of non-Federal licensed radio stations"—*e.g.,* LightSquared's base stations—"when choosing operating frequencies during the design and acquisition of their equipment so as to reduce the susceptibility for receiving harmful interference."[163] In the case of "off-the-shelf" receivers, the Redbook relies on the similar exhortation in Section 15.17 of the Commission's rules.[164] In other words, the Redbook specifically cautions agencies that if they purchase receivers that operate in frequencies that overlap with high-power operations—*e.g.*, by "listening" in the MSS/ATC Band in which LightSquared operates—those receivers may not function properly.

Second, the Redbook establishes that even licensed GPS receivers would not be entitled to interference protection where they operate outside of the spectrum designated for GPS use. In fact, the Redbook defines the same basic scheme for relative spectrum rights, based on

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[160] *NTIA Redbook* §§ 7.8, 7.9 (emphasis added).

[161] *Id.* at § 7.8.

[162] *Id.* at § 7.9

[163] *Id.* at § K.1.3.

[164] 47 C.F.R. § 15.17.

allocation priority, as the Commission's rules. Thus, Section 4.1.3 of the Redbook provides that "[a]n assignment that is in conformity with the service allocation (as amplified by pertinent footnotes) for the band in which it is contained takes precedence over assignments therein that are not in conformity . . . ."[165] As discussed above, LightSquared's ATC operations conform to the U.S. Table, whereas GPS operations in the MSS/ATC Band (whether commercial or government) do not.

The Redbook also establishes that any impact on government GPS operations must be judged based on effects within the boundaries of the defined "L1" GPS signal—which the Redbook specifies as the following portion of the GPS Band: 1575.42 ± 12 MHz.[166] To the extent that GPS receivers are entitled to *any* protection, it is within these bounds. Thus, for example, the Redbook restricts the ability of government users to "re-radiate" in the 1575.42 ± 12 MHz band,[167] but does not offer any protection to GPS devices operating in other spectrum.

Furthermore, the Redbook incorporates by reference the rules and recommendations of the ITU, which govern in the absence of a specific standard in the Redbook itself.[168] In addition, the Redbook specifies that where a federal agency operates in a manner inconsistent with those rules or recommendations, and such failure leads to an "instance of harmful interference," the responsibility for eliminating that interference "shall rest with the agency operating in nonconformance."[169] In other words, federal agencies operate in a manner inconsistent with ITU recommendations at their own risk.

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165 *NTIA Redbook* § 4.1.3.

166 *Id.* §§ 8.3.29, 8.3.30.

167 *Id.*

168 *Id.* at § 5.1.1.

169 *Id.* at § 5.1.2.

Applicable ITU recommendations establish that cognizable interference into GPS operations should be evaluated based on the impact to those operations within the defined boundaries of the "L1" GPS signal. For example, ITU-R M.1787 specifies that any evaluation of the interference impact into the U.S. GPS satellite network should assume an "L1" signal with a range of 1575.42 ± 15.345 MHz.[170] This is roughly consistent with the Redbook and the U.S. Air Force's interface specification for GPS, which define the "L1" signal as 1575.42 ± 12 MHz. Similarly, ITU-R M.1903 specifies that any evaluation of the interference impact into GPS receivers from non-RNSS sources should assume that such receivers operate in a manner consistent with the characteristics of certain specified reference antenna types—including by operating within a defined "signal frequency range" within the GPS Band, and employing appropriate filtering technologies.[171] Numerous other ITU recommendations reinforce the conclusion that cognizable interference into GPS operations is limited to specific frequency ranges in the GPS Band.[172]

As detailed above, "overload" in the vicinity of LightSquared's transmitters occurs where a GPS device receives "signals . . . outside the frequency bands allocated to GPS." GPS receivers that are federal stations that experience "overload" thus necessarily operate in a manner inconsistent with the expectations reflected in the ITU recommendations and the Redbook provisions cited above.[173] Accordingly, even if overload to a GPS receiver from LightSquared's licensed, primary operations could be construed as legally cognizable "harmful interference"—which it is not—it would be the obligation of the government (or more likely the

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170 *See* Recommendation ITU-R M.1787, Annex 2, Table 2-1 (Jan. 2012).

171 *See* Recommendation ITU-R M.1903, Annex 2, at 13 (Jan. 2012).

172 *See, e.g.*, Recommendation ITU-R M.1318 (2005-2007); Recommendation ITU-R M.1477 (May 2000).

173 *See also Public Notice* at 2 n.6.

government contractor who provided the receiver)—and not LightSquared—to bear the costs of curing that issue. As such, just as with commercial GPS receivers, the Commission cannot and should not invoke the need to protect GPS receivers that are federal stations as reasons either to vacate the *Conditional Waiver Order* or to suspend LightSquared's ATC authority.

Third, the Redbook establishes that even where one governmental spectrum use has clear priority over another spectrum use, the government user still must take reasonable measures to mitigate the potential for interference. Thus, for example, Section 2.3.7 acknowledges that "engineering solutions to mitigate interference may require the cooperation of all parties involved in the application of reasonable and practicable measures to avoid causing or being susceptible to harmful interference."[174] In addition, Section 2.3.6 provides that in assigning radio frequencies, the federal government should be guided by the need to "avoid[] . . . harmful interference and . . . use . . . frequencies in a manner which permits and encourages the most beneficial use of the radio frequency spectrum in the national interest"—including by "employ[ing] up-to-date spectrum conserving techniques as a matter of normal procedure."[175] The *Public Notice* reflects an abandonment of that cooperation process in a manner than violates NTIA's own rules.

For all of these reasons, the stated federal interests in the use of GPS receivers do not justify the precipitous actions proposed in the *Public Notice*.

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174 *NTIA Redbook* § 2.3.7.

175 *Id.* at § 2.3.6.

4. Section 25.255 Does Not Create Additional Protection Rights

The foregoing analysis is unaffected by the adoption of Section 25.255 of the Commission's rules,[176] which GPS interests have tried to invoke during the course of this proceeding: (i) as if it were some type of a "cure all" for their infirm legal status as unlicensed, non-conforming users of the MSS Bands; and (ii) as somehow defining the right of GPS receivers to protection from "overload" in the MSS Bands. But Section 25.255 does nothing of the sort. As its title indicates, that rule simply provides "*Procedures* for resolving allegations of harmful interference related to operation of ancillary terrestrial components operating in the 1.5./1.6 GHz, 1.6/2.4 GHz and 2 GHz bands."[177] In other words, Section 25.255 prescribes an explicit "dispute resolution" process to be used in the event of "harmful interference" (which does not exist in this case). Notably, Section 25.255 provides a different type of interference resolution mechanism than the one that the Commission often imposes in circumstances where one party's spectrum usage rights are subordinate to another's.[178]

If harmful interference is caused to other services by MSS ATC operations, either from ATC base stations or mobile terminals, the ATC operator must resolve any such interference. If the MSS ATC operator claims to have resolved the interference and other operators claim that interference has not been resolved, then the parties to the dispute may petition the Commission for a resolution of their claims.

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176 47 C.F.R. § 25.255.

177 *Id*. (emphasis added).

178 In such cases, the Commission often requires that the subordinate spectrum user cease operations immediately upon notification that "harmful interference" has occurred. *See, e.g.,* Intelsat Licensee LLC, IBFS File No. SAT-MOD-20110420-00073, Grant ¶ 1; 47 CFR § 15.5(c) ("The operator of a radio frequency device shall be required to cease operating the device upon notification by a Commission representative that the device is causing harmful interference.").

Section 25.255 does not define what constitutes legally cognizable "harmful interference," though. As demonstrated above, that determination requires an analysis of the circumstances giving rise to the alleged interference, and of the relative rights of the affected parties in the spectrum band at issue under the Commission's existing rules, policies, and precedent—including the U.S. Table. In fact, and as explained above, the Commission authorized ATC as an allocated spectrum use in the United States by adding a footnote to the U.S. Table clarifying that ATC is encompassed within the existing primary allocation for MSS in the MSS/ATC Band. As also explained above, under long-established precedent, the asserted inability of certain GPS receivers to operate properly in spectrum that has not been allocated for GPS does not constitute legally cognizable "harmful interference."[179]

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[179] Nothing in the *Big LEO Order* alters this analysis. *See Mobile Satellite Service in the 1610-1626.5/2482.5-2500 MHz Bands,* 9 FCC Rcd 5936 (1994) ("*Big LEO Order*"). *The Big LEO Order* arose in a rulemaking proceeding, in which the Commission was considering whether to allow ATC operations in the 2493-2495 MHz band for the first time, significantly reducing the existing spectral separation between ATC operations and certain terrestrial fixed operations above 2495 MHz. Moreover, the 2493-2495 MHz band was and is allocated under the U.S. Table on a co-primary basis for both MSS and terrestrial fixed service. *See* 47 C.F.R. § 2.106. In other words, the impact at issue in that proceeding was not "overload" as defined in the *Public Notice* (the impact of a receiver operating on a non-conforming basis outside the specified allocation in the U.S. Table). Rather, that case involved something else entirely—the impact of ATC in a band segment in which another service (terrestrial fixed) had a co-primary allocation. Furthermore, that case involved the impact of ATC *outside* of the then-authorized ATC band. In contrast, LightSquared is merely using spectrum consistent with an ATC allocation that has existed for nearly a decade, pursuant to rules and standards to which the GPS community agreed long ago, and in the absence of an allocation for GPS in the band segment at issue. Moreover, unlike the GPS receivers at issue here, the potentially affected terrestrial receivers at issue in that decision were licensed, and there was no apparent solution on the terrestrial receiver side given the then-existing limitations on receiver design in that band. *See* Reply Comments of Sprint Nextel Corporation, IB Docket No. 07-253, at 13-17 (Jan. 3, 2008). For all of these reasons, the *Big LEO Order* concerned entirely different circumstances and has no bearing on the parties' rights and responsibilities in this case.

Any contrary conclusion would be inconsistent with decades of Commission precedent, and would stand the U.S. Table on its head. Moreover, providing interference protection to unregulated receivers that operate in spectrum that has not been allocated for their intended purpose would undermine the Commission's ability to fulfill its public interest mandate through the active management of U.S. spectrum resources.[180] Instead of having the *Commission* determine what spectrum uses are most consistent with the public interest—and thus deserving of interference protection—providing interference protection to nonconforming spectrum uses by unlicensed and unregulated receivers would allow any equipment manufacturer to hijack the Commission's policy agenda by foreclosing other, intended spectrum uses.

The *2003 ATC Order*, which promulgated Section 25.255, reinforces the notion that Section 25.255 was not meant to enlarge the scope of legally cognizable "harmful interference" to include GPS receiver "overload" effects. While numerous aspects of the *2003 ATC Order* and related decisions demonstrate as much, the following examples are illustrative.

First, the *2003 ATC Order* adopted a rule (since revised) that required an ATC applicant to protect GPS operations above 1559 MHz, but did not require protection of any GPS operations in the MSS/ATC Band.[181] That GPS rule merely required compliance with "limits on emissions in the 1559-1610 MHz band"[182]—*i.e.*, out-of band emission limits—and did not purport to address "overload" at all. The Commission described that GPS protection rule as sufficient "to accomplish the stated intention of establishing . . . RNSS-protection requirements

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180 *See, e.g.*, 47 U.S.C. § 303(c).

181 Section 25.253(a)(6) at the time required an ATC applicant in the MSS/ATC Band to "demonstrate how its ATC network base stations and mobile terminals will comply with the Global Mobile Personal Communications by Satellite (GMPCS) system requirements *to protect the radionavigation satellite services (RNSS) operations in the allocation above 1599 MHz." See* 47 C.F.R. § 25.253(a)(6) (2003) (emphasis added).

182 *See MSV ATC Order* ¶ 34.

for ATC transmitters . . . ."[183] Moreover, the Commission expressly found that a demonstration of "compliance with the applicable RNSS-band emission limits in the Commission's rules" would satisfy the relevant "equivalent RNSS-protection requirements for ATC transmitters" in those rules.[184] NTIA itself recognized that the applicable ATC out-of-band emissions limits served as "protection requirements of RNSS receivers from the emissions of [ATC base stations and mobile terminals]."[185]

Second, the *2003 ATC Order* makes clear that Section 25.255 was implemented to provide a procedural mechanism for resolving only those types of legally cognizable interference already addressed by the ATC rules and the *2003 ATC Order*.[186] In other words, Section 25.255 was meant to provide a vehicle to address types of "harmful interference" already cognizable under the Commission's rules and already addressed by other ATC rules. Significantly, those rules do not provide any "overload" protection for GPS receivers, even though the Commission was fully aware of the potential for "overload" effects at the time it adopted that rule.

Third, the *2003 ATC Order* made clear that Section 25.255 procedures applied to cases involving out-of-band emissions but not cases involving "overload." The Commission specifically noted that Section 25.255 would be available in the event that the adopted out-of-band emissions limits were inadequate to prevent 2 GHz Band ATC operations from causing out-of-band interference into personal communications service ("PCS") devices.[187] In the very next paragraph, however, in discussing the potential that those same PCS devices would experience

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183 *Id.*

184 *Id.* at ¶¶ 34-35.

185 *See 2005 NTIA Letter*.

186 *See 2003 ATC Order* ¶ 104.

187 *Id.* at ¶ 119.

"overload," the Commission did not reference Section 25.255 but instead made clear that "even though the potential for PCS receiver desensitization or overload from ATC operations exists," such potential should be mitigated through appropriate PCS handset design modifications.[188]

Fourth, the *2003 ATC Order* requires Big LEO Band ATC operators to protect from "brute force overload" only certain Broadcast Auxiliary Service ("BAS"), fixed, and mobile operations that share a co-primary allocation in the affected band.[189] The *2003 ATC Order* did not purport to provide such protection in any bands in which terrestrial licensees did not already enjoy such co-primary status. In other words, the *2003 ATC Order* provided "overload" protection only for certain spectrum uses that had a legitimate basis for expecting to be able to operate in the affected band under the U.S. Table.

Fifth, the Commission required that Big LEO Band ATC operators protect from "overload" only "previously licensed" users, and not any unlicensed or subsequently licensed BAS, fixed, and mobile operations—or, for that matter, any nonconforming uses of spectrum. The Commission reached this decision in no small part because it is appropriate to expect those unlicensed and subsequently licensed spectrum users to resolve the issue through proper receiver design. In light of the critical limitation of the Big LEO Band protection obligation to "previously licensed" spectrum users, it would be utterly inconsistent to read Section 25.255 to require MSS/ATC Band operators to protect unlicensed, nonconforming GPS operations.

Considering the foregoing, and the fact that "[t]he FCC does not at the present, have a convenient regulatory handle to resolve interference due to overload,"[190] there is no valid

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188 *Id.* at ¶ 120.

189 *Id.* at ¶ 203.

190 *See FCC Staff Report on Radio Frequency Interference*, GN Docket No. 78-369, at 28. (Jun. 16, 1981).

basis on which to interpret Section 25.255 as a "catch all" provision that requires LightSquared alone to resolve overload concerns about unregulated GPS receivers, or risk having its authorization suspended. Taken to its logical conclusion, applying 25.255 in that manner would allow the manufacturer of the worst-engineered and cheapest receiver made overseas to undermine the goals of the *National Broadband Plan* and to destroy U.S. investment in U.S. telecommunications businesses.

Fortunately, under longstanding Commission practices that the *2003 ATC Order* did not modify, the correct approach to resolve the current issue is to encourage the GPS industry "to cooperate in resolving the problem."[191] Indeed, requiring the GPS industry to solve the problems that it created is consistent with the Commission's recommendation that manufacturers of unintentional radiators (such as GPS receivers) take authorized spectrum uses into account so as to reduce the susceptibility for receiving harmful interference.[192]

In sum, Section 25.255 is a procedural rule that encourages parties to cooperate to address cognizable "harmful interference" that may arise as the result of MSS/ATC operations, and specifies that the Commission may intervene if necessary. The rule articulates an explicit "dispute resolution" process that falls well short of warranting either rescission of the *Conditional Waiver Order* or suspension of ATC authority. More fundamentally, nothing in Section 25.255 alters the substantive rights of any spectrum user, or purports to expand the

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191 *Id.*

192 *See* 47 CFR § 15.17(a) ("Parties responsible for equipment compliance are advised to consider the proximity and the high power of non-Government licensed radio stations . . . so as to reduce the susceptibility for receiving harmful interference. Information on non-Government use of the spectrum can be obtained by consulting the Table of Frequency Allocations in §2.106 of this chapter.")

definition of "harmful interference" to the nonconforming and unlicensed uses of spectrum at issue here.

5. <u>At a Minimum, the Commission Must Address the Relative Rights of LightSquared and GPS Manufacturers and Users Before Proceeding Further with the Actions Proposed in the *Public Notice*</u>

At a minimum, the issues raised above and in LightSquared's Petition for Declaratory Ruling must be resolved prior to proceeding further with the actions proposed in the *Public Notice*, *i.e.*, vacating the *Conditional Waiver Order* or suspending or modifying LightSquared's ATC authority. The relative interference protection rights and responsibilities of MSS/ATC licensees and GPS manufacturers—and whether the stated GPS interference concerns are indeed "legitimate" [193]—have been squarely placed before the Commission for resolution. Once the Commission confirms LightSquared's rights in the manner requested in LightSquared's Petition, the central basis of the actions proposed in the *Public Notice* will fall away, and the Commission will have no basis for seeking to vacate the *Conditional Waiver Order* or to suspend LightSquared's ATC authority. As a matter of logic and of law, further action at this time on the proposals set forth in the *Public Notice* would be wholly premature.

B. The Proposed Suspension of LightSquared's ATC Authority is a Dramatic Change of Course to the Commission's Historical Approach to ATC Implementation and Is Beyond the Bureau's Delegated Authority

Prior to issuing the *Public Notice*, the Commission never even *suggested* the possibility of suspending LightSquared's ATC authority. Notably, the *Conditional Waiver Order* requires LightSquared to complete the TWG process "to the Commission's satisfaction before LightSquared commences offering commercial service *pursuant to this waiver* on its . . .

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[193] *Public Notice* at 4.

MSS frequencies."[194] Nothing in the *Conditional Waiver Order* suggests that the Commission could or would suspend LightSquared's underlying ATC authority if the TWG process were not completed successfully. To the contrary, in adopting the *Conditional Waiver Order* the Commission recognized the limited scope of the relief sought by LightSquared (waiver of the integrated service gating criteria) and declined to re-litigate matters that had been settled previously and that were not implicated directly by that requested relief.[195]

Critically, the full Commission has strongly suggested that the Bureau may not address any GPS receiver overload concerns simply by suspending LightSquared's authority or otherwise requiring LightSquared to take corrective action on a unilateral basis. The Commission's *MSS Flexibility Order*, for example, adopted in mid-2011, acknowledged that the Bureau had adopted the *Conditional Waiver Order*, but "emphasize[d] that responsibility for protecting services rests not only on new entrants but also on incumbent users themselves, who must use receivers that reasonably discriminate against reception of signals outside their allocated spectrum."[196] The Commission expressly noted that "[i]n the case of GPS . . . extensive terrestrial operations have been anticipated in the L Band for at least 8 years."[197]

Furthermore, in the *MSS Flexibility Order* the Commission noted its intent to "look closely at additional measures that may be required to achieve efficient use of the spectrum, including the possibility of establishing receiver standards relative to the ability to

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194 *Conditional Waiver Order* ¶ 41 (emphasis added).

195 *See* Section I.E, *supra*; *see also, e.g.*, *Conditional Waiver Order* ¶ 24 n.107 (declining to entertain AT&T's request to reconsider conditions on LightSquared's license as "beyond the scope of this proceeding").

196 *See Fixed and Mobile Services in the Mobile Satellite Service Bands at 1525-1559 MHz and 1626.5-1660.5 MHz, 1610-1626.5 MHz and 2483.5-2500 MHz, and 2000-2020 MHz and 2180-2200 MHz*, 26 FCC Rcd 5710, at ¶ 28 (2011) ("*MSS Flexibility Order*").

197 *Id.*

reject interference from signals outside their allocated spectrum."[198] Consistent with this statement, LightSquared has formally requested that the Commission initiate a proceeding to consider the adoption of such standards for GPS devices,[199] and the Commission has taken an affirmative step forward in this regard by holding a two-day workshop on receiver standards.[200] In other words, the Commission has identified a clear path forward, LightSquared has provided a vehicle for proceeding along that path, and the *Public Notice* suddenly and without justification proposes to proceed in an entirely different direction that would undermine the Commission's broader objectives.

Suspending or vacating LightSquared's ATC authority to protect GPS receivers from "overload" also would be inconsistent with decades of Commission policy. Most obviously, the *Commission* has already decided that the public interest does *not* require ATC operators to protect GPS devices from "overload." As discussed above, in developing its ATC rules the Commission has focused on curbing the potential for *out-of-band* interference into the GPS Band (read: the allocated band in which GPS receivers *should* be operating). The Commission has taken this path with full knowledge that GPS receivers could "overload" when in the vicinity of ATC transmitters in certain cases.[201]

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198 *Id.*

199 *See* LightSquared Inc., Request for Initiation of Proceeding (filed Feb. 7, 2012) (docket number not yet assigned) ("*Receiver Standards Petition*").

200 *Public Notice*: *Office of Engineering and Technology, Wireless Telecommunications Bureau, and Office of Strategic Planning Announce Workshop on "Spectrum Efficiency and Receiver Performance,"* DA 12-280 (Feb. 24, 2012).

201 *See Deere Comments* at 6 (stating that power from ATC base stations could be sufficient to overload the "sensitive receiving amplifiers of the GPS terminals"); *Inmarsat Petition to Deny* at 9-10 (stating that power from ATC base stations could "overload" GPS receivers); *Inmarsat Comments* at 17-18 and Technical Annex at 8-9 (stating that base station operations could overload GPS receivers).

Tellingly, the GPS industry itself repeatedly has endorsed the approach of applying only out-of-band emissions limits in the MSS/ATC Band. As discussed above, during the development of the ATC rules the GPS industry sought protective out-of-band emissions limits. The GPS industry achieved such limits in LightSquared's case through careful negotiations, and upon doing so announced that those negotiations had "considered all relevant issues."[202] The GPS industry—and ultimately both the Commission and NTIA[203]—did not see "overload" as an issue that warranted regulation, notwithstanding the "increased user density from potentially millions of MSS mobile terminals operating in ATC mode" and "tens of thousands of ATC wireless base stations."[204] This would have been a logical conclusion because the risk of "overload" is extremely manageable through appropriate receiver design alone, as evidenced by the performance of many of the devices tested by the TWG, and the record in this proceeding.[205]

Indeed, Commission precedent makes clear that overload is a *receiver* problem that must be addressed through appropriate *receiver* design. While the Commission has afforded manufacturers flexibility to employ a variety of receiver designs, reflecting trade-offs between cost and robustness, it has done so with the understanding that the manufacturers and users of those receivers must bear the risk of any resulting incompatibility with licensed spectrum users in adjacent bands. Thus, as the Commission recognized in establishing the rules for terrestrial

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202 *See USGIC Reply to Comments* at 2.

203 Tellingly, NTIA also supported this approach, citing this agreement as evidence that effective technical solutions "are attainable by the MSS ATC communities and agreeable with the GPS community." *See January 2003 Letter* at 3.

204 *See USGIC Reply to Comments* at 2.

205 *See, e.g.*, Javad Ashjaee, *A Technical Story of a Bad Filter and a Good Filter Which Turned Political* (Dec. 23, 2011), attached to Letter to FCC from LightSquared, IB Docket 11-109 (Mar. 16, 2012) ("*Ashjaee White Paper*"); *January 20 LightSquared* Letter.

uses of MSS/ATC Band, it generally has not regulated "the susceptibility of receivers to interference from transmissions on nearby frequencies," but instead has chosen to "rely on the marketplace—manufacturers and service providers—to decide how much susceptibility to interference will be acceptable to consumers."[206]

The simple fact is that GPS manufacturers could have designed their receivers with greater filtering or frequency discrimination capabilities—perhaps at a slightly higher cost—but chose not to do so. Permitting GPS manufacturers to shift costs onto MSS ATC licensees—which have no control over GPS receiver design—would lead to "moral hazard" and market failure. For this reason, the Commission has rejected prior attempts by the commercial GPS industry and others to shift the costs of compatibility (including overload) onto licensed operators—including MSS ATC licensees.

For example, in *AirTouch Satellite Services,* AirTouch (a provider of MSS) sought a license to deploy mobile handsets in the Big LEO Band in accordance with out-of-band power limits that had been established through a negotiated rulemaking, with the participation of the GPS industry. The U.S. GPS Industry Council objected to such deployment, claiming, among other things, that tighter out-of-band power limits were necessary to protect newer, "semi-codeless" GPS receivers that were more susceptible to interference. The Commission rejected this claim, observing that the GPS industry had known of MSS deployment plans for years, and that the new GPS receivers "appear to have been introduced to the market without any reasonable expectation, based on FCC rules, that they would be protected from interference."[207] Consequently, AirTouch could not be made to shoulder the burden of the GPS industry's poor receiver design.

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[206] *2005 ATC Order* ¶ 56.

[207] *AirTouch Satellite Services US, Inc.*, 14 FCC Rcd 17328, at ¶ 15 (1999).

Similarly, prior to the adoption of the *2003 ATC Order*, various PCS interests raised concerns that PCS handsets operating in the 1930-1990 MHz band "would not be able to adequately filter out transmissions from nearby MSS ATC handsets . . . ."[208] In rejecting PCS industry proposals to establish a guard band or otherwise constrain MSS/ATC operations to mitigate the possibility of "overload," the Commission recognized that PCS carriers had been "aware of potential interference from MSS systems in adjacent spectrum, and could have taken this into account in the design of their equipment."[209] The Commission also found that any incompatibility could be "mitigated by future PCS handset design modifications and through a cooperative effort by PCS and MSS licensees to resolve these issues."[210]

In light of the foregoing precedent and pronouncements by the full Commission, the International Bureau has no delegated authority to take the action proposed in the *Public Notice*.[211] The Bureau, for example, has no authority to act in proceedings which involve, *inter alia*, (i) "new or novel arguments not previously considered by the Commission," or (ii) "facts or arguments which appear to justify a change in Commission policy."[212] Here, the questions raised regarding the co-existence of GPS receivers with MSS/ATC are novel enough that LightSquared has been compelled to file a *Petition for Declaratory Ruling* to resolve them. And in any event, the foregoing discussion illustrates that the actions proposed in the *Public Notice*

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208 *2003 ATC Order* ¶ 117.

209 *Id.* at ¶ 118.

210 *Id.* at ¶ 120.

211 *See* 47 C.F.R. §§ 0.51, 0.261.

212 47 C.F.R. § 0.261(b)(1)(i),(ii).

plainly would be a dramatic reversal of Commission policy that can only be effected by the full Commission.[213]

III. THE EXECUTIVE BRANCH TESTING PROVIDES NO CREDIBLE BASIS FOR THE ACTIONS PROPOSED IN THE *PUBLIC NOTICE*

The rush to judgment in the *Public Notice* triggered by the *NTIA Letter* is troubling on many levels. Among other things, the *Public Notice* raises the possibility of an indefinite suspension of LightSquared's *entire* ATC authority based on the *NTIA Letter*. This potentially includes LightSquared's authority to operate in the 1.6 GHz uplink portion of the MSS/ATC Band, even though the *NTIA Letter* itself purports to address only "interference associated with LightSquared's planned terrestrial base stations" in the 1.5 GHz downlink portion of the MSS/ATC Band,[214] and even though the 1.6 GHz uplink portion of the MSS/ATC Band could be used independently of the 1.5 GHz portion. This alone demonstrates the serious errors that could flow from the Commission's uncritical reliance on the substance of the *NTIA Letter*.

The release of the *Public Notice* proposal to suspend all or a significant portion of LightSquared's ATC authorization within one day of the *NTIA Letter* also suggests that the Commission has arbitrarily and capriciously abdicated its statutory responsibilities under the Act to exercise its independent judgment and rely on its own technical expertise. While it is entirely proper for the Commission to "consult" with NTIA in resolving issues involving GPS (as the Commission stated it would do and has done previously),[215] the Commission may not blindly defer to another agency's judgment in matters involving frequency bands that are designated for non-federal use. While there always is a need for independent, reasoned analysis by the

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213 *Cf. Delmarva Educational Association*, 19 FCC Rcd 6793, at ¶ 7 (2004).

214 *Public Notice* at 4.

215 *See id. at* 3; *Conditional Waiver Order* ¶ 44.

Commission, that need is particularly pronounced here: the testing upon which NTIA bases its conclusions was technically flawed. In addition, NTIA's conclusions conflict with scientific evidence of compatibility submitted previously in the record in this proceeding, which demonstrates that it is feasible for LightSquared to deploy ATC under its modified proposals. The testing referenced in the *NTIA Letter* also is inherently biased and tainted by potential conflicts of interest.

A. NTIA's Technical Conclusions are Not Supported by the Evidence

Worse than looking at a glass that is half full and calling it half empty, NTIA has looked at a glass that is more than 99 percent full and called it not full enough. The only usable evidence that NTIA reviews in the *NTIA Letter*, collected from its own tests and those of the TWG, shows that well over 99 percent of existing GPS devices are compatible with LightSquared's network with respect to at least the Lower 10 MHz channel. This demonstrated compatibility includes: (i) cellular devices, which constitute the vast majority and the fastest growing segment of GPS devices in use today; (ii) personal/general navigation devices, when the data is properly analyzed; (iii) most timing devices; and (iv) existing space-based receivers.

Looked at objectively, the only potential incompatibility for existing GPS devices that has been identified in scientific testing and analysis concerns a relatively small number of high precision devices. And to the extent that users expect to operate these devices near LightSquared base stations, most can be fixed with a new antenna or with an improved receiver that is likely to be needed soon anyway due to market demands for greater precision that is made possible by using "new" GPS signals and access to non-U.S. RNSS networks. NTIA does not disagree that these accommodation measures could be effective, but according to the *NTIA*

Letter, has decided not to conduct the follow-up tests that NTIA says it needs to confirm the utility of filter-based solutions for high precision devices.[216]

Aviation receivers represent the only category for which the overload impact on existing devices is still under review. By the end of 2011, discussions between FAA and LightSquared had progressed to the point that, as the *NTIA Letter* states, any concerns about interference at higher altitudes (above 1800 feet) were "expected to be acceptable."[217] The only remaining issue was with respect to lower-altitude operations, a subject the FAA raised only in the final weeks of the discussions with LightSquared, which the FAA cut short before any reasonable conclusions could be reached about either the scope of the concern or the options for accommodation.

The status of testing for each of these categories of devices is discussed in more detail in the Technical Appendix and its exhibits, and is summarized further here in the order presented in the *NTIA Letter*.

1. The TWG Tests and NTIA-Sponsored Tests All Show Compatibility of Cellular Devices

While seeming to take no comfort from the results, NTIA accurately reports that recent tests it oversaw confirm the results of the TWG that the tens of millions of cellular GPS receivers, the largest and fastest growing category of GPS receivers, are compatible with LightSquared's current ATC plans. As discussed in the Technical Appendix, the cellular device tests have been by far the most comprehensive and rigorous. Moreover, these results demonstrate that, when the manufacturer makes the effort, even the most compact and

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216 *See NTIA Letter* at 5-7.

217 *Id.* at 5.

inexpensive consumer devices can be designed and built to perform as required while also made compatible with LightSquared's ATC operations in the MSS/ATC Band.

2. Correcting Only Two Errors Among the Many in the Executive Agency Tests and Analysis Shows that Personal/General Navigation Devices Are Compatible With LightSquared Operations

The Technical Appendix provides a detailed litany of the many failures of NTIA's program to test personal/general navigation devices to comply with widely-accepted testing standards, any one of which would be sufficient to throw out the results – from the biased selection of devices for testing, to permitting the very manufacturers who oppose LightSquared to manage the testing, to failing to explain glaring inconsistencies, to permitting manufacturers to make unrecorded modifications to the devices during testing. But, despite all these flaws, if only two major errors in NTIA's analysis of the data are corrected, they too show consistency with the TWG test results for the same devices: with those errors corrected, all but a few unusual devices would pass, and even these devices would likely pass if other errors were corrected.

Those two key errors are the assumptions NTIA makes regarding (i) the "power on the ground" of LightSquared's base stations at a typical GPS receiver and (ii) the threshold for determining when GPS receivers do not work properly when overload conditions exist. Of these, the most critical erroneous assumption is that LightSquared's power on the ground will be about *32 times* higher than the level to which LightSquared has committed to limit itself (-15 dBm instead of the -30 dBm). Here, NTIA also has failed to take into account LightSquared's commitment to limit the power of base stations installed at lower heights and taken the unscientific position of insisting that the analysis must be done based on the assumption that every personal/general navigation device will always have a clear, unobstructed line of sight to each LightSquared base station within more than a mile, regardless of the actual blockage environment.

As LightSquared demonstrates in its Technical Appendix, when LightSquared's actual proposed base station power levels are analyzed, even using conservative propagation models, in a typical environment like the Washington, D.C. metro area, the conditions NTIA describes exist in less than one percent of LightSquared's planned coverage area. The propagation model LightSquared proposed (a version of the Walfisch Ikegami Line of Sight or "WILOS" model that LightSquared proposed to modify to be even more conservative) is more conservative than what is typically used for the design of wireless networks, overstating the power on the ground, but nonetheless was marginally acceptable to LightSquared as a compromise. The NPEF Report comparing WILOS to the NTIA-preferred model mischaracterizes LightSquared's proposed power level for lower-height base stations, badly distorting the results. As described more fully in the Technical Appendix, when LightSquared's proposed power levels are more properly characterized, it is readily apparent that the modified WILOS model is indeed a conservative and appropriate model that would amply capture situations where overload could occur whereas NTIA's propagation model is radically burdensome and without any scientific justification.

NTIA also rejected a LightSquared proposal to manage power on the ground by LightSquared's conducting post-deployment measurements to detect and fix any base station "hot spots" that could unintentionally exceed the -30 dBm limit, as well as to fix hot spots in the event they are identified by others. Using such an approach would guarantee that whatever the propagation, GPS receivers would be exposed to no more than the prescribed power on the ground. NTIA fails to even mention these LightSquared compromise proposals, let alone justify its rejection of them.

With respect to the second key error, involving the threshold at which a GPS receiver does not operate properly when overload conditions exist, NTIA's analysis assumes that the proper threshold is a 1 dB degradation in the device's carrier-to-noise ratio, also referred to as a 1 dB reduction in C/N_0. *All* of the objective evidence, however, contradicts the use of 1 dB C/N_0 as a valid measure of determining when personal/general navigation devices fail. As discussed in detail in the Technical Appendix, the tests done by the TWG on these devices showed *no correlation* between a 1 dB reduction in C/N_0 and a loss of positioning accuracy. Other variables are typically more important in determining the position accuracy of a GPS receiver, including the number of visible satellites, variations in their power, and ionospheric and tropospheric delay. Relative to these, a small change in C/N_0 is of no more than minimal significance.

Unlike the personal/general navigation device tests, the tests of cellular device measured observed loss of position accuracy in each defined device "failure" based on whether the device provided the required accuracy with a sufficiently high probability. This approach, which focuses on the intended use of the receiver and its observable behavior and acknowledges the inherent, random variability in the instantaneous position error during testing, is a much more useful approach than measuring a fixed, 1 dB C/N_0 that has no demonstrated correlation to GPS device performance. Furthermore, it is based on industry standards for mobile phones and would be equally usable and applicable to testing the impact of overload on personal/general navigation devices. Those tests required a more sophisticated test set-up and slightly more test time, but they provide a much more reliable indication of actual impact on performance.

Consistent with all of this evidence, the Commission itself has already rejected the use of 1 dB C/N_0 as an accurate measure of determining when GPS receivers do not operate properly. Specifically, the Commission concluded in the proceeding establishing emissions limits in the GPS Band for ultra-wide band ("UWB") devices that no correlation has ever been made between this slight rise in the noise floor and adverse impact on device performance. Tests performed by NTIA, DOT, and Time Domain all demonstrate that GPS receivers are capable of rejecting higher UWB emission levels even when the GPS received signals are at minimal levels and the emissions from the UWB devices are adjusted to produce a maximum impact on the GPS receiver.[218] Indeed, the Commission went even further in specifically rejecting certain flawed assumptions that NTIA made that are very similar to those it makes here, saying that NTIA's calculations are "based on worst case conditions, *e.g.*, no intervening objects, the maximum emission from the UWB device directed towards the GPS receiver, and perfect antenna alignment between the UWB device and the GPS receiver."[219] It would be arbitrary and capricious for the Commission to rely now on a standard that it previously refused to apply for the very reasons that LightSquared has identified here.

Neither NTIA nor NPEF makes any attempt to provide scientific evidence that the choice of testing threshold correlates to actual device performance. NTIA concedes that there is no "industry-specified performance metric" for personal/general navigation devices. NTIA's only attempt at justifying a 1 dB loss in C/N_0 as the relevant threshold is that it has used this

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218 *Revision of Part 15 of the Commission's Rules Regarding Ultra-Wideband Transmission Systems*, 18 FCC Rcd 3857, at ¶ 14 (2003) ("*Part 15 Revision Order*"). Moreover, the use of a 1 dB threshold would be especially inappropriate here as a limit on a licensee's operations *in its own authorized frequency band* to protect against overload to GPS receivers operating in the adjacent band. In contrast, the Commission's use of a 1 dB increase in the noise floor has been limited to those cases in which the Commission sought to establish limits on out-of-band emissions into an adjacent band. Here, with respect to out-of-band emissions into the GPS Band, LightSquared has agreed already to stringent limits and there is no claim that LightSquared's out-of-band emissions are a problem. *See* Section I.B.2, *supra*.

219 *Part 15 Revision Order* ¶ 14.

threshold in the past, which completely begs the question of whether that past use was scientifically justified. NTIA also neglects to say that its past use was strictly limited to identifying a threshold when the measured energy is inside the GPS Band and not outside the GPS Band, as is the case here. Moreover, in the case of mobile phones, there are industry standards that consider the impact of adjacent band signal power levels; the LTE standard permits a loss of up to 6 dB of C/N_0.

3. Consideration of Potential Aviation Receiver Compatibility is Incomplete

While the FAA and LightSquared had engaged in analyses of aviation GPS receivers, that process was cut short by the FAA's sudden decision in mid-December to cease further discussions with LightSquared. Those discussions up to that point had been comprehensive and productive, focusing on defining the scope of the FAA's GPS-based requirements, the complicated issues around how to model interference in the air, and consideration of potential accommodation options, primarily with respect to appropriate changes in LightSquared's ATC operations.

At the time FAA stopped discussions, there were a few issues outstanding regarding higher-altitude operations on which the FAA position is more conservative than justified by the science. However, as NTIA notes, sufficient agreement existed on the estimated compatibility requirements such that LightSquared would have been able to accept the FAA position if necessary, and was prepared to proceed in a manner that would meet the FAA's requirements. The only remaining obstacle was resolution of compatibility issues surrounding lower-altitude applications of aviation receivers, a category that FAA introduced only late in the process. Even though the June 2011 RTCA Report had indicated that interference to lower-altitude operations was not problematic, the FAA began to raise concerns about that determination for the first time only in the last few weeks of its discussions with LightSquared, once higher-altitude issues seemed likely to be resolved.

The FAA Report on which NTIA relies acknowledges that the lower-altitude analysis is incomplete. When the FAA cancelled further discussions with LightSquared, it had not yet defined its lower-altitude requirements for evaluating LightSquared's operations and significant issues remained as to how to properly model compatibility in the air in those cases. LightSquared's attempts to discuss accommodation options were rejected as impractical almost before they were received and were not substantively evaluated. As discussed further in the Technical Appendix, Exhibit B, LightSquared considers its proposal to limit "power in the air" around its base stations and near flight paths to be practical and straightforward to enforce. However, LightSquared also recognizes that additional discussions with the FAA may be needed. LightSquared remains committed to that exercise whenever the FAA is willing to resume participation and is confident that it can result in an approach that establishes compatibility to the satisfaction of both the FAA and LightSquared.

If LightSquared's approach to lower-altitude compatibility proves unproductive, then it would be appropriate to re-examine the application of the FAA's certification standards for GPS receivers on which the compatibility analysis has been based. NTIA and the FAA provide no support for their conclusion that it would be impractical to update the FAA standards to take more realistic parameters into account.[220] This conclusion appears particularly arbitrary when one considers that the aviation community has often imposed new requirements when it is in the public interest and has responded quickly when necessary to upgrade certification standards. The FAA has a range of methods to ensure ongoing safety of air navigation—from

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[220] *See NTIA Letter* 5.

issuing airworthiness directives to promulgating new receiver standards to informing operators of any special operating procedures or constraints in effect.

In this case, the available evidence strongly suggests that updating current aviation GPS receiver standards to take more realistic parameters into account is appropriate and feasible. All of the certified aviation devices that have been tested show that they are substantially unaffected by LightSquared operations—far more resilient than required by the FAA certification standards that were used in the analysis. If further tests were to confirm this to be the case for other certified receivers, adopting a new standard for the compatibility analysis would not impose any costs on aircraft operators. Even if such testing revealed that a relative few aviation devices would need to be retrofitted to meet a new standard, this could well be practical. Although the FAA rejected this possibility out of hand in its January report, it has provided no evidence in support of its conclusion. LightSquared is confident that, as with other mistaken initial impressions the feasibility of retrofitting GPS devices with better filters, it is likely to prove far easier for aviation devices than some have suggested.[221] It would be inappropriate in any circumstance for parties who waited years to raise overload concerns to deem those purported problems insolvable—and to demand retraction of a licensee's authority and elimination of its multi-billion dollar investment—after only weeks of testing and discussion. It is especially inappropriate under the terms of *Order* that required the parties to "fully study" the issue and to "identify any measures necessary."[222]

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[221] *See Ashjaee White Paper* at 7-8.

[222] *Conditional Waiver Order* ¶ 41.

4. <u>The Few Models of Timing Devices That May Have Limited Incompatibility With LightSquared Operations Can Be Replaced With Inexpensive Resilient Devices</u>

The *NTIA Letter* does not discuss standard timing devices, which constitute the vast majority of GPS timing devices and are widely used to synchronize information technology and communications networks. Instead, the *NTIA Letter* focuses selectively on the few timing devices that are in the high precision category (used primarily for scientific applications).[223] There is no dispute that the TWG tests show that widely deployed and available standard timing devices are compatible with LightSquared operations on its Lower 10 MHz channel. There is also substantial evidence that replacement external antennas with enhanced filters are available from mainstream manufacturers for users that want a greater degree of operating margin.[224]

There are a very small number of high precision timing receivers, typically used for scientific applications, which use receiver architectures similar to high precision positioning receivers. The discussion below regarding high precision receivers also applies to these devices.

5. <u>Any High Precision Devices That May Be Incompatible Can Be Made Robust with Currently Available Preselector Filters</u>

LightSquared, working with several manufacturers of high precision devices, has demonstrated the viability of filter solutions to provide compatibility without adversely affecting performance, cost, or size.[225] The *NTIA Letter* does not dispute this progress. Instead, it reiterates the need to conduct its own tests and analysis of these solutions, but then abruptly

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223 *NTIA Letter* at 6.

224 *See, e.g., January 20 LightSquared Letter*.

225 *See* Letter from FCC from LightSquared, IB Docket No. 11-109, Summary and Assessment at 1-9 (Dec. 23, 2011); *see also January 20 LightSquared Letter*, Summary and Assessment at 1-6 (Jan. 20, 2012).

declines to do so.[226] There is no analysis rebutting LightSquared's evidence, and once again, the Commission may not rationally treat other parties' failure to fully participate in the process directed by the *Conditional Waiver Order* as a basis to find it "highly unlikely" that *LightSquared* can "*satisfy*" the *Order's* requirements.[227]

6. The Existing Space-Based Receivers Have Been Shown to Be Compatible with LightSquared ATC Operations

As with high precision devices, the *NTIA Letter* does not take issue with the findings of the TWG that existing space-based receivers are compatible with LightSquared's operations.[228] NTIA notes that next-generation space-based receivers, not yet launched, will require modification to be compatible with LightSquared's operation. But NTIA does not suggest that any such modification would be impractical or has not been considered.

B. The Executive Agency Testing Is Inherently Unreliable Because It Is Tainted by a Potential Conflict of Interest

The testing and analysis reflected in the *NTIA Letter* is inherently unreliable because it is tainted by a potential conflict of interest. That testing was spearheaded by the National Space-Based Positioning, Navigation and Timing (PNT) Executive Committee (EXCOM), with significant input from an Advisory Board consisting of industry representatives that serve as special Government employees ("SGEs"). One such SGE is the Vice-Chairman of the Advisory Board—Dr. Bradford Parkinson— who has both pecuniary interests in, and a fiduciary duty to, Trimble Navigation Limited ("Trimble"), a leading manufacturer of GPS devices.

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226 *NTIA Letter* at 6.

227 *Public Notice* at 4.

228 *Id.*

Under 18 U.S.C. § 208, the federal conflict of interest statute, SGEs may not participate in any proceeding or render any advice with respect to matters in which they have a "financial interest."[229] For these purposes, a "financial interest" is defined to mean "the potential for gain or loss . . . as a result of governmental action on the particular matter."[230] An interest is disqualifying "if the particular matter will have a direct and predictable effect on that interest."[231]

From the *NTIA Letter*, it is clear that the PNT EXCOM has played a significant role in shaping the government's evaluation and response to LightSquared's ATC proposals. Moreover, it is apparent that the PNT Advisory Board has been integrally involved in the EXCOM's ongoing analysis of LightSquared's proposed operations—and even filed a pleading before the Commission urging that the *Conditional Waiver Order* be rescinded.[232]

It is equally clear that the decisions of and advice given by the PNT Advisory Board could have a financial impact on GPS manufacturers and their principals. For example, if LightSquared is permitted to implement its network, GPS manufacturers could be required to retrofit poorly designed GPS devices that have been deployed. Thus, any GPS representative sitting on the PNT Advisory Board would have an obvious "financial interest" in the Board's consideration of matters related to LightSquared.

In Dr. Parkinson's case, these circumstances create a potential conflict of interest that preclude him from providing impartial advice to key government decision makers (including in NTIA) regarding LightSquared's proposed network. Yet Dr. Parkinson has made recommendations directly adverse to LightSquared's interests before the Commission and other

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229 18 U.S.C. § 208(a).

230 5 C.F.R. § 2640.103.

231 *Id.*

232 *See* Letter to FCC from National PNT Advisory Board, IB Docket No. 11-109, at 1 (Aug. 3, 2011).

agencies, and apparently has sought to undermine LightSquared in the eyes of numerous executive branch agencies—including those that transact business with and through the EXCOM.[233] Dr. Parkinson has publicly betrayed his bias by stating that he "personally think[s] [that] [LightSquared] are a bunch of greedy guys that are like the worst of the people in real estate."[234] One can only guess at how this bias may have influenced NTIA's or other federal agency deliberations as reflected in the *NTIA Letter*.

More generally, recent allegations in the press suggest that the testing cited in the *NTIA Letter* is but one manifestation of a broader effort by the commercial GPS industry and certain of NTIA's constituent agencies to "'synch up' . . . in order to defeat LightSquared's plans to build the nation's first wholesale broadband network."[235] If the GPS industry and certain government agencies have collaborated in this fashion, it is all the more reason for the Commission to discard NTIA's conclusions.

IV. THE COMMISSION MUST ENGAGE IN A REASONED ANALYSIS OF THE EXECUTIVE AGENCY TESTING

A. The *Public Notice* Evidences No Critical Examination of the Executive Agency Testing

Part and parcel of the Commission's obligation to conduct a "reasoned analysis" of the record in this proceeding is the need to critically examine the reports attached to the *NTIA Letter*. In particular, the Commission must evaluate the substance of the *NTIA Letter* in light of

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233 Dr. Parkinson has done so without obtaining any ethics waiver from the National Aeronautics and Space Administration (which oversees the operations of the PNT). *See* Letter to Michael D. Bopp from Michael C. Wholley (Jan. 5, 2012) ("[N]o waivers under 18 U.S.C. § 208(b) have been granted by the National Aeronautics and Space Administration, to members of the National Space-Based Position, Navigation, and Timing (PNT) Advisory Board.").

234 E. Krigman, *LightSquared Foe Bias On GPS?*, POLITICO (Oct. 20, 2011).

235 E. Krigman, *DoD Official Urged "Synch Up" With GPS Lobby to Stop LightSquared*, POLITICO (Mar. 1, 2012).

the findings of the TWG, which was specifically established by the Commission for the purpose of studying issues attending the co-existence of LightSquared ATC and GPS operations, and studying ways to address those issues effectively. The TWG was co-chaired by Charles Trimble and Jeff Carlisle. The TWG testing was completed by independent labs, and the testing program was directed by work groups made up of different representatives from across the industry and government. All parties had access to information as it was developed, and everyone had a say in the process used to determine what GPS receivers were tested.

The measurements performed by the TWG sought to assess the actual impact of LightSquared's licensed operations on GPS devices. Consequently, GPS devices were tested against 3 dB and 6 dB C/N_0 standards, as well as the 1 dB C/N_0 standard. GPS devices also were tested to evaluate changes in positional accuracy, time to lock, and other end user-relevant metrics at that range of responses. Because this methodology was used, the TWG testing dispels the myth that a decrease in C/N_0 necessarily translates into a material reduction in GPS receiver performance. Indeed, testing showed that for general navigation devices, there was no change in the relevant performance metrics—even at degradation levels as high as 6 dB C/N_0.

In contrast, the analysis upon which the *NTIA Letter* relies examined only whether there was a 1 dB C/N_0 increase, but did not look at higher increases in the noise floor or whether end user-relevant performance was impacted. Consequently, the *NTIA Letter* reaches fundamentally different conclusions than the TWG test results would support (except for cellular devices, which constitute the overwhelming majority of GPS receivers). Viewed objectively, no scientifically valid evidence exists that even 1% of GPS receivers would experience adverse performance consequences as a result of LightSquared's operation, as currently proposed.

B. The Commission Cannot Ignore NTIA's Long-Standing Acceptance of the Parameters of LightSquared's ATC Authority in Evaluating the Credibility of the Executive Agency Testing

As recounted above, throughout the decade-long regulatory process of implementing and refining LightSquared's ATC authorization, all involved parties—including the Commission, NTIA, federal spectrum users, and the GPS industry—requested that LightSquared agree to out-of-band emissions limitations as the sole and preferred means to protect GPS receivers. The Commission cannot simply discard the long history by concluding in a single sentence that because "the test results stated in the *NTIA Letter* appear to apply to the full LightSquared ATC service authorized in 2004 and 2010,"[236] they warrant the potential imposition of the most severe remedy at the Commission's disposal. As detailed above, in planning and deploying its network, LightSquared has consulted extensively with all involved federal spectrum users and the GPS industry and has acted in complete conformance with all steps requested to do all that it can to ensure that LightSquared's network is compatible with GPS devices. NTIA's latest submission must be examined thoroughly and critically against this backdrop, and any change in position must be clearly articulated and fully substantiated. Neither NTIA nor the Commission has done so.

V. THE COMMISSION MUST SEARCHINGLY CONSIDER ALTERNATIVES THAT WILL CONTINUE TO FOSTER THE DEVELOPMENT OF LIGHTSQUARED'S ATC NETWORK AND ALSO FACILITATE ITS CO-EXISTENCE WITH GPS OPERATIONS

The *Public Notice* presents a false choice between the preservation of LightSquared's ATC authority, on the one hand, and the maintenance of GPS service, on the other, when both in fact can be accommodated. The *NTIA Letter* is flatly incorrect in its conclusion that "at this time. . . there are no mitigation strategies that both solve the interference

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236 *Public Notice* at 4.

issues and provide LightSquared with an adequate commercial network deployment."[237] A number of alternatives exist that the Commission can and must evaluate in resolving issues of GPS receiver co-existence with ATC before the Commission may take the actions proposed in the *Public Notice*. Indeed, any license modifications in the face of a failure to consider alternatives to effectively shutting down LightSquared's 4G LTE network would represent the epitome of "arbitrary and capricious" administrative action.[238]

First, as discussed, the most legally appropriate alternative to foster GPS receiver compatibility with LightSquared ATC operations is for the Commission to recognize clearly and emphatically LightSquared's superior spectrum rights in its licensed MSS/ATC Band vis-à-vis both commercial and government GPS user receivers with respect to overload.[239] This would mean that "overload" experienced by GPS receivers that "listen" in the MSS/ATC Band can in no way be deemed cognizable "harmful interference," which would consequently drive the GPS industry to adopt pro-active measures to facilitate the co-existence of GPS receivers with ATC—measures which, to date, some in that industry have been unwilling even to entertain.

In this regard, even the *NTIA Letter* acknowledges a number of GPS-side solutions exist that are consistent with recognizing LightSquared's primary status relative to GPS receiver use of the MSS/ATC Band, and that could be implemented effectively to solve any "overload" problem, including the adoption of GPS receiver standards and the retrofitting of existing GPS receivers.[240] Although these steps might take some time to implement, this is hardly LightSquared's fault or problem; the GPS industry and NTIA have known of

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[237] *NTIA Letter* at 8.

[238] *See Motor Vehicle Mfrs. Ass'n v. State Farm Mut. Auto. Ins. Co.,* 463 U.S. 29, 43 (1983).

[239] *See generally Petition for Declaratory Ruling*.

[240] *NTIA Letter* at 7.

LightSquared's ATC deployment plans for years, and even now the necessary implementation could be expedited (although neither the GPS industry nor NTIA has taken aggressive corrective action in this regard). As stated in a proceeding involving potential overload of satellite earth station receivers, "[i]t is not Commission policy to protect… against all emissions from adjacent bands; this particularly true when the emissions are a foreseeable result of prior allocation orders."[241] In the interim, there is absolutely no reason that that LightSquared should pay the price for the mistakes of others, or that the interests of unlicensed GPS receivers "squatting" in the MSS/ATC Band should come at the expense of the hundreds of millions of Americans who would be deprived of new, competitive wireless broadband services provided over LightSquared's network.

Second, even assuming that a legally cognizable "harmful interference" problem did exist, the Commission still would be obligated to engage in a reasoned analysis of potential solutions to that problem without suspending LightSquared's entire ATC authorization. First and foremost, LightSquared already has offered good-faith solutions over and above the protections contained in the Commission's rules and the terms of LightSquared's ATC authority that would voluntarily constrain LightSquared's operations in various ways in order to protect GPS receivers while still allowing LightSquared to implement its network, at least initially, using its Lower 10 MHz downlink channel at 1.5 MHz and the entire 1.6 GHz uplink portion of the MSS/ATC Band. While these efforts have been met only with resistance and derision by the GPS industry, they are viable proposals—supported by the TWG testing and the record to date—that are required to be considered. While the *Public Notice* suggests (mistakenly) that it is not likely that LightSquared will be able to satisfy the requirements of the *Conditional Waiver Order*

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[241] *Wireless Operations in the 3650-3700 MHz Band*, 22 FCC Rcd 10921, at ¶60 (2007).

in the near term, it does so only with respect to half of LightSquared's spectrum—the 1.5 GHz downlink band that is "associated with LightSquared's planned terrestrial base stations." [242] The *Public Notice* does not even suggest any remedial action with respect to the 1.6 GHz uplink portion of the MSS/ATC Band. [243]

Third, if the Commission, albeit inappropriately, intends to continue to accord regulatory priority to GPS receivers at the expense of LightSquared's licensed ATC operations, then the history, equities, and degree of investment and reliance by LightSquared—as well as the Commission's legal responsibilities—demand that the Commission, working with LightSquared and NTIA, identify and engineer a partial or total exchange of alternative terrestrial spectrum rights, which could be used without any impact on existing GPS receivers. Contrary to NTIA's assertion that no options exist, this approach clearly would offer a "mitigation strateg[y]" that would "both solve the interference issues and provide LightSquared with an adequate commercial network deployment."[244] Indeed, this approach would be consistent with the advocacy of GPS interests that repeatedly have claimed (erroneously) that the *only* solution to the "overload" problem is for LightSquared to operate in alternative spectrum.[245]

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242 *Public Notice* at 4.

243 *See* Sections I.A and I.B, *supra*, for a complete explanation of the spectrum licensed to LightSquared and its relationship to the GPS Band.

244 *NTIA Letter* at 8. Critically, NTIA is in no position to judge what level of commercial deployment would be "adequate" from LightSquared's perspective, nor is NTIA is in any position to judge whether alternatives to the use of spectrum in the MSS/ATC Band are available to LightSquared, or could be made available through Commission action. For these and other reasons, the Commission should recognize that NTIA's conclusions emanate from an unduly narrow and biased analysis of potential accommodation strategies that does not provide an adequate basis for Commission action.

245 *See, e.g.*, Comments of Deere & Company, IB Docket No. 11-109, at v (Aug. 1, 2011) ("Deere submits that the Commission should focus its efforts on identifying other spectrum to support high powered terrestrial operations.").

In this regard, ample Commission precedent exists for this sort of spectrum rationalization—particularly when viewed as necessary to provide a public good such as national defense or public safety. For example, the Commission relocated the Digital Electronic Messaging Service ("DEMS") from the 18 GHz band to the 24 GHz band based on national security concerns.[246] In that case, the Commission acted at the request of NTIA, in order to address Department of Defense concerns regarding potential interference from DEMS into military satellite earth stations in Denver and Washington, D.C. operating in the 18 GHz band. By relocating DEMS to the 24 GHz band, the Commission resolved these concerns, as well as concerns about the sharing of the 18 GHz band with commercial satellite services.[247]

The Commission also effected a similar spectrum rationalization transaction when it reconfigured the 800 MHz band to resolve interference issues resulting from the differing uses of the interleaved channels in the band.[248] In recognition of the "public interest benefit derived from robust and reliable public safety communications," as well as the spectrum rights surrendered by Nextel in the 800 MHz band, the Commission provided Nextel with spectrum in the 1.9 GHz band.[249]

In neither of these cases did the Commission suspend, vacate or otherwise effectively terminate the authority of an existing licensee—even though, in those cases, the Commission had clear evidence that such operations were incompatible with other licensed uses.

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246 *See Amendment of the Commission's Rules to Relocate the Digital Electronic Message Service From the 18 GHz Band to the 24 GHz Band and to Allocate the 24 GHz Band for Fixed Service*, 12 FCC Rcd 3471 (1997); *aff'd*, 13 FCC Rcd 15147 (1998).

247 In doing so, the Commission invoked the "military function" exception to the Administrative Procedures Act, facilitating Commission action within approximately two months and without notice and comment procedures. *See* 5 U.S.C. § 553(a)(1).

248 *See Improving Public Safety Communications in the 800 MHz Band*, 19 FCC Rcd 14969 (2004).

249 *Id.* at ¶ 5.

In stark contrast, no such valid evidence exists here; moreover, GPS receivers are unlicensed devices operating on a non-conforming basis in the MSS/ATC Band, and GPS manufacturers have "unclean hands" extending from their failure to design sufficiently robust receivers despite ample forewarning as to the nature of LightSquared's proposed ATC operations. Indeed, those manufacturers should be deemed legally foreclosed from raising *now* issues that were germane to other notice and comment proceedings in which the manufacturers did not merely tacitly acquiesce, but affirmatively supported the authorization that they now, belatedly, dispute.[250] Even so, LightSquared is willing to explore such rationalization alternatives if doing so will enable it to implement its network in a manner compatible with existing GPS devices. Any failure by the Commission to consider such alternatives would represent a failure of the administrative process that disserves the American public.

VI. SUSPENDING OR VACATING LIGHTSQUARED'S ATC AUTHORIZATION WOULD CAUSE ENORMOUS HARM TO THE PUBLIC INTEREST AND, VIOLATE THE ADMINISTRATIVE PROCEDURE ACT; IT ALSO WOULD BREACH LIGHTSQUARED'S CONTRACT WITH THE COMMISSION AND VIOLATE LIGHTSQUARED'S CONSTITUTIONAL RIGHTS

In proposing to write off the billions of dollars that LightSquared and its investors and predecessors have invested expressly to aid the Commission in achieving its broadband policy goals, the Commission has threatened a course of action that would have immense adverse near-term and long-term consequences for LightSquared and the American public as a whole. LightSquared has expended enormous amounts of time, money, and resources to deploy its planned 4G LTE broadband network and thus extend competitive broadband access to hundreds of millions of consumers. The basic legal framework upon which LightSquared relied

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[250] The principle of judicial estoppel should preclude the GPS industry from reopening this issue at this late date. *See New Hampshire v. Maine*, 532 U.S. 742, 749 (2001); *Global NAPS, Inc. v. Verizon New England, Inc.*, 603 F.3d 71, 91 (1st Cir. 2010); *Time Warner Cable*, 21 FCC Rcd 9016, at ¶ 13 & n.25 (2006).

to design and constructed significant elements of its network at a cost of more than $4 billion to date was established by final order for almost seven years. Yet, the *Public Notice* suddenly proposes effectively to stop LightSquared's deployment dead in its tracks.

The proposed actions cannot and should not stand. The general public interest harms flowing from them would be enormous and quantifiable, as would the specific damages to LightSquared as a result of the Commission's breach of its agreement with LightSquared. The agency's proposed actions also would violate LightSquared's constitutional rights.

A. The Precipitous Suspension of LightSquared's ATC Authority Cannot Be Squared with the Public Interest

1. The *Public Notice* Threatens the Loss of Critical National Wireless Broadband Capacity

Now more than ever, the United States requires additional spectrum that will be devoted to providing cutting-edge wireless broadband services. Only last month, the President's Council of Economic Advisers issued a report cataloguing the tremendous benefits that wireless broadband can bring to American consumers, including (i) serving as a platform for innovation, (ii) providing significant benefits for public safety, and (iii) providing transformative positive effects on the economy by fostering job creation, growth and investment.[251] However, the report reiterated that none of these benefits can be realized unless our country can "find" additional capacity, since the surge in wireless data traffic has caused a "spectrum crunch":

> [O]ne industry forecaster projects that mobile data traffic will increase by a factor of 20 between 2010 and 2015. It is unlikely that wireless carriers will be able to accommodate this surging demand without additional spectrum. Other approaches to expanding the capacity of wireless networks, including improvements in spectral efficiency, increases in network density

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[251] Executive Office of the President, Council of Economic Advisers, THE ECONOMIC BENEFITS OF NEW SPECTRUM FOR WIRELESS BROADBAND (Feb. 2012), *available at* http://www.whitehouse.gov/sites/default/files/cea_spectrum_report_2-21-2012.pdf.

> through cell site construction, and offloading traffic to wireline networks via Wi-Fi or other antenna systems, will likely be insufficient to allow capacity to keep up with demand. *In short, the projected growth in data traffic can be achieved only by making more spectrum available for wireless use.*[252]

For nearly a decade, LightSquared has been working with regulators, engineers, and the GPS industry to bring additional broadband spectrum to the U.S. market. LightSquared's proposed network, which would effectively and innovatively utilize MSS/ATC Band capacity, stands as a rare and important solution to meet the soaring demand for high-speed wireless broadband capacity with the growth of mobile broadband devices such as smart phones and tablets. The Commission repeatedly has acknowledged this very point, concluding that the "public interest is best served by permitting MSS licensees flexibility to improve MSS by having the option of deploying MSS/ATC to improve spectrum efficiency and achieve other public-interest goals," and citing the enormous benefits from LightSquared's operations specifically.[253]

For the Commission to now abandon LightSquared and the MSS/ATC Band, after coming this far to foster their development, would be a disastrous policy reversal with far-reaching adverse economic effects, depriving hundreds of millions of U.S. consumers of access to critical mobile broadband service (particularly in rural areas), stifling the creation of tens of

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252 *Id*. at i (emphasis added).

253 *2003 ATC Order* ¶ 18; *see also, e.g., 2005 ATC Order* ¶ 8 (noting that ATC authority would enhance MSS capabilities, facilitate spectral efficiency, expand consumer choice, increase competition, extend the consumer market reach of MSS providers, and enhance global public service and safety communications capabilities); *MSV ATC Order* ¶ 92 (concluding that LightSquared's proposed operations would serve the public interest); *Globalstar Licensee LLC*, FCC 08-254, at ¶ 11 (Oct. 31, 2008) (*citing* the *2003 ATC Order* ¶ 23 for the proposition that the integration of ATC into MSS systems will foster the development of new and innovative service offerings that satellite-only MSS systems cannot offer, including, *e.g.*, ubiquitous digital telecommunications and broadband services and other services that take advantage of the unique coverage and capacity characteristics of ATC-enabled MSS) ("*Globalstar Order*").

thousands of American jobs, and wasting billions of that were invested to fulfill the Commission's mandate to LightSquared and its investors. It simply cannot be that within the span of two years, LightSquared's nationwide network could go from playing a critical role in addressing the United States' pressing need to expand access to broadband services[254] to a potential nullity, based solely on the GPS industry's conclusory and hyperbolic assertions and NTIA's unquestioning reliance on flawed and biased test results.

The great public interest in fostering the growth of wireless broadband demands that the Commission find a way for LightSquared to deploy its ATC network. The Commission has recognized the need for receiver manufacturers to design robust receivers with sufficient filtering and/or frequency discrimination capabilities, or bear the costs for their failure to do so—"incumbent users," it has said, "must use receivers that reasonably discriminate against reception of signals outside their allocated spectrum."[255] As discussed above and elsewhere, LightSquared's deployment (and the attendant benefits of the broadband service that it will provide) may not be compromised by failures of GPS receiver design. Rather, the Commission should press for the technical solutions and adjustments by the GPS industry necessary to ensure that the tremendous public benefits of LightSquared's network are not thwarted by the belated objections of an industry that long ago should have updated its products to cease encroaching on LightSquared's spectrum.

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254 *See, e.g.*, NATIONAL BROADBAND PLAN at 88 (noting that LightSquared's spectrum had not been fully exploited, and recommending that the Commission and other agencies "work closely with L Band licensees and foreign governments to accelerate efforts to rationalize ATC-authorized L Band spectrum to make it usable for broadband ATC service.").

255 *See, e.g., MSS Flexibility Order* ¶ 28.

2. <u>The Long-Term Public Interest Harms Stemming from the Commission's Reversal of Course Would Be Substantial</u>

The Commission has recognized that stability in the enjoyment of spectrum rights is essential to facilitating network implementation, encouraging investment, and ensuring that scarce spectrum resources flow to their highest and best use (either through auctions or secondary markets regimes).[256] The Commission's proposed course here would sharply undermine these public interest objectives by shaking public confidence in the integrity of the Commission's rules and policies, casting a long shadow on upcoming spectrum auctions, chilling investment in our nation's telecommunications infrastructure, and burdening U.S. economic growth.

At the Mobile World Congress in Barcelona only a few weeks ago, Chairman Genachowski explained how the Commission is focused on "strengthening incentives for investment in mobile infrastructure," and recognized that "[w]ireless infrastructure doesn't build by itself. It requires many billions of dollars in investment – overwhelmingly by private companies."[257] And, the Chairman declared, "*regulatory certainty and predictability promotes investment*."[258] The *Public Notice* is diametrically opposed to that principle, and to the basic economic insight expressed by the Chairman; if acted upon, the *Notice* will curb investment and

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[256] *See, e.g., Promoting Efficient Use of Spectrum Through Elimination of Barriers to the Development of Secondary Markets*, 18 FCC Rcd 20604 (2003) (establishing policies to eliminate regulatory uncertainty surrounding terrestrial spectrum leasing arrangements, and thus promote more efficient, innovative, and dynamic use of the spectrum); *FCC Spectrum Policy Task Force Report*, ET Docket No. 02-135, at 11 (Nov. 15, 2002) ("[I]n determining whether to reallocate spectrum for another use or to change particular service rules, the Commission has considered the reliance interests of existing spectrum users, including their investments and reasonable expectations, in order to make sure any transition to new uses is equitable.")

[257] Julius Genachowski, Chairman, Federal Communications Commission, Remarks as Prepared for Delivery, GSMA Mobile World Congress, at 3 (Feb. 27, 2012).

[258] *Id*. at 4 (emphasis supplied).

growth in one of the most vital segments of the American economy, with profound implications for consumers, workers, and businesses throughout the country.

As Dr. Coleman Bazelon observes in his analysis, attached as Exhibit 6 hereto, "[s]etting aside the significant direct economic harm LightSquared and U.S. wireless broadband consumers caused by derailing LightSquared's deployment of LTE," the Commission's proposed actions here will both distort future reallocations of radio spectrum and limit further investment in new spectrum related services.[259] Specifically, Dr. Bazelon focuses on the cost imposed on future investment engendered by the regulatory uncertainty associated with the Commission's indefinite suspension or revocation of all or a significant portion of LightSquared's ATC authorization. Dr. Bazelon also observes that this inefficiency "is compounded by the market distortion resulting from the continued support of the commercial GPS industry in the form of subsidy and effective rights to" the MSS/ATC Band.[260] And in terms of long-term incentives, he notes that "permitting the GPS industry to effectively occupy spectrum that it is not authorized to use creates a serious 'moral hazard'" that gives incumbent GPS manufacturers and "users little incentive to invest in technology to mitigate the potential interference problem their unauthorized use creates."[261]

These detrimental public interest effects are quantifiable. In the *Public Notice*, the Commission has signaled an unprecedented "willingness—absent licensee malfeasance—to

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259 C. Bazelon, *Implications of Regulatory Inefficiency for Innovative Wireless Investments* at 1 (Mar. 16, 2012), attached as Exhibit 6 hereto. ("*Bazelon Regulatory Inefficiency Paper"*).

260 *Id*. at 2. Dr. Bazelon notes that by using the GPS satellite network free of charge, commercial GPS device manufacturers enjoy substantial benefits at no cost, effectively reducing their network investment costs to zero and distorting commercial GPS users' investment decisions. *Id.* at 18-23. He estimates that amount of the implicit federal subsidy for this industry is approximately $18 billion. *Id*. at 23-24.

261 *See id.* at 2.

revoke spectrum licenses even after capital investments have been made on projects that had substantial consumer and societal benefit."[262] Dr. Bazelon uses a simple cash flow model to identify at least two separate impacts on spectrum values resulting from the increased regulatory risk to FCC spectrum license holders that is portended by the proposed suspension of LightSquared's ATC authorization: (i) a direct decrease in expected industry cash flows, and (ii) a higher industry cost of capital. These effects would result in literally *billions* of dollars of lost value and decreased investment in the sector over time:

> Clearly, any factor that reduces the value of licensed spectrum will impact future investments in the wireless industry in a number of ways. For instance, lower spectrum values would result in lower FCC auction receipts. If the expected value of the [National Broadband Plan's] suggested 500 MHz of spectrum was worth $100 billion, a 5% increase in license revocation risk could reduce the value of that spectrum by as much as 10% or $10 billion. Perhaps more important than the direct impacts on federal auction receipts, however, is the impact of lower expected returns on private sector investment in wireless broadband. . . . Added regulatory uncertainty implies that some previously profitable projects will no longer be undertaken. Even for wireless broadband projects that continue to be profitable under such uncertainty, lower returns will make investing less attractive than alternative investments not impaired by increased license revocation risk. In turn, investors will be more difficult and even profitable projects will be delayed.[263]

Ultimately, Dr. Bazelon observes, the reduced network investments that would result from less profitable spectrum deployment opportunities would have ripple effects throughout the economy, and risks serious economic harm on a macro level.[264]

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262 *Id.* at 9.

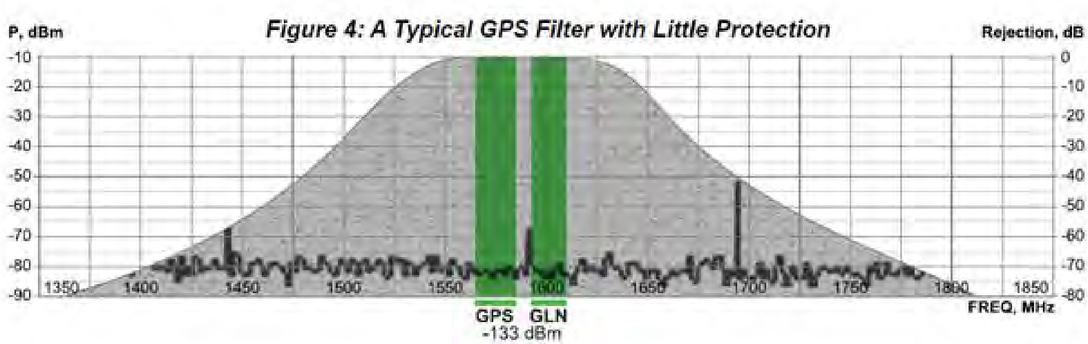
263 *Id*. at 17-18.

264 *Id*. at 26-27.

The public interest demands that the Commission avert the sweeping adverse consequences threatened by the *Public Notice*, and that it proceed instead with the steps necessary to enable LightSquared to deploy and operate its innovative 4G LTE network.

3. <u>The Proposed Actions Threaten Grave Long-Term Effects on United States Spectrum Policy</u>

Proceeding to vacate the *Conditional Waiver Order* or to suspend LightSquared's ATC authorization in whole or in part in order to protect GPS receivers from "overload" would turn the U.S. Table on its head, undermining the carefully balanced regulatory scheme that it represents, by conferring *de facto* allocation status upon nonconforming operations, and precluding the allocated use of the MSS/ATC Band for its intended purpose. And there is no limiting principle. Such an interpretation would allow a GPS user—or any other nonconforming user—to extend its "listening" activities into *any* adjacent band, and then assert a right to "protection" from primary operations in that band. This is not a theoretical concern. As illustrated below,[265] the typical filter used in some GPS receivers enables the reception of signals over hundreds of MHz of spectrum:



The prospect of protecting, at LightSquared's expense, unregulated GPS receivers that use the MSS/ATC Band on a non-conforming basis raises a number important public interest

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265 *See generally Ashjaee White Paper*.

questions that the Commission must resolve before taking the actions proposed in the *Public Notice*:

<u>How much more spectrum will be lost to unregulated GPS receivers</u>?

As shown above, a GPS filter with little protection is potentially vulnerable to "noise" from high-powered terrestrial transmitters using spectrum that is relatively far away from the L1 GPS signal centered at 1575.42 MHz. One stated reason is that this type of GPS receiver design makes it easier for the device to have a single RF "front end" that also receives MSS augmentation signals in the MSS/ATC Band.[266] Of course, that rationale easily could be extended to allow the manufacture of a device that also receives the L5 GPS signal in the 960-1215 MHz band,[267] that has a filter that extends over about 1 GHz of spectrum, and that is vulnerable to the same types of "overload" concerns in significant portions of the range between the L1 signal and the L5 signal. Would that device be protected from "overload" in every segment of the radiofrequency spectrum from 1215 MHz to 1559 MHz? What impact would such protection have on the many existing terrestrial fixed allocations in the 1215 MHz to 1559 MHz range?[268] Would existing terrestrial uses of those frequencies be blocked and would future uses be precluded? And if not, how could the different treatment of LightSquared be sustained? How much impact would this risk have on the auction of spectrum in the affected frequency ranges?

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266 *See Deere Petition for Reconsideration* at 6 (admitting that Deere has "opened up" its GPS receivers to "listen" across the MSS Bands); *see also* Section II.A.2.b, *supra.*

267 *See Lockheed Martin Corporation Application To Launch and Operate a Geostationary Orbit Space Station in the Radionavigation-Satellite Service at 107.3 W.L.*, DA 06-2424, IBFS File No. SAT-LOA-19990427-00046, at ¶ 4 n.15 (Sept. 8, 2005) ("*Lockheed Order*").

268 *See* 47 C.F.R.§ 2.106.

Who else would be protected and at what cost?

The rationale advanced by the GPS industry to justify the unprecedented action proposed in the *Public Notice* is that the U.S. GPS system is somehow at risk (which is not true). If that rationale is accepted, however, the Commission needs to consider whether the same logic would apply to any unregulated receivers that communicate with any RNSS spacecraft. For example, would this mean that any unregulated receivers that communicate with privately-owned spacecraft that provide GPS augmentation signals are similarly protected, such as the Lockheed Martin[269] and Inmarsat[270] systems, even though those companies have no control over the receivers that are used on their systems? And how could the non-conforming use of spectrum to communicate with those private networks rationally be protected over the licensed use of allocated spectrum by LightSquared? Would this mean than the RNSS systems of other nations, such as the Chinese COMPASS system, the Russian Glonass system, and the European Galileo system, would warrant similar protection? Would "hostile" nations be able to effectively hijack U.S. spectrum policy by flooding the market with cheap, unregulated devices that are not compatible with neighboring spectrum uses in the U.S. and then demanding interference protection? Would the failure to provide those nations with the same type of protection as the GPS system violate U.S. treaty obligations?[271] Would denying protection by holding those other

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269 *See generally Lockheed Order.*

270 *See Inmarsat Hawaii Order* (waiving FCC rules to permit unlicensed GPS (RNSS) terminals to receive transmissions from a U.K.-licensed Inmarsat satellite).

271 *See, e.g., Agreement on the Promotion, Provision and Use of Galileo and GPS Satellite-Based Navigation Systems and Related Applications*, at 16 (June 26, 2004), *available at* http//www.gps.gov/policy/cooperation/europe/2004/gps-galileo-agreement.pdf; *Amendment of the Commission's Regulatory Policies to Allow Non-U.S.-Licensed Spaced Stations to Provide Domestic and International Satellite Service in the United States*, 12 FCC Rcd 24094 (1997) (discussing U.S. WTO commitments in the communications area).

nations to stricter standards than those to which the United States holds itself raise the same types of treaty concerns?

Protecting unlicensed spectrum users at the expense of a licensed user not only creates these types of issues in the band segments that are near the spectrum allocated for RNSS, but also threatens to call *all* licensed spectrum rights into question, and to undermine the certainty and stability necessary to encourage investment in innovative next-generation broadband communications networks. Investors will be unwilling to invest in such networks if their operations can be compromised at any time due to the ostensible need to protect unlicensed, nonconforming spectrum uses. That is especially true where, as here, the affected parties have sat on their concerns for years, only to raise them at the eleventh hour, and have failed to take any steps to avoid a problem that is entirely within their control.

B. The Commission's Proposed Action Would Violate The Administrative Procedure Act

For reasons set forth throughout this submission, the course of action proposed in the *Public Notice* would be an extraordinary arbitrary and capricious agency action that cannot be squared with the most basic requirements of the Administrative Procedure Act. Indeed, the sudden reversal the Commission has proposed would directly assault the core function and purpose of the APA by treating years of prior Commission legal proceedings as a sham and nullity.

As explained above, the current proceeding was prompted by GPS interests that were on notice more than a decade ago of possible "overload" associated with LightSquared's operation of its network. In a series of legal proceedings conducted pursuant to statutorily-required notice and comment procedures that began in 2001, those interests had the opportunity to step forward and oppose LightSquared's intended use of the MSS/ATC Band on the basis of (purported) overload concerns. Instead, the GPS interests came forward repeatedly—in 2002, 2004, and 2009—to provide *support* for LightSquared's ATC authorizations in letters submitted to the Commission stating that interference concerns had been resolved.[272] The Commission relied upon those interests' support in granting LightSquared's authorization and approving its operational plans, and LightSquared, in turn, relied upon the Commission and the agreement and actions of the GPS industry in expending billions to develop its network.

Those numerous prior proceedings conducted by the Commission regarding LightSquared had legal meaning and effect: their function under the law was to notify potentially affected parties of the Commission's proposed course of action so they could step forward to assert their interests and provide their evidence, and so the Commission could then proceed to make an informed, legally-binding decision. That legal process—which is governed by statute and volumes of decisional law—would be rendered a sham and a farce if an agency's practice were to reverse a series of decisions made after notice and comment years earlier, in reliance on which private parties had invested billions, because parties belatedly came forward with matters that they knew about for years but failed to raise when called to do so.

The *Conditional Waiver Order* imposed a new condition on LightSquared that, the *Public Notice* concedes, was unrelated to the waiver LightSquared sought and concerned matters that GPS interests were on notice to raise *before* the Commission permitted—and ordered—LightSquared to invest billions. If the Commission now follows through on the action

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[272] *See 2003 ATC Order* ¶ 184 (citing "agreement . . . submitted to the FCC jointly by the GPS Industry Council and MSV"); *MSV ATC Order* ¶ 11 n.23 (citing letter from U.S. GPS Industry Council supporting MSV's application for ATC authorization); *SkyTerra Modification Order* ¶ 4 ("SkyTerra and USGPS subsequently submitted a joint letter resolving the concerns raised in the USGPS comments.").

proposed in the *Public Notice*, it will constitute an unprecedented subversion of its own prior proceedings, and of the legal processes set forth in the Communications Act and the APA.

Simply, a government cannot operate this way, least of all an agency that enters binding agreements and orders for private companies to spend billions to advance the public interest. The Commission cannot expect such an arbitrary, capricious, and destructive pattern of conduct to withstand judicial review.

C. The Proposed Actions Would Breach the Commission's Contract With LightSquared and Violate LightSquared's Constitutional Rights

The course of action proposed in the *Public Notice*, which would undercut billions of dollars in investments that the Commission ordered LightSquared to make at breathtaking speed in exchange for regulatory approval of its proposed network, would violate the core guarantees of fair treatment and protection of private property rights enshrined in the Constitution. LightSquared has invested significant resources in its broadband network, including building two state-of-the-art communications satellites, implementing coordination agreements with other spectrum users, developing and deploying the necessary hardware, and developing the technology to prevent disruption of GPS. All told, the full rollout of LightSquared's network will cost tens of billions of dollars.[273]

LightSquared worked relentlessly to achieve the Commission's broadband vision. Based upon the agency's repeated explicit (and implicit) findings over a period of years that ATC operations in general and LightSquared's operations in particular will serve the public interest, LightSquared and its investors devoted massive resources to building out its network in

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[273] The mere release of the *Public Notice* itself has already had a negative impact in the value of LightSquared's spectrum, as well as increased volatility in spectrum-related stock. *See Bazelon Regulatory Inefficiency Paper* at 17.

the expedited frame that the Commission demanded.[274] For the Commission to backtrack at this late stage in a fashion that would destroy LightSquared's business, *after* LightSquared and its investors have invested billions of dollars in its wireless 4G LTE network, and *after* the commercial GPS industry has supported the development of ATC for years based on negotiated GPS protection criteria, would be unconscionably arbitrary agency action that would breach LightSquared's contract with the government, violate its constitutional rights, and expose the federal government to massive liability. For these reasons—as well as for all the reasons set forth above—the Commission must not proceed down the path proposed in the *Public Notice*.

1. <u>Suspending LightSquared's ATC Authority Would Violate Its Contractual Rights</u>

In 2010, the Commission made a commitment to LightSquared to permit it to go forward with its network in exchange for valuable promises that LightSquared would rapidly build out its network to meet goals set forth in the National Broadband Plan. It was well understood by all parties that LightSquared was making those commitments in exchange for regulatory approval for its plan to build a terrestrial network—as numerous documents from that time attest. The Commission and the GPS industry had been on notice for *years* that potential

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274 *See, e.g.*, *MSV ATC Order* ¶ 2 ("[I]mplementation of ATC, pursuant to these rules, would increase network capacity and efficiency of spectrum use, extend coverage for handset operation in places where MSS operators have previously been unable to offer reliable service, make possible substantial economies of scale, improve emergency communications, and enhance competition."). *See also SkyTerra Subsidiary LLC*, 25 FCC Rcd 2022, at ¶ 13 (2010) ("We find that granting the subject application will serve the public interest by facilitating more efficient spectrum use and provision of advanced broadband services [and] enable [LightSquared] to operate in wider contiguous spectrum bands, thereby facilitating provision of high-speed broadband services to users in the United States."); *Globalstar Order* ¶ 11 (*citing* the *2003 ATC Order* ¶ 23 for the proposition that the integration of ATC into MSS systems will foster the development of new and innovative service offerings that satellite-only MSS systems cannot offer, including, *e.g.*, ubiquitous digital telecommunications and broadband services and other services that take advantage of the unique coverage and capacity characteristics of ATC-enabled MSS).

overload concerns were a factor to consider when approving LightSquared's plans and requiring its mammoth build-out, but in repeated notice and comment proceedings provided for by statute the GPS industry raised no such concern—rather, it actively supported LightSquared's proposed MSS/ATC Band spectrum use—and the Commission entered into its agreement with LightSquared. The Company then spent enormous sums of money to achieve the public-policy objectives that the Commission had made the price for its regulatory approval. Now, after entering this agreement with LightSquared and *ordering* it to expend billions of dollars, the Commission has capriciously announced its intention to breach the agreement.

The Federal Government may not proceed in this way and if it does, it must pay the price. The Supreme Court and Federal Circuit have made clear that where an agency promises a party a certain regulatory treatment as part of a bargained-for exchange, a breach of that promise requires the government to compensate the party under the ordinary rules of contract law.[275] The Supreme Court has been especially careful to police this fundamental limitation on arbitrary agency action when the government body enters into a mutual compact with a private entity to advance public-policy goals. As the Court explained over a hundred years ago, "[i]t would hardly be credible that capitalists about to invest money in what was then a somewhat uncertain venture, . . . would at the same time . . . give the right to the [government] to change at its pleasure from time to time those important and fundamental rights affecting the very existence and financial success of the company."[276]

Thus, in the *Winstar* case, the Court required the federal government to pay contract damages for breaching its regulatory promise. A federal agency had promised certain

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275 *See, e.g.*, *United States v. Winstar Corp.*, 518 U.S. 839 (1996); *Fifth Third Bank of W. Ohio v. United States*, 402 F.3d 1221 (Fed. Cir. 2005).

276 *Detroit v. Detroit Citizens' Street Ry. Co.*, 184 U.S. 368, 385 (1902).

thrifts favorable regulatory treatment if they would agree to merge with failing thrifts insured by a government corporation, but after the mergers had taken place, Congress enacted a statute that reneged on that promise. The Supreme Court made clear that where an agency guarantees regulatory treatment in exchange for promises by the private party—a type of contract that is "especially appropriate in the world of regulated industries, where the risk that legal change will prevent the bargained-for performance is always lurking in the shadows"—the government must pay damages to compensate the party if it later reneges on its promise.[277]

There can be little doubt that the Commission entered into an agreement with LightSquared and that it breached that agreement—a breach even more unconscionable than the breach in *Winstar*, since it was effected by the same government body that made the promise.[278] The basic requirements for a contract with a government agency are identical to any other contract: "(1) mutuality of intent to contract; (2) consideration; (3) an unambiguous offer and acceptance[;] and (4) 'actual authority' on the part of the government's representative to bind the government."[279] It is black letter law, moreover, that "no single document incorporating all the contract terms" is required; "such documents are not legal prerequisites to a contractual obligation."[280] Rather, courts examine "documents such as correspondence, memoranda and

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277 *Winstar*, 518 U.S. at 869 (plurality op.); *see also id.* at 921 (Scalia, J., concurring in the judgment ("[T]he promise to accord favorable regulatory treatment must be understood as (unsurprisingly) a *promise* to accord favorable regulatory treatment.").

278 To the extent the Commission's action were based on the Consolidated Appropriations Act of 2012, then that legislative act would breach the Commission's contract with LightSquared and suffer from the same constitutional defects discussed below.

279 *Schism v. United States*, 316 F.3d 1259, 1278 (Fed. Cir. 2002) (en banc) (citation omitted).

280 *Fifth Third Bank*, 402 F.3d at 1229.

[agency] resolutions" to discern whether these requirements are met.[281] The central question is whether "the government, in exchange for [a promise by the party], also made promises that certain regulatory treatment would be extended and maintained."[282]

The Commission's and LightSquared's conduct, oral communications, and writings make clear that the Commission entered into a contract with LightSquared where it guaranteed the ability to build out its network in exchange for helping the Commission achieve important public-policy objectives at a highly accelerated pace: The Commission accepted LightSquared's offer to undertake massive investments in its 4G LTE network to further the Commission's goals for universal broadband access if the Commission would give LightSquared the regulatory treatment it wanted regarding its ATC authorization.

During negotiations between Harbinger and the Commission concerning the transfer of control of SkyTerra (LightSquared's predecessor) to Harbinger, LightSquared made a voluntary commitment "to build a terrestrial network using SkyTerra's ATC authorizations" and imposed that as a specific condition on the transfer of control.[283] Specifically, LightSquared at huge expense "committed to a build-out schedule of its 4G terrestrial network that will provide coverage in the United States to at least 100 million people by December 31, 2012, at least 145 million people by December 31, 2013, and at least 260 million people by December 31, 2015."[284] In a letter to the Commission, LightSquared set forth in unmistakable terms that its "commitments are contingent upon a grant of the applications filed by SkyTerra for modification of its ATC authority . . . being granted prior to or concurrently with the grant of the Transfer of

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281 *Cal. Fed. Bank, FSB v. United States*, 245 F.3d 1342, 1347 (Fed. Cir. 2001); *see also Hometown Fin., Inc. v. United States*, 409 F.3d 1360, 1365 (Fed. Cir. 2005).

282 *First Commerce Corp. v. United States*, 335 F.3d 1373, 1383 (Fed. Cir. 2003).

283 *Harbinger Transfer Order* ¶ 72.

284 *Id.* ¶ 56.

Control Applications."[285] The network LightSquared committed to build conferred an enormous benefit on the Commission by directly advancing the goals outlined in the National Broadband Plan. "These documents, together with the other documents, facts, and circumstances" of the case, are "abundant documentary proof of mutual intent" to enter into a contract.[286]

The Commission accepted LightSquared's offer by granting the transfer of control application and LightSquared's application to modify its ATC authority. LightSquared invested billions of dollars in building out its network based on the authority provided for in the grant of the ATC modification application, *i.e.*, the promise of a regulatory disposition or environment that would enable LightSquared to use its MSS/ATC Band spectrum to deploy a nationwide terrestrial wireless network. Those billions of dollars would have been unrecoverable without the Commission's reciprocal agreement that LightSquared would be able to operate its network and redeem its investment. It "would, indeed, have been madness for [LightSquared] to have engaged in these transactions" without the understanding that its investments would not be entirely wasted by the sudden whim of the Commission.[287] Indeed, the very fact that it would be unlawful for LightSquared to construct and operate its terrestrial network without the regulatory guarantee is "convincing evidence that the parties intended for [the ATC authorization] provisions to be contractual obligations."[288] In short, just as in *Winstar*, the actions proposed in the *Public Notice* would breach contractual commitments that induced LightSquared to expend

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285 Letter to FCC from Harbinger Capital Partners Funds, IB Docket No. 08-184 (Mar. 26, 2010) (attached as Appendix B to the *Harbinger Transfer Order*).

286 *Hometown Fin.*, 409 F.3d at 1366. *See Harbinger Transfer Order* ¶ 62. *See also Conditional Waiver Order* ¶ 7.

287 *Winstar*, 518 U.S. at 910 (plurality op.).

288 *Barron Bancshares, Inc. v. United States*, 366 F.3d 1360, 1378 (Fed. Cir. 2004); *see also LaSalle Talman Bank, F.S.B. v. United States*, 317 F.3d 1363, 1378 (Fed. Cir. 2003) ("[T]here would be little reason for any thrift to assume added liabilities if that assumption would place it in immediate danger of receivership and dissolution.").

billions of dollars. They would directly contravene the Commission's acceptance of LightSquared's commitments in exchange for allowing LightSquared to buildout its 4G LTE network pursuant to that authorization as modified in 2010. And they would expose the government to liability for billions of dollars that LightSquared invested in reliance on the government and to build out the network that it had committed to establish.[289]

2. The Proposed Action Would Be An Unconstitutional Taking of LightSquared's Property Without Just Compensation

If taken, the actions proposed in the *Public Notice* would expose the government to financial liability for another reason: They would constitute a taking of LightSquared's property without just compensation in violation of the Fifth Amendment of the Constitution. The government is not permitted to destroy the value of private property through regulation without paying for it. Where "the magnitude of a regulation's economic impact and the degree to which it interferes with legitimate property interests" are severe, the courts will not hesitate to order the government compensate the property owner.[290]

The Commission itself has recognized that Commission licenses may create enforceable property interests,[291] and has increasingly treated licenses as property, including by

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289 The action proposed in the *Public Notice* would also violate the implied covenant of good faith and fair dealing. "The duty of good faith and fair dealing is inherent in every contract" and "[t]he United States, no less than any other party, is subject to this covenant." *Precision Pine & Timber, Inc. v. United States*, 596 F.3d 817, 828 (Fed. Cir. 2010). The Commission's about-face due to GPS industry pressure and its immediate resort to the most drastic remedy—effective revocation of LightSquared's ATC authority—is the antithesis of good faith and fair dealing.

290 *Lingle v. Chevron U.S.A. Inc.*, 544 U.S. 528, 540 (2005).

291 *See, e.g.*, *In re of Facilitating the Provision of Spectrum-Based Services to Rural Areas, and Promoting Opportunities for Rural Telephone Companies to Provide Spectrum-Based Services, Report and Order and Further Notice of Proposed Rulemaking*, 19 FCC Rcd. 19078 ¶¶ 48-49 (2004).

auctioning them for billions of dollars.[292] Yet, the proposed actions would, in an instant, destroy much of the value of numerous property interests held by LightSquared, including property interests relating to and flowing from its spectrum license, the real property and equipment it has acquired to build out its network, its contractual relationships with customers, and its rights pursuant to its implied contract with the Commission. Indeed, this would constitute a *per se* taking under well-settled Fifth Amendment jurisprudence,[293] because the Commission's proposed actions would effectively eliminate LightSquared's ATC authorization and thus its contractual rights to operate a network pursuant to that authorization. Also, without a suitable substitute for the spectrum usage rights provided by the ATC authorization, there would be no reasonable and economically beneficial use for the billions of dollars in capital investments that LightSquared made in technology specific to the terrestrial component of its network.

The Commission's action would also constitute a regulatory taking under the standard announced in *Penn Central Transportation. Co. v. New York City*, 438 U.S. 104 (1978), which looks to the "economic impact of the regulation" and in particular, its effect on investment-backed expectations, as well as to the "character of the government action."[294] The economic impact in this case is colossal. LightSquared poured billions of dollars into helping the Commission achieve its goal of universal broadband on an expedited timeframe, but that investment will have been wasted if the Company's ATC authorization is revoked. And given the Commission's many assurances that LightSquared would be permitted to construct this network, there is no serious question that suddenly derailing the project would "interfere with

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[292] *See, e.g.*, *FCC v. NextWave Pers. Commc'ns. Inc.*, 537 U.S. 293, 296 (2003).

[293] *See Lingle*, 544 U.S. at 538.

[294] *Penn Central Transp. Co. v. New York City*, 438 U.S. 104, 124 (1978).

distinct investment-backed expectations."[295] LightSquared invested billions of dollars to implement an ATC network to utilize the MSS/ATC Band spectrum based on the Commission's repeated and specific assurances that LightSquared would be able to (and indeed was required to) operate a network pursuant to LightSquared's ATC authorization. Finally, the "character of the governmental action"[296] is a physical interference by the government because it would effectively prohibit LightSquared's terrestrial network from occupying the portion of the spectrum that is being used by some GPS receivers (albeit in a manner inconsistent with the U.S. Table).

The "character" of the Commission's proposed actions is, in addition, an unprecedented disregard for private investment and property rights. Terminating LightSquared's authority would not amount to merely incidental "interference [that] arises from some public program adjusting the benefits and burdens of economic life to promote the common good."[297] The Commission's entire course of conduct was intended to *induce* LightSquared to expend significant resources to rapidly deploy a network to *advance* the public interest. LightSquared consulted with all interested parties, including the GPS industry, before building out its terrestrial network. That network will, as the Commission has repeatedly announced, result in enormous benefits for the public, including increasing competition in the wireless industry and providing broadband in remote areas. The only basis for the decision to suspend or vacate LightSquared's authorization would be to give an unmerited windfall to the GPS industry by failing to recognize that under longstanding principles governing spectrum use, it is GPS manufacturers that must bear the cost of resolving overload, not LightSquared or the public.

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295 *Id.*

296 *Id.*

297 *Id.*

The fact that the action proposed in the *Public Notice* would constitute an uncompensated taking is also underscored by the stunningly retroactive character of the proposal, which would render worthless investments made in reliance on Commission's guarantees and at the Commission's urging—the action therefore violates the Takings Clause's basic guarantee against action that fundamentally changes the economic consequences of past behavior. As Justice Scalia has explained, "[a] rule that has unreasonable secondary retroactivity — for example, altering future regulation in a manner that makes worthless substantial past investment incurred in reliance upon the prior rule—may" be so irrational as to be invalid.[298] In *Eastern Enterprises v. Apfel*, 524 U.S. 498 (1998), the Supreme Court held that retroactive legislation imposing severe economic costs on parties has constitutional consequences. "Retroactive legislation," the plurality in that case said, "presents problems of unfairness that are more serious than those posed by prospective legislation, because it can deprive citizens of legitimate expectations and upset settled transactions."[299] As a consequence, regulation is "unconstitutional if it imposes severe retroactive liability on a limited class of parties that could not have anticipated the liability, and the extent of that liability is substantially disproportionate to the parties' experience." In such circumstances, just compensation is required under the Takings Clause.[300] The proposed action here, which would declare on the eve of its launch that LightSquared's network previously-approved is now unlawful, is an egregious case of retroactive lawmaking. The Constitution's private-property protections forbid such confiscatory government action.

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[298] *Bowen v. Georgetown Univ. Hosp.*, 488 U.S. 204, 220 (1988) (Scalia, J., concurring).

[299] *Id.* at 533.

[300] *Id.* at 528–29 (plurality op.); *see also id.* at 547–50 (Kennedy, J., concurring in the judgment) (arguing that such regulation is invalid under the Due Process Clause).

Stripping LightSquared of billions of dollars in property value simply does not comport with the Fifth Amendment's basic protection for private property. If the Commission proceeds on this course, it will be subject to the damages remedy that the Constitution guarantees.

3. The Proposed Action Would Violate the Due Process Clause

The proposed indefinite suspension of LightSquared's ATC authorization would also violate the basic guarantee of fair treatment and rational decision-making embodied in the Fifth Amendment's Due Process Clause. That clause prohibits arbitrary government deprivation of property,[301] and the Commission has long understood that "the denial of a broadcast license triggers due process protection."[302] As shown above, the Commission's proposed actions have no basis in the record and would amount to completely arbitrary agency action.[303] The course proposed in the *Public Notice* also would constitute an unprecedented and unsupported reversal of positions taken by the Commission over a period of years, depriving LightSquared of billions of dollars of investment with no meaningful opportunity to defend its interests from a patently flawed government report produced in circumstances which, at a minimum, raise serious concerns of improper bias and influence. Such outcomes simply cannot be squared with the Due Process Clause.

This deprivation of LightSquared's property rights would result from a course of conduct that departed dramatically from basic norms of government process. For years, the GPS industry had the opportunity to voice concerns about the LightSquared's network through notice and comment proceedings conducted according to statutory requirements. But not only did the

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301 *See, e.g.*, *County of Sacramento v. Lewis*, 523 U.S. 833, 845 (1998).

302 *Trinity Broad. of Fla., Inc. v. FCC*, 211 F.3d 618, 628 (D.C. Cir. 2000).

303 *See* Sections II-V, *supra*.

industry decline to express those concerns, it actively supported LightSquared, until suddenly changing its position after LightSquared had expended enormous resources building its network. In the context of administrative decision-making, however, Due Process entails a guarantee that regulated parties can rely on agency decision-making processes without fear that other members of the public will ambush them with objections that should have been raised years earlier, and that an agency will respond by suddenly reversing course to accommodate out-of-time objections that go to the very heart of a long-standing regulatory program. Due Process "protects the interests in fair notice and *repose*,"[304] but if the Commission allows the GPS industry to lie in wait for years only to ambush LightSquared's investment long after the time to object had passed, it will have exceeded constitutional limits on its ability to disrupt the settled expectations of regulated parties.

The Supreme Court has not hesitated to police agency action under the Due Process Clause in industries that are subject to heavy regulation. In setting the constitutional limits on public rate regulation, for example, the Court has made clear that rates that are "so unreasonable as to practically destroy the value of the property of [such] companies . . . conflict with the Constitution of the United States, as depriving the companies of their property without due process of law."[305] The "guiding principle" is that the regulatory action cannot be "so unjust as to be confiscatory."[306] Few actions are more confiscatory than requiring a company to expend billions in resources as part of a regulatory program and then depriving the company of any return on that investment.

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304 *Landgraf v. USI Film Products*, 511 U.S. 244, 267 (1994) (emphasis added).

305 *Covington & Lexington Tpk. Rd. Co. v. Sandford*, 164 U.S. 578, 592 (1896).

306 *Duquesne Light Co. v. Barasch*, 488 U.S. 609, 615 (1989).

The severely retroactive character of the proposed action, discussed above, is only further evidence that the Commission would violate Due Process if it proceeds down this course. As Justice Kennedy explained in *Eastern Enterprises*, quoting Justice Story, "'[r]etrospective laws are, indeed, generally unjust; and, as has been forcibly said, neither accord with sound legislation nor with the fundamental principles of the social compact.'"[307] It simply does not comport with the core fairness guarantee of Due Process to induce a company to spend billions to advance a public program and then to declare that the company may not recoup that investment. Yet that is precisely what is proposed here. The Commission induced LightSquared to rely on its regulatory approval and now threatens to retract that approval on the basis of concerns that were raised and resolved years ago. That cannot be reconciled with the fundamental guarantee of Due Process.

4. The Proposed Action Would Violate the Equal Protection and Bill of Attainder Clauses

The Commission's proposed action would also violate the Constitution's guarantees against the imposition of a unique punishment on a single person or entity. The Equal Protection Clause prohibits "arbitrary government classification," including the infliction of harm on a single entity in a way that is arbitrary or unfair.[308] LightSquared is a "class of one" that is being "intentionally treated differently from others similarly situated" and "there is no rational basis for the difference in treatment."[309] As explained, transmissions from other spectrum users have as much or more impact on GPS receivers than LightSquared's network would. There is no rational basis for the Commission to eliminate LightSquared's ATC

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[307] *Eastern Enters.*, 524 U.S. at 547 (Kennedy, J., concurring in the judgment).

[308] *Engquist v. Or. Dep't of Agric.*, 553 U.S. 591, 601 (2008).

[309] *Id.*

authority based on interference concerns, but to allow devices to continue causing the same amount of, or more, impact.

The Bill of Attainder Clause (Art. I §9 cl. 3) likewise prohibits any attempt to "'legislatively determine guilt and inflict punishment upon an identifiable individual without provision of the protections of a judicial trial.'"[310] The Commission's proposed actions here would be tantamount to a bill of attainder, the hallmarks of which are a severe burden on an individual party, a discernible "intent to punish," and action that "falls within the historical meaning of legislative punishment."[311] There can be no doubt that confiscation of property, which has occurred here, was a historical form of punishment. It is also plain that the burden in this case is so severe that it could not possibly be justified by a legitimate purpose. And the differential treatment of LightSquared compared to other spectrum users that cause the same or more impact on GPS receivers—combined with the sudden reversal of Commission policy immediately in the wake of a flawed and biased report—suggests a punitive purpose.

* * *

These violations of LightSquared's contractual and constitutional rights not only would subject the Commission to suit and massive liability for the deprivation of LightSquared's investment-backed expectations, but provide an independent basis for concluding that the actions proposed in the *Public Notice*—if executed—would be arbitrary, capricious, and contrary to law.

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310 *Selective Serv. Sys. v. Minn. Pub. Interest Research Grp.*, 468 U.S. 841, 846-47 (1984) (citation omitted).

311 *See Joint Anti-Fascist Refugee Comm. v. McGrath*, 341 U.S. 123, 143 (1951) (Black, J., concurring).

VII. NEITHER SUSPENDING NOR VACATING LIGHTSQUARED'S ATC AUTHORITY IS PERMITTED OR REQUIRED BY RECENT LEGISLATION

Nothing in recent legislation permits, much less requires, the Bureau or the Commission to suspend LightSquared's ATC authority. As the *Public Notice* recognizes, Section 628 of the Consolidated Appropriations Act of 2012 prohibits the Commission from using funds made available through that Act "to remove the conditions imposed on commercial terrestrial operations in the [*Conditional Waiver Order*], or otherwise permit such operations, *until* the Commission has resolved concerns of potential widespread harmful interference by such commercial terrestrial operations to commercially available Global Positioning System devices."[312] Section 911 of the National Defense Authorization Act of 2012 contains similar language.[313]

These statutes thus are expressly tethered to the *Conditional Waiver Order* and the terrestrial-only mobile user terminals that are the focus of that order. Nothing in these statutes addresses LightSquared's underlying ATC authorization. Indeed, they restate the condition already imposed by the Commission in the *Conditional Waiver Order*, and indicate Congress's expectation that the Commission will complete—rather than abandon midstream—the resolution process established by the order.[314]

Furthermore, nothing in these statutes affects the legal standards that governs the relative priority of spectrum users and establishes, *inter alia*, that unlicensed users operating in a manner that is not consistent with the U.S. Table (*i.e.*, GPS users "listening" in the MSS/ATC

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312 *See* Consolidated Appropriations Act of 2012, Pub. L. No. 112-74, § 628 (enacted Dec. 23, 2011) (emphasis added).

313 *See* National Defense Authorization Act of 2012, Pub. L. No. 112-81, § 911 (enacted Dec. 31, 2011).

314 *Id.*

Band) cannot claim protection from licensed users operating in a manner consistent with a primary spectrum allocation (*i.e.*, MSS/ATC operators in the MSS/ATC Band). More broadly, nothing in these statutes purports to permit or require the Commission to alter previous public interest determinations with respect to: (i) MSS/ATC operations generally; (ii) the relative rights and obligations of MSS/ATC Band licensees vis-à-vis GPS receivers that are also using the MSS/ATC Band; or (iii) the need for manufacturers of GPS devices that are susceptible to "overload" from licensed emissions in the adjacent MSS/ATC Band to shoulder the burden of coexistence with ATC operations.

These statutes simply direct the Commission to use its existing authority to "resolve[] concerns of potential widespread harmful interference" in the context of an ongoing dispute. They do not say anything about resolving such concerns using different factors or considerations than those that the Commission has employed and developed over many decades. To the contrary, Congress's choice of the well-defined term "harmful interference," without any new or special definitions, in the context of an ongoing dispute, indicates an affirmative intent *not* to alter the existing regulatory standards.[315]

As the Commission is well aware, a variety of proceedings are pending or have been proposed which, individually or in combination, provide the opportunity to "resolve" the

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[315] It is a settled principle of statutory construction that legislative language should not be interpreted to depart from long established practices or policies unless Congress clearly and unmistakably expresses its intention to make such a change. *See Jones v. United States*, 526 U.S. 227, 234 (1999) (It is a "fair assumption that Congress is unlikely to intend any radical departures from past practice without making a point of saying so."); *Robertson v. R.R. Labor Bd.*, 268 U.S. 619, 627 (1925) ("It is not lightly to be assumed that Congress intended to depart from a long established policy."); *cf. Pasquantino v. United States*, 544 U.S. 349, 359 (2005) (recognizing "the canon of construction that statutes which invade the common law . . . are to be read with a presumption favoring the retention of long-established and familiar principles, except where a statutory purpose to the contrary is evident").

claims by unlicensed GPS users of "potential widespread harmful interference" within the meaning of Sections 628 and 911. These include the *Petition for Declaratory Ruling*, LightSquared's request for the development of GPS receiver standards,[316] and the proceedings in connection with the *Conditional Waiver Order*. The following are appropriate conclusions for the Commission to draw from the applicable facts and law developed in these proceedings:

- As detailed in the *Petition for Declaratory Ruling*, recognize that GPS receivers have no right to overload protection from authorized operations in the adjacent MSS/ATC Band.[317]

- As described in the *Petition for Declaratory Ruling*, find that any risk of "overload" that GPS receivers face is a function of receiver design, and is within the control of the receiver manufacturers, which therefore must bear responsibility for solving the problem.[318]

- As explained in the *Petition for Declaratory Ruling*, find that the "overload" effects experienced by GPS receivers that are "listening" in the MSS/ATC Band cannot be construed as cognizable "harmful interference."[319]

- Conclude that the *potential* "overload" risk is not, in fact, present, or that any "overload" effect is not "harmful" or "widespread."

- Find that any risk of "overload" can be mitigated.

- As detailed in the record in this proceeding and as partially summarized in the *Public Notice*, conclude that the GPS industry should be estopped and is legally precluded from complaining about licensed MSS/ATC operations because the industry, over a period of years and in public proceedings, repeatedly endorsed such operations and the terms on which such operations would be conducted.[320]

- As proposed in LightSquared's *Receiver Standards Petition*, establish reliability standards for GPS receivers to ensure that such GPS receivers perform as intended, taking into account licensed operations in adjacent spectrum bands—

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316 *See generally Receiver Standards Petition*.

317 *Petition for Declaratory Ruling* at 11-22.

318 *Id.* at 23-29.

319 *Id.* at 17.

320 *See LightSquared December 20* Letter at 2-6.

including the portions of the MSS/ATC Band in which LightSquared is authorized to operate.[321]

Any one or more of these conclusions would "resolve[] concerns of potential widespread harmful interference" and thus fully comport with Sections 628 and 911.

VIII. CONCLUSION

For the foregoing reasons, the Commission cannot and should not take the actions proposed in the *Public Notice*, and instead should continue to foster the development of LightSquared's licensed ATC network for the benefit of U.S. consumers.

Respectfully submitted,

/s/ Jeffrey J. Carlisle

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321 *Receiver Standards Petition* at 4-11.

EXHIBIT 1

LIST OF SOURCE ABBREVIATIONS

<u>Exhibit 1: List of Source Abbreviations</u>

Short Citation	Citation to Full Source
1979 Receive-Only Earth Station Order	*Regulation of Domestic Receive-Only Satellite Earth Stations*, 74 FCC.2d 205 (1979).
1986 Receive-Only Earth Station Order	*Deregulation of Domestic Receive-Only Satellite Earth Stations*, 104 FCC.2d 348 (1986).
2002 MSV-GPS Joint Letter	Letter to FCC from Mobile Satellite Ventures L.P. and the U.S. GPS Industry Council, IB Docket No. 01-185 (July 17, 2002).
2003 ATC Order	*Flexibility for Delivery of Communications by Mobile Satellite Providers in the 2 GHz Band, the L-Band, and the 1.6/2.4 GHz Band*, 18 FCC Rcd 1962 (2003).
2003 USGIC Petition for Reconsideration	Petition for Reconsideration of the U.S. GPS Industry Council, IB Docket No. 01-185 (June 11, 2003).
2004 NTIA Letter	Letter to FCC from NTIA, IBFS File No. SAT-MOD-20031118-00333 (Apr. 21, 2004).
2004 USGIC Letter	Letter to FCC from U.S. GPS Industry Council, IBFS File No. SAT-MOD-20031118-00333 (Mar. 24, 2004).
2005 ATC Order	*Flexibility for Delivery of Communications by Mobile Satellite Service Providers in the 2 GHz Band, the L Band, and the 1.6/2.4 GHz Bands*, Memorandum Opinion and Order and Second Order on Reconsideration, 20 FCC Rcd 4616 (2005).
2005 NTIA Letter	Letter to FCC from NTIA, IBFS File Nos. SAT-AMD-20031118-00332 and SAT-MOD-20031118-00033 (May 25, 2005).
2009 GPS Comments	Comments of the U.S. GPS Industry Council, IBFS File No. SAT-MOD-20090429-00047, at 2 (Jul. 10, 2009).
2009 SkyTerra-GPS Joint Letter	Letter to FCC from USGIC, and SkyTerra Subsidiary LLC, IBFS File Nos. SAT- MOD 20090429-00046 (Aug. 13, 2009).
Ashjaee White Paper	Javad Ashjaee, *A Technical Story of a Bad Filter and a Good Filter Which Turned Political*, attached to Letter to FCC from LightSquared, IB Docket 11-109 (Mar. 16, 2012).
Bazelon Regulatory Inefficiency Paper	C. Bazelon, *Implications of Regulatory Inefficiency for Innovative Wireless Investments* (Mar. 15, 2012).
Big LEO Order	*Mobile Satellite Service in the 1610-1626.5/2482.5-2500 MHz Bands*, 9 FCC Rcd 5936 (1994).
Conditional Waiver Order	*LightSquared Subsidiary LLC*, 26 FCC Rcd 566 (2011).
December 12 LightSquared Letter	Letter to FCC from LightSquared, IB Docket No. 11-109 (Dec. 12, 2011).
December 20 LightSquared Letter	Letter to FCC from LightSquared, IB Docket No. 11-109 (Dec. 20, 2011).

December 7 LightSquared Letter	Letter to FCC from LightSquared, IB Docket No. 11-109 (Dec. 7, 2011).
Deere Comments	Comments of Deere & Company, IBFS File Nos. SAT-ASG-20010302-00017 (May 7, 2011).
Deere Petition for Reconsideration	Petition for Reconsideration of Deere & Company, IBFS File No. SAT-MOD-20101118-00239 (Feb. 25, 2011).
Engelman Letter	Letter to Marlene H. Dortch, Secretary, FCC from Richard B. Engelman, Chief Engineer, International Bureau, FCC, IB Docket No. 01-185 (Feb. 3, 2005).
Flexibility Notice	*Flexibility for Delivery of Communications by Mobile Satellite Providers in the 2 GHz Band, the L-Band, and the 1.6/2.4 GHz Band*, Notice of Proposed Rulemaking, 16 FCC Rcd 15532 (2001).
Globalstar Order	*Globalstar Licensee LLC,* FCC 08-254 (Oct. 31, 2008).
Harbinger Transfer Order	*SkyTerra Communications, Inc., Transferor and Harbinger Capital Partners Funds, Transferee*, 25 FCC Rcd 3059 (2010).
Inmarsat Comments	Comments of Inmarsat Ventures plc, IB Docket No. 01-185 (Oct. 22, 2001).
Inmarsat Hawaii Order	Inmarsat Hawaii Inc., IBFS File No. SES-MSC-20100415-00483 (Jul. 13, 2010).
Inmarsat Petition to Deny	Inmarsat Ventures plc, Partial Petition to Deny, IBFS File No. SAT-ASG-20010302-00017 (Apr. 18, 2001).
January 20 LightSquared Letter	Letter to FCC from LightSquared, IB Docket No. 11-109 (Jan. 20, 2012).
January 2003 NTIA Letter	Letter to FCC from NTIA, IB Docket No. 01-185 (Jan. 24, 2003; rec'd Feb. 10, 2003).
January 2011 NTIA Letter	Letter to FCC from NTIA, IBFS File No. SAT-MOD-20101118-00239 (Jan. 12, 2011).
LightSquared Recommendation	Recommendation of LightSquared Subsidiary LLC, File No. SAT-MOD-20101118-00239 and IB Docket No. 11-109 (filed Jun. 30, 2011).
Lockheed Order	*Lockheed Martin Corporation Application To Launch and Operate a Geostationary Orbit Space Station in the Radionavigation-Satellite Service at 107.3 W.L.*, DA 06-2424, IBFS File No. SAT-LOA-19990427-00046 (Sept. 8, 2005).
MSS Flexibility Order	*Fixed and Mobile Services in the Mobile Satellite Service Bands at 1525-1559 MHz and 1626.5-1660.5 MHz, 1610-1626.5 MHz and 2483.5-2500 MHz, and 2000-2020 MHz and 2180-2200 MHz*, 26 FCC Rcd 5710 (2011).
MSV ATC Order	*Mobile Satellite Ventures Subsidiary* LLC, 19 FCC Rcd 22144 (2004).

NATIONAL BROADBAND PLAN	Federal Communications Commission, CONNECTING AMERICA: THE NATIONAL BROADBAND PLAN (2010), *available at* http://www.broadband.gov/plan.
November 2002 NTIA Letter	Letter to FCC from NTIA, IB Docket No. 01-185 (Nov. 12, 2002; rec'd Feb. 10, 2003).
NTIA Letter	Letter to Julius Genachowski, Chairman, Federal Communications Commission from Lawrence E. Strickling, Assistant Secretary for Communications and Information, U.S. Dep't of Commerce (Feb. 14, 2012).
NTIA Redbook	U.S. Department of Commerce, NTIA, *Manual of Regulations and Procedures for Federal Radio Frequency Management* (2011).
Part 15 Revision Order	*Revision of Part 15 of the Commission's Rules Regarding Ultra-Wideband Transmission Systems*, 18 FCC Rcd 3857 (2003).
Petition for Declaratory Ruling	LightSquared Petition for Declaratory Ruling, IB Docket No. 11-109 (filed Dec. 20, 2011).
Public Notice	*Public Notice*, International Bureau Invites Comment on NTIA Letter Regarding LightSquared Conditional Waiver, IB Docket No. 11-109, DA 12-214 (rel. Feb. 15, 2012).
QUALCOMM Order	*QUALCOMM, Inc.*, 4 FCC Rcd 1543 (1989).
Receiver Standards Petition	*The Development of Rules Establishing Reliability Standards for Commercial Radionavigation-Satellite Service Receivers*, LightSquared Request for Initiation of Proceeding (filed Feb. 7, 2012) (docket number not yet assigned).
Regulatory Inefficiency	C. Bazelon, *Implications of Regulatory Inefficiency for Innovative Wireless Investments* (Mar. 16, 2012).
Section 25.131 Waiver Notice	*Public Notice: National Telecommunications and Information Administration Provides Information Concerning Executive Branch Recommendations for Waiver of Part 25 Rules Concerning Licensing of Receive-Only Earth Stations Operating with Non-U.S. Radionavigation Satellites*, DA 11-498 (Mar. 15, 2011).
SkyTerra Modification Order	*SkyTerra Subsidiary LLC*, 25 FCC Rcd 3043 (2010).
SkyTerra Re-Use Order	*SkyTerra Subsidiary LLC*, 25 FCC Rcd 2022 (2010).
USGIC Reply to Comments	Reply to Comments of U.S. GPS Industry Council, IB Docket No. 01-185 (Sept. 4, 2003).

EXHIBIT 2

FCC NONCONFORMING USE PRECEDENT

Exhibit 2: FCC Nonconforming Use Precedent

LMSS/VMES

- *QUALCOMM, Inc.*, 4 FCC Rcd 1543, at ¶ 11 (1989) (waiving Section 2.106 to permit operation of land mobile terminals to receive transmissions in the 11.7-12.2 GHz band on a non-interference basis to all other services).

- *Fugro-Chance, Inc.*, 10 FCC Rcd 2860 (1995) (waiving Section 2.106 to permit operation of receive-only mobile earth terminals in the 11.7-12.2 GHz band on a non-interference basis).

- *Raysat Antenna Systems*, LLC, 23 FCC Rcd 1985, at ¶ 12 (2008) (waiving Section 2.106 to permit RaySat to receive LMSS transmissions in the 11.7-12.2 GHz FSS band, and providing that Raysat must accept interference from all primary and secondary service allocated to that band).

- *L-3 Communications Titan Corp.*, 24 FCC Rcd 3047, ¶ 10 (2009) (waiving Section 2.106 to permit L-3 to receive LMSS transmissions in the 11.7-12.2 GHz FSS band, and providing that L-3 must accept interference from all primary and secondary service allocated to that band).

ESV

- *Mobile Satellite-Based Communications Services by Crescomm Transmission Services, Inc. and Qualcomm Inc.*, 11 FCC Rcd 10944, at ¶¶ 9-10 (1996) (waiving Section 2.106 to permit Crescomm and Qualcomm to conduct MSS operations in the Ku Band and providing that Crescomm and Qualcomm "must accept interference from any other authorized service in these bands.").

AMSS

- *USA Today Sky Radio*, 7 FCC Rcd 7943, at ¶ 6 (1992) (waiving Section 2.106 to permit Sky Radio to conduct AMSS operations in the 11.7-12.2 GHz band "subject to any interference from services that conform to the allocation table.").

- *The Boeing Company*, 16 FCC Rcd 5864, at ¶¶ 9 an 16 (2001) (waiving Section 2.106 to permit Boeing to conduct AMSS transmit/receive operations in the Ku Band and requiring Boeing "to accept interference from authorized users of the 12 GHz band").

- *ARINC Incorporated*, 20 FCC Rcd 7553, at ¶ 58 (2005) (waiving Section 2.106 to permit ARINC to conduct transmit/receive AMSS operations in the Ku Band, and providing that "ARINC, as a non-conforming user, must accept interference from lawful operation of any station authorized to operate in the 11.7-12.2 GHz band . . . .").

- *ViaSat Inc.*, 22 FCC Rcd 19964, at ¶¶ 26, 28 (2007) (waiving Section 2.106 to permit ViaSat to conduct transmit/receive AMSS operations in the Ku Band and providing that ViaSat "must accept interference from lawful operation of any station in the 11.7-12.2 GHz band in accordance with the U.S. Table of Frequency Allocations . . . .").

- *Row 44, Inc.*, 24 FCC Rcd 10223, at ¶¶ 33, 35 (2009) (waiving Section 2.106 to permit Row 44 to conduct transmit/receive AMSS operations in the Ku Band and providing that Row 44 "licensee must accept interference from lawful operation of any station in the 11.7-12.2 GHz band in accordance with the U.S. Table of Frequency Allocations . . . .").

- *Panasonic Avionics Corp.*, 26 FCC Rcd 12557, at ¶ 11 (2011) (waiving Section 2.106 to permit Panasonic to conduct transmit/receive AMSS operations in the Ku Band and providing that "Panasonic's downlink operations . . . may not claim interference protection from such services.").

FSS in MSS Allocation

- *Motorola Satellite Communications, Inc.*, 11 FCC Rcd 13952, at ¶ 11 (1996) (waiving Section 2.106 to permit FSS transmit/receive terminals to operate in MSS/RDSS bands "with the usual stipulation that the nonconforming service may only be provided on a non-harmful interference basis vis-à-vis any licensed service provided in conformance with the Table of Allocations.").

- *AirTouch Satellite Services US, Inc.*, 14 FCC 17328, at ¶ 22 (1999) (waiving Section 2.106 to permit FSS transmit/receive terminals to operate in MSS/RDSS bands "with the usual stipulation that the nonconforming service may only be provided on a non-harmful interference basis vis-à-vis any licensed service provided in conformance with the Table of Allocations.").

GSO in NGSO Band

- *contactMEO Communications, LLC*, 21 FCC Rcd 4035, at ¶ 34 (2006)(waiving Section 2.106 to permit GSO FSS operations in the 18.8-19.3 GHz band, and requiring contactMEO to accept interference from all primary and secondary operations in this band).

- *Northrop Grumman Space & Mission Systems Corp.*, 24 FCC Rcd 2330, at ¶¶ 76 and 90 (2009) (waiving Section 2.106 to permit: (i) NGSO operations in the 19.7-20.2 GHz band and (ii) GSO operations in the 18.8-19.3 GHz band, subject to the condition that "[a]s a non-conforming user, Northrop Grumman's operations will be on a non-harmful interference basis, and Northrop Grumman will not be protected from interference from other allocated non-Federal and Federal operations" and must "accept interference from all operations with superior status").

- *Hughes Network Systems, LLC*, 26 FCC Rcd 8521, at ¶ 13 (2011) (waiving Section 2.106 to permit GSO operations in the 18.8-19.3 GHz band on an unprotected basis).

NG104

- *EchoStar KuX Corporation*, 20 FCC Rcd 919, at ¶ 13 (2004) (waiving Section 2.106 n.NG104 to permit the provision of domestic services in the 11.45-11.7 GHz Band after EchoStar agreed to accept any level of interference from FS stations into its receive-only earth stations' operations in the extended Ku-band).

- *EchoStar Satellite LLC*, 20 FCC Rcd. 930, at ¶ 13 (2004) (waiving Section 2.106 n.NG104 to permit the provision of domestic services in the 11.45-11.7 GHz Band after EchoStar agreed to accept any level of interference from FS stations into its receive-only earth stations' operations in the extended Ku-band).

- *EchoStar KuX Corporation*, 20 FCC Rcd 942, at ¶ 14 (2004) (waiving Section 2.106 n.NG104 to permit the provision of domestic services in the 11.45-11.7 GHz Band after EchoStar agreed to accept any level of interference from FS stations into its receive-only earth stations' operations in the extended Ku-band).

- *PanAmSat Licensee Corp.*, Order and Authorization, 20 FCC Rcd 14642, at ¶ 10-11 (2005)) (waiving Section 2.106 n.NG104 to permit the provision of domestic services in the 11.45-11.7 GHz Band after PanAmSat agreed to accept any level of interference from FS stations into its receive-only earth stations' operations in the extended Ku-band).

EXHIBIT 3

2002 MSV-GPS JOINT LETTER

ORIGINAL

EX PARTE OR LATE FILED

ORIGINAL

RECEIVED

JUL 17 2002

FEDERAL COMMUNICATIONS COMMISSION
OFFICE OF THE SECRETARY

July 17, 2002

Via Hand Delivery

Ms. Marlene H. Dortch
Secretary
Federal Communications Commission
445 12th Street, S.W.
Washington, D.C. 20554

Re: Ex Parte Notice
IB Docket No. 01-185
File No. SAT-ASG-20010302-00017 et al.

Dear Ms. Dortch:

We are pleased to inform you that the U.S. GPS Industry Council ("Council") and Mobile Satellite Ventures L.P. ("MSV") have agreed on specific out-of-band emission ("OOBE") limits into the entire GPS band for the ancillary terrestrial component ("ATC") base stations and terminals that MSV will deploy in connection with its proposed next-generation Mobile Satellite Service system as described in the attached document. These OOBE limits are intended to protect GPS receivers.

These limits are -100 dBW/MHz for ATC base stations and initially -90 dBW/MHz for terminals operating in an ATC mode. For new terminals, the limit will be tightened to -95 dBW/MHz within five years from the date MSV service commences. This increase in protection is to account for a greater density of users and the need to protect GPS receivers from the aggregation of interference from multiple sources. MSV currently plans that all MSV terminals will include GPS chipsets and process GPS signals.

These OOBE limits are appropriate considering that MSS services, technical characteristics, operational interference scenarios, and expected density are published and understood. MSV's proposed terrestrial augmentations are also well known. Consequently, these OOBE limits developed for the MSV service are unlike the OOBE limits required to address emerging novel communication techniques with 1) poorly documented technical and operational characteristics; 2) ubiquitous deployment in a broad range of electronic devices; and 3) deployment in large-scale, overlapping networks.

MSV and the Council therefore urge the Commission to adopt in the referenced proceedings the OOBE limits set out in the attached document and as described above.

Please direct any questions regarding this matter to the undersigned.

Respectfully submitted,

MOBILE SATELLITE VENTURES L.P.

By: ______________________
Bruce D. Jacobs

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Its Attorneys

THE U.S. GPS INDUSTRY COUNCIL

By: ______________________
Raul R. Rodriguez

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Its Attorneys

cc (w/ attach.; by hand): Thomas Tycz
James Ball
Breck Blalock
Ron Repasi
Trey Hanbury

A More Restrictive Emission Limit in GPS Band Is Appropriate for ATC Operations

- Current MSS emission limit (-70 dBW/MHz) was derived to protect aviation GPS from satellite-based services
  - 100 feet separation, -10 dB GPS antenna gain towards emitter, resulting in 76.1 dB emission attenuation
- There is likely to be a greater density of users operating in the ATC mode than in the satellite mode
- Users operating in the ATC mode are more likely to be in close proximity to terrestrial GPS users
  - Indoor users include FCC mandated E-911 terminals
  - At 2 meters, attenuation is only 42.4 dB
    - -70 dBW/MHz results in interference that is 29 dB above the thermal noise floor

MSV Emission Limits

- For Base Stations
  - Use filtering to achieve -100 dBW/MHz, or lower
  - Achievable with larger envelope filters
- For Terminals
  - Use filtering to achieve -90 dBW/MHz, or lower, in short-term
  - Migrate to -95 dBW/MHz, or lower, for new terminals in 5 years (from the date MSV service is operational)
  - Either limit is still above thermal noise at 2 meters
- All limits are applicable from 1559 MHz to 1605 MHz to protect modern GPS receiver multipath mitigation technology

Agreement
on the Out-of-Band Emissions Limits

Mobile Satellite Ventures L.P.

The U.S. GPS Industry Council

17 July 2002

EXHIBIT 4

2009 SKYTERRA-GPS JOINT LETTER

August 13, 2009

Via Electronic Filing (IBFS)

Ms. Marlene H. Dortch
Secretary
Federal Communications Commission
445 12th Street, S.W.
Washington, DC 20554

Re: Ex Parte Letter
SkyTerra Subsidiary LLC
File Nos. SAT-MOD-20090429-00046, SAT-MOD-20090429-00047, SES-MOD-20090429-00536

Dear Ms. Dortch:

We are pleased to inform you that, in connection with the above-referenced applications of SkyTerra Subsidiary LLC ("SkyTerra") to modify its Ancillary Terrestrial Component authorization (the "ATC Modification Application"), the U.S. GPS Industry Council ("Council") and SkyTerra have agreed on out-of-band emissions ("OOBE") limits for the operation of low-power base stations with a maximum EIRP of -4 dBW/MHz that are intended to be deployed indoors ("femtocells") and personal computer ("PC") data cards communicating with such base stations.[1] Specifically, SkyTerra will limit OOBE for femtocells and data cards communicating with such femtocells to less than -114.7 dBW/MHz and -111.7 dBW/MHz in the 1559-1605 MHz band, respectively. These limits are intended to reduce the potential for harmful interference to GPS receivers operating indoors, thereby addressing the concerns expressed by the Council in its Comments regarding the ATC Modification Application.[2]

SkyTerra and the Council therefore urge the Commission to adopt the OOBE limits set forth in this letter as a license condition to the grant of the ATC Modification Application.

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1 The reference to "PC data cards" is intended to mean RF devices that work in conjunction with a PC or laptop computer, including external PC devices, such as USB modems, Type II PC cards, and ExpressCards, and internal PC devices that provide the same data communications functionality as such external devices. The reference is not intended to include handsets that are capable of voice and data transmissions independent of a PC, even if such device could function as an external PC modem.

2 *See* Comments of the U.S. GPS Industry Council (July 10, 2009). The Council is separately filing a letter withdrawing its Comments, as a result of this agreement.

Please direct any questions regarding this matter to the undersigned.

Respectfully submitted,

SkyTerra Subsidiary LLC	The U.S. GPS Industry Council
By: _________/s/___________	By: _________/s/___________
Bruce D. Jacobs	Raul R. Rodriguez
Pillsbury Winthrop Shaw Pittman LLP 2300 N Street, NW Washington, DC 20037 *Counsel for SkyTerra Subsidiary LLC*	Leventhal Senter PLLC 2000 K Street, NW Washington, DC 20006-1809 *Counsel for the U.S. GPS Industry Council*

cc (via email):

William Bell
Howard Griboff
Kathyrn Medley
Robert Nelson

CERTIFICATE OF SERVICE

I, Renee Williams, a secretary with the law firm of Pillsbury Winthrop Shaw Pittman LLP, hereby certify that on this 13th day of August 2009, I served a true copy of the foregoing by first-class United States mail, postage prepaid, upon the following:

Tom Houtman
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EXHIBIT 5

LIGHTSQUARED PETITION FOR RECONSIDERATION OF DEERE LICENSE RENEWAL

Before the
FEDERAL COMMUNICATIONS COMMISSION
Washington, D.C. 20554

In the Matter of	)	
	)	IBFS File No. SES-RWL-20110908-01047
Application of Deere & Co.	)	
	)	Call Sign E010011
For Renewal of Earth Station License	)	
	)	

PETITION FOR RECONSIDERATION

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October 14, 2011

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PETITION FOR RECONSIDERATION

LightSquared Inc., together with its affiliates (collectively, "LightSquared"), petitions for reconsideration[1] of the L-Band receive-only license renewal application filed by Deere & Company ("Deere") on September 8, 2011, and granted on September 13, 2011, with no public notice of the application prior to grant.[2] As explained herein, renewal was and is inappropriate because: (i) Deere apparently holds no license to renew; (ii) Deere has been improperly attempting to use its L-Band receive-only operations to undermine the implementation of LightSquared's 4G LTE wireless network in the L Band, contrary to the public interest; and (iii) publicly available information calls into serious question whether Deere's operations and representations have been consistent with the terms of its authorization, the Communications Act, and the Commission's rules and policies. Accordingly, Deere's renewal application should be denied on reconsideration, or, at a minimum, renewed with significant limiting conditions.

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1 *See* 47 U.S.C. § 405(a); 47 C.F.R. § 1.106.

2 *See* IBFS File No. SES-RWL-20110908-01047. Because the grant was placed on public notice on September 14, 2011, s*ee* Report No. SES-01380 (Sep. 14, 2011), this petition is timely filed, s*ee* 47 C.F.R. § 1.106(f). Critically, LightSquared had no meaningful opportunity to oppose Deere's license renewal application, which was granted without public notice *five days* after it was filed. The renewal also was issued on the same day that LightSquared was apprised by the Commission that the deployment of its integrated satellite and terrestrial network would be delayed to accommodate the concerns of Deere and other members of the global positioning device industry, *see Status of Testing in Connection with LightSquared's Request for ATC Commercial Operating Authority*, DA 11-1537, (Sep. 13, 2011), exacerbating the consequences of Deere's renewal grant. Accordingly, good cause exists for LightSquared to participate in this proceeding now. *See* 47 C.F.R. § 1.106(b)(1).

I. INTRODUCTION AND SUMMARY

The Commission's rules provide that an earth station renewal application can be granted *only* if the Commission finds that: (i) the applicant is legally, technically, and otherwise qualified; (ii) the proposed facilities and operations comply with all applicable rules, regulations, and policies; and (iii) grant of the application will serve the public interest, convenience and necessity.[3] Implicit in the rules is a fourth requirement: the applicant must hold an existing license that can be renewed.

As an initial matter, it appears that Deere's L-Band receive-only license terminated by operation of law over nine years ago. Accordingly, there is no license for the Commission to renew, and no basis for sustaining the Commission's "renewal" grant. Furthermore, Commission rules preclude Deere from attempting to reinstate, at this late date, a license that became automatically null and void in 2002.[4]

Even if Deere did hold a valid L-Band receive-only license, Deere still would not satisfy the applicable renewal standard for earth stations because, *inter alia*, Deere has been using its L-Band operations in a manner contrary to the public interest, convenience, and necessity. Although Deere's license allowed it to receive Inmarsat mobile-satellite service ("MSS") signals in a mere 2.5 kHz of L-Band spectrum, Deere has attempted to wield that authority as a weapon to foreclose: (i) the implementation of LightSquared's nationwide 4G LTE wireless network in any part of the 66 MHz of L-Band spectrum available for that express purpose; (ii) the delivery of a competitive wireless broadband alternative to hundreds of millions of Americans; and (iii) the delivery of an effective broadband solution to parts of America that have no broadband service today.[5] Stated another way, Deere is impermissibly attempting to leverage a license it once held in a small sliver of spectrum to block the use of a

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3 47 C.F.R. § 25.156(a).

4 *See* 47 C.F.R. § 25.163.

5 *See, e.g.*, Comments of Deere & Company, IB Docket No. 11-109, at 5 (Aug. 1, 2011) (urging the Commission to "focus its efforts on identifying other spectrum" to support LightSquared's broadband operations). Deere seeks to foreclose LightSquared's use of any part of the 1525-1544/1545-1559 MHz downlink band for ATC. The inability to use that downlink band for ATC could effectively foreclose use of the corresponding channels at 1626.5-1645.5/1646.5-1660.5 MHz.

spectrum band that is approximately *twenty-six thousand times as large* and that would be used to advance the goals of the *National Broadband Plan*[6] and otherwise provide significant public interest benefits.

Because Deere's license was sought and granted on a non-interference basis, Deere had and has no legally cognizable expectation that its operations would be protected in any event. And to the extent that Deere is now operating on an unauthorized basis (which appears to be the case, as explained below), Deere clearly has no right to interference protection. Even if Deere asserts the right to operate on an unlicensed basis, Commission precedent is clear that such users are unprotected and have no basis to complain about licensed uses of spectrum, like LightSquared's.[7]

Deere's operations also appear to be inconsistent with its licensed parameters. Specifically, based on evidence reviewed to date, Deere is likely:

(i) Operating outside of the specific frequencies once authorized;

(ii) Operating unauthorized antenna/receiver types;

(iii) Receiving transmissions from unauthorized points of communication;

(iv) Operating more than the 10,000 terminals it was authorized to deploy;

(v) Operating receivers that do not conform to the MSS allocation in the 1525-1559 MHz band, without having first obtained a required waiver of the U.S. Table of Allocations;

(vi) Operating transmit/receive devices that are outside the scope of its authority; and

(vii) Failing to maintain adequate "control" of radiocommunication devices.

This noncompliance would call into question Deere's qualifications to serve as a Commission licensee. At a minimum, the Commission should ask the Enforcement Bureau to conduct a

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6 *See* CONNECTING AMERICA: THE NATIONAL BROADBAND PLAN, at 9, *available at* http://www.broadband.gov/plan/ ("*National Broadband Plan*").

7 *See Regulation of Domestic Receive-Only Satellite Earth Stations*, 74 FCC 2d 205, at ¶ 28 (1979) (unlicensed receive-only earth stations have "no assurances" of interference-free reception, and must forgo the right to file petitions or "other forms of complaint or relief . . . on the basis of experienced or anticipated interference"); 47 C.F.R. § 15.5(b) (unlicensed Part 15 devices must cause "no harmful interference" and accept interference from authorized radio stations and other Part 15 devices).

thorough inquiry into the nature of Deere's activities and its representations to the Commission to determine whether Deere has acted in accordance with the terms of its existing license, the requirements of the Communications Act, and the Commission's rules and policies. Any findings that Deere has not done so would warrant denying the renewal application and potentially imposing other sanctions.

If, after completing such an inquiry, the Commission nevertheless decides to grant renewal, it should do so only with clear and unambiguous conditions requiring Deere to operate on a strict noninterference basis, while satisfying minimum standards to ensure the compatibility of its equipment with other users of the 1525-1559 MHz band.

II. BACKGROUND

LightSquared. LightSquared's predecessors were first authorized in 1989 to provide MSS in the L Band.[8] Since the mid-1990s, the company has operated across North America using the capacity of two satellites—MSAT-1 and MSAT-2. More recently, LightSquared has procured replacements that are some of the most sophisticated commercial communications spacecraft ever built. The first, SkyTerra 1, was placed into service earlier this year. The construction of the second, SkyTerra 2, is substantially complete; the satellite is undergoing testing and otherwise being readied for launch. The advanced design of the new LightSquared satellites enables communication with smartphones that have the same form factor as the wireless devices that consumers use today.

LightSquared's new spacecraft are part of the Commission-authorized integrated satellite and terrestrial network that LightSquared is building to provide broadband to 260 million Americans by the end of 2015. Specifically, a 2004 Commission decision authorizes LightSquared to deploy a complementary terrestrial infrastructure in any part of

8 *Amendment of Parts 2, 22 and 25 of the Commission's Rules to Allocate Spectrum for and to Establish Other Rules and Policies Pertaining to the Use of Radio Frequencies in a Land Mobile Satellite Service*, 4 FCC Rcd 6041 (1989); *remanded by Aeronautical Radio, Inc. v. FCC*, 928 F.2d 428 (D.C. Cir. 1991); *on remand*, 7 FCC Rcd 266 (1992); *aff'd, Aeronautical Radio, Inc. v. FCC*, 983 F.2d 275 (D.C. Cir. 1993); *see also AMSC Subsidiary Corporation*, 8 FCC Rcd 4040 (1993).

the 66 MHz of the L Band where its satellites may operate.[9] LightSquared has made significant strides in constructing this terrestrial network, which, coupled with its satellite network, will enable the provision of seamless broadband connectivity across the United States. The deployment of this ancillary terrestrial component ("ATC") network has been fully coordinated with Inmarsat, which is Deere's satellite service provider.

Thus, LightSquared's 4G LTE network promises to be a competitive alternative to the wireless networks of companies like AT&T and Verizon, and will continue the long tradition of LightSquared and its predecessors as a positive competitive force in the MSS industry.[10] LightSquared's network also will advance the Commission's goals in the areas of access, spectrum efficiency, and public safety. At present, however, LightSquared is not able to actually commence operating the terrestrial component of this 4G LTE network because of the objections of companies such as Deere.

Deere License. In 2001, Deere sought and the Commission granted a receive-only license to permit Deere to receive "differential correction data" from Inmarsat MSS satellites in a small, discrete portion of the L Band.[11] In its license application, Deere expressly represented: "*Deere accepts license condition [sic] that its receivers accept interference.*"[12] This statement was not qualified in any way, and has never been altered through a subsequent license modification. Deere's original license grant limited its receive-only operations to one narrow 2.5 kHz channel in one polarization centered at one specific frequency—authorizing Deere to use the equivalent of about 1/26,000th of the L Band.[13] In

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9 *See Mobile Satellite Ventures Subsidiary LLC*, 19 FCC Rcd 22144, at ¶¶ 18-26 (2004).

10 *See, e.g.*, *FCC Report to Congress as Required by the ORBIT Act*, Eighth Annual Report, 22 FCC Rcd 11347 (2007) (noting that LightSquared's predecessor-in-interest, MSV, contributes to "substantial competition" in the MSS industry).

11 *See* IBFS File No. SES-LIC-20010112-00051, Application, at Att. B.

12 *See* IBFS File No. SES-LIC-20010112-00051, Application, at Att. A n.1 (emphasis added).

13 Deere's "license" subsequently was modified to include an additional channel—after the date on which it would have terminated automatically by operation of law. *See* IBFS File No. SES-MFS-20071107-01535 (granted Mar. 27, 2008); *see also infra* Section III.

addition, Deere's license was conditioned on its compliance with the *Comsat Order*,[14] which specifically imposed a noninterference condition on Deere's operations.[15] As explained herein, it is unclear whether Deere's actual operations are consistent with the terms of this license, which appears to have terminated automatically in 2002 in any event.

Deere Statements. In recent months, Deere has made numerous public statements asserting (wrongly) that: (i) it is entitled to interference protection throughout the 1525-1559 MHz downlink portion of the L Band; and (ii) the Commission must curtail the deployment of LightSquared's 4G LTE network—contrary to the objectives set forth in the *National Broadband Plan*—in order to protect Deere's receive-only operations. For example:

- In Reply Comments filed in mid-August, Deere asserted that "[r]eceivers that are intentionally designed to downlink signals across the full range of space-to-earth L-Band frequencies"—*i.e.*, the 1525-1559 MHz band—"including Deere's StarFire system, are . . . entitled to interference protection from all other L-Band spectrum users, including LightSquared's proposed terrestrial network."[16]

- In Comments filed in early August, Deere suggested that the Commission must protect Deere's receive-only operations in the 1525-1559 MHz band and should "focus its efforts on identifying other spectrum" to support LightSquared's broadband operations.[17]

- In a recent *ex parte* presentation, Deere asserted that "StarFire frequencies can be assigned anywhere in [the 1525-1559 MHz] band," and suggested that the Commission should prevent "harmful interference" into these operations.[18]

- Deere has asserted that "[s]upport of all these signals requires the antenna and first-stage amplifier/filters of [Deere's] high-precision receivers to be responsive to frequencies between 1525 MHz and 1610 MHz. In addition,

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14 *Comsat Mobile Communications*, 16 FCC Rcd 21661 (2001) ("*Comsat Order*").

15 *See* IBFS File No. SES-LIC-20010112-00051, License, at Section H.a., Condition 5830.

16 *See* Reply Comments of Deere & Company, IB Docket No. 11-109, at 23 (Aug. 15, 2011).

17 *See* Comments of Deere & Company, IB Docket No. 11-109, at 5 (Aug. 1, 2011).

18 *See* Letter from Counsel for Deere & Company, to Secretary, FCC, IB Docket No. 11-109, Att. at 3, 19 (Aug. 22, 2011) (page 19 of which is attached as Exhibit A hereto).

> at least 10% (9 MHz) additional margin must be provided at each end of the pass band to accommodate manufacturing process variability."[19]

As explained below, these statements are fundamentally inconsistent with the nature and scope of Deere's *actual* rights to operate in the 1525-1559 MHz band.

III. COMMISSION RECORDS REFLECT THAT DEERE'S LICENSE TERMINATED AUTOMATICALLY IN 2002, LEAVING NO AUTHORITY TO RENEW

Deere's L-Band receive-only license was granted initially in 2001. Under the then-applicable version of Section 25.133 of the Commission's rules, and the terms of Deere's license, Deere was required to bring its facilities into use within 12 months of the date of grant (*i.e.*, by October 9, 2002).[20] Under Section 25.161(a) of the Commission's rules as it existed in 2001 (and until late 2003), Deere's license was subject *to automatic termination without further notice* upon the "expiration of the required date of completion of construction or other required action specified in the authorization . . . *if a certification of completion of the required action has not been filed with the Commission* . . . ."[21] Notably, Deere's license also included conditions providing for such automatic termination.[22]

In preparing this petition, LightSquared, through counsel, conducted a thorough review of the Commission's electronic databases and the Commission's Public Reference Room regarding Call Sign E010011, and made informal inquiries of Commission staff. LightSquared has found no evidence that Deere filed the requisite certificate of completion.

Unless Deere submitted its certificate of completion in a timely fashion, Deere's license *automatically became null and void on October 9, 2002*, pursuant to Section

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19 Petition for Reconsideration of Deere & Company, SAT-MOD-20101118-00239, Exh. B, at 1 (Feb. 25, 2011).

20 *See* 47 C.F.R. § 25.133(a) (2001).

21 *See* 47 C.F.R. § 25.161(a) (2002) (emphasis added).

22 *See* IBFS File No. SES-LIC-20010112-00051, License, at Section A; Section H.a, Conditions 5018 & 5779; Section H.b. (requiring Deere to file a certificate of completion, and providing for automatic license termination if facilities are not operational, by October 9, 2002).

25.161(a) (as in effect at the time).[23] Thus, any use by Deere of the L Band to receive communications from Inmarsat spacecraft since then would have been unauthorized. Moreover, Deere should not have submitted a renewal application, and the Commission should not have granted a renewal, as Deere held no continuing authority for the Commission to renew.[24]

IV. RENEWAL WAS AND IS CONTRARY TO THE PUBLIC INTEREST

Even if Deere did hold a valid L-Band receive-only license, Deere did not satisfy the applicable renewal standard for earth stations. Therefore, the renewal application should be denied on reconsideration.

A. LightSquared's Next-Generation 4G LTE Wireless Network Will Deliver Significant Public Interest Benefits

As the *National Broadband Plan* recognizes, "[m]obile broadband is the next great challenge and opportunity for the United States. It is a nascent market in which the United States should lead."[25] In order to realize the numerous public interest benefits of mobile broadband services, the *Plan* recommends that the Commission make additional spectrum available for mobile broadband use,[26] and specifically urges the acceleration of the terrestrial deployment in MSS spectrum, including in the L Band.[27] By granting additional flexibility to conduct terrestrial operations using L-Band spectrum, the Commission advanced this goal, making more than 60 MHz of additional spectrum readily available for mobile broadband applications.

LightSquared's business model will ensure that the benefits of this decision are realized by consumers throughout the United States. LightSquared is implementing the

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23 *See, e.g.*, *PanAmSat Licensee Corp.*, 16 FCC Rcd 11534, at ¶¶ 10-11 (2001).

24 Section 25.163 of the Commission's rules precludes the reinstatement of Deere's license nine years later. *See* 47 C.F.R. § 25.163(a) (petitions for reinstatement of authorizations terminated under Section 25.161 must: (i) be filed within 30 days of termination; (ii) explain the failure to submit the required filing in a timely manner; and (iii) detail the procedures established to ensure timely filings in the future).

25 *See National Broadband Plan*, at 9.

26 *Id.* at 10.

27 *Id.* at 87-88.

world's first wholesale-only integrated wireless broadband and satellite network, capable of providing connectivity throughout the United States. This network will provide a tremendous benefit to rural America, which has been routinely underserved by advanced technology, and will promote economic development. Because the network integrates satellite and ground-based wireless coverage, LightSquared will provide uninterrupted service even during power outages and other emergencies—a major benefit to first responders and public safety agencies.

LightSquared plans to invest $14 billion in network infrastructure, deployment, and operations over the next eight years. LightSquared's investment will create economic opportunities and job growth. In fact, LightSquared's system will support 15,000 jobs over the course of its five-year buildout.

LightSquared's innovative network also will strengthen and invigorate competition in the wireless broadband industry. Among other things, LightSquared's unique wholesale model will allow new wireless operators to provide services that otherwise might not have been possible. LightSquared will provide wholesale services using an open architecture that is intended to offer access to an affordable nationwide 4G LTE network for wireless operators that otherwise would not be in a position to offer competitively-priced and nationally-available mobile broadband service to their own retail customers. This will facilitate the ability of these operators to compete against Verizon, AT&T, and T-Mobile. In addition, LightSquared's deployment will increase the amount of valuable wireless spectrum in the market, place downward pressure on the cost of wireless capacity, and improve quality of service and lower prices for consumers.

These are but a few of the many public interest benefits that will flow from the significant investment LightSquared is making to provide for more intensive use of the L Band and further the other goals of the *National Broadband Plan*.[28]

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[28] *See also LightSquared Subsidiary LLC*, 26 FCC Rcd 566, at ¶¶ 29-35 (2011) (noting numerous public interest benefits stemming from LightSquared's 4G LTE wireless network).

B. Deere Is Leveraging Its Expired License in Order To Undermine LightSquared's 4G Network, and Broader Commission Policy

As noted above, in recent months Deere has made numerous public statements asserting that the Commission should curtail the deployment of LightSquared's terrestrial broadband network in the L Band in order to preserve Deere's ability to manufacture, market and operate receivers across the entire 1525-1559 MHz downlink portion of this band (even though Deere held a license to operate in only a very small segment of this band). In other words, Deere has made clear its plans to use any authority granted through renewal as part of an effort to foreclose LightSquared from implementing its nationwide 4G LTE wireless network. On this basis alone, the Commission should deny Deere's renewal application on reconsideration.

It bears emphasis that Deere's statements reflect a fundamental misunderstanding of the nature and scope of the rights Deere once held under its L-Band receive-only license—a misunderstanding that would be perpetuated if the renewal grant is allowed to stand as is. Moreover, Deere's assertions are inconsistent with Commission policy that end users of a satellite operator's service may not leverage that derivative right in order to prevent the satellite operator from coordinating use of the radio spectrum in the way it deems most appropriate. And they also are inconsistent with Commission policy that users of a small sliver of spectrum should not be allowed to use their authorizations to block others from deploying service to the public in a much larger spectrum band.[29]

As discussed in greater detail below: (i) Deere's license compelled it to operate on a non-interference basis and limited those operations to one narrow 2.5 kHz channel in one polarization; (ii) Deere was and is required to operate in a manner consistent with the existing coordination agreement between MSS operators in the L Band, which provides the basis on which LightSquared is building its 4G LTE wireless network in the L Band; and (iii) even if Deere's license were valid, Deere would have lost any interference protection it may have once enjoyed by operating at variance with its license. More broadly,

[29] *Cf. FWCC Request for Declaratory Ruling*, 16 FCC Rcd 11511, at ¶ 17 (2001) (limiting spectrum available for blanket-licensed CSATs in order to avoid affecting the ability of terrestrial services to use spectrum for advanced telecommunications).

Deere's apparently unauthorized operations provide an independent basis for denying its renewal application, and therefore should be investigated thoroughly by the Commission. (*See* Section V*, infra*).

1. Deere's License Always Was Subject to a Non-Interference Condition

As an initial matter, Deere's operations always were to be conducted on a non-interference basis because: (i) that is the basis upon which Deere sought authority, and (ii) that is the basis on which Deere's operations were licensed. As noted above, Deere's initial license application included an explicit representation that "Deere accepts license condition [sic] that its receivers accept interference."[30] This representation was not qualified in any way, and has never been altered through a subsequent license modification. Deere's license necessarily was limited by the scope of the authority sought in its application.[31] Thus, even in the absence of any explicit licensing condition, Deere was bound to operate on a non-interference basis.[32] Moreover, Deere was limited to operating on one narrow 2.5 kHz channel in one polarization in the 1525-1559 MHz downlink segment of the L Band; while Deere subsequently modified its license to add an additional 2.5 kHz channel in the same polarization,[33] Deere's license apparently had terminated by operation of law by this point, for the reasons provided above.

2. Deere's Use of the L Band Is Derivative of the Rights of Its L-Band MSS Space Segment Provider Following Coordination

As an end-user of an L-Band MSS satellite system, Deere's rights to operate in the L Band are derivative of the rights of the satellite network from which it receives service.

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30 *See* IBFS File No. SES-LIC-20010112-00051, Application, at Att. A n.1.

31 *Cf. Graphnet Systems, Inc.*, 67 FCC 2d 1043, at ¶ 6 (1978) (authority limited to that sought in application).

32 This is consistent with the manuals for Deere's receivers, which assert that they are Part 15 devices that must be operated on a non-interference basis. *See, e.g.*, *See* StarFire RTK 900 and 450 MHz Radios Operator Manual, *available at* http://manuals.deere.com/omview/OMPFP10776_19/?tM= (last visited Oct. 13, 2011) ("These devices comply with Part 15 of the FCC Rules.").

33 *See* IBFS File No. SES-MFS-20071107-01535 (granted Mar. 27, 2008).

Deere can have no greater rights than the rights of its satellite service provider, which is Inmarsat. Inmarsat, in turn, is required to coordinate its MSS system with other MSS operators, such as LightSquared.[34] Most recently, that coordination was effectuated in a 2007 agreement with LightSquared's predecessor which (i) resolved an eight-year-old coordination deadlock that previously existed, and (ii) after ratification of the United States, Canadian, and United Kingdom Administrations, facilitated the resolution of dozens of controversies before the Commission over the previously uncoordinated use of the L Band by end users like Deere itself.[35]

A multinational agreement entered into in 1996 provided for the L Band to be shared among satellite networks, including those operated by Inmarsat and LightSquared, through a spectrum sharing arrangement providing for each operator to use distinct band segments while serving the same geographic area (but providing for spectrum reuse across different geographic areas), and while ensuring that adjacent spectrum uses remain compatible with each other.[36] A few years later, however, difficulties in the annual review of that arrangement led to a deadlock among the affected satellite operators, leaving great uncertainty about the services that could be provided in the L Band—whether by new, state-of-the-art spacecraft, or by complementary ATC facilities. In December 2007, Inmarsat and LightSquared entered into a comprehensive international coordination agreement with respect to their current and future satellite networks, as well as with respect to any ATC that either party might deploy. Among other things, and consistent with the encouragement of the Commission,[37] that coordination agreement also allows for the deployment of an ATC network at different parameters than the "default" ATC rules. Thus, operations by one party

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34 *See generally SatCom Systems, Inc. and TMI Communications and Company, L.P.*, 14 FCC Rcd 20798, at ¶ 8 (1999).

35 *See Press Release: SkyTerra, Mobile Satellite Ventures and Inmarsat Sign Spectrum Coordination and Cooperation Agreement* (Dec. 21, 2007), *available at* http://www.skyterra.com/media/press-releases-view.cfm?id=158&yr=2007.

36 *See International Action: FCC Hails Historic Agreement on International Satellite Coordination*, News Release, Report No. IN 96-16 (Jun. 25, 1996).

37 *Flexibility for Delivery of Communications by Mobile Satellite Service Providers in the 2 GHz Band, the L-Band, and the 1.6/2.4 GHz Bands*, 20 FCC Rcd 4616, at ¶¶ 43-47 (2005).

to that agreement that are consistent with that coordination agreement cannot be deemed to constitute "harmful interference" into the network of the other party. The ATC deployment that LightSquared has planned and is authorized to deploy is fully consistent with that agreement with Inmarsat.

In summary, then, Deere's operations are subject to the terms of the existing coordination agreement between LightSquared and Inmarsat, as MSS system operators in the L Band. Conceptually, this coordination agreement is no different than the coordination agreements in the fixed-satellite service ("FSS") industry that separated potentially "incompatible" single carrier per channel ("SCPC") VSAT traffic from higher-powered analog video traffic—agreements on which the Commission relied for decades. Longstanding precedent makes clear that the Commission: (i) relies on this coordination process to facilitate efficient use of the limited spectrum resource; (ii) allows satellite operators to make a variety of tradeoffs—including tradeoffs based on business considerations—in the course of coordination; and (iii) relies on satellite operators and their customers to honor those agreements.[38] Therefore, an earth station operator has no basis upon which to claim the existence of "harmful interference" from any operations that are consistent with the terms of a coordination agreement to which its space segment provider is bound. For this reason, the Commission routinely has required earth station licensees in the L Band to operate subject to the results of coordination, and on a non-interference basis in the absence of a coordination agreement.[39] Deere has been subject to these very conditions.

When the Commission established its rules for L-Band ATC operations, it anticipated that MSS operators would enter into arrangements like the LightSquared-Inmarsat coordination agreement to facilitate the "efficient and intensive use" of the L Band and "bring

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38 *See, e.g.*, *Satellite Network Earth Stations*, 20 FCC Rcd 5666, at ¶ 51 (2005); *Fixed-Satellite Service (Reconsideration of 1988 Orbital Assignment Plan)*, 5 FCC Rcd 179, at ¶ 32 (1990); *Orion Satellite Corp.*, 5 FCC Rcd 4937, at ¶ 14 (1990); *GE American Communications*, 3 FCC Rcd 6871, at ¶ 2 (1988).

39 *See, e.g.*, *Comsat Order* ¶ 115(d).

more options for high-quality communications at reasonable cost to all Americans."[40] Thus, while the Commission established certain "default" technical rules, the Commission expressly encouraged and empowered L-Band MSS satellite operators to negotiate and agree to less restrictive L-Band ATC operational limits in order to promote more efficient use of the spectrum.[41] Two years later, when the Commission modified its ATC rules on reconsideration, it made clear that satellite coordination agreements would *automatically supersede* the default limits specified in its rules.[42] By way of example, Section 25.253(a)(2) provides that "[a]ny future coordination agreement between the [MSS operators] governing ATC operation will supersede" the "default" in-band and out-of-band emissions limitations specified in the rule.[43]

Thus, the Commission clearly intended that such negotiated coordination agreements could be used to define the rights of MSS operators vis-à-vis each other as well as the derivative rights of their respective customers (in this case, Deere). Allowing a single receive-only operator, such as Deere, to "veto" such an arrangement would undermine the value of such agreements, and moreover would be inconsistent with the framework set forth in the ITU Radio Regulations.

The Commission already has concluded as much in its 2010 *SkyTerra Order*, which rejected claims that L-Band earth station licensees (such as Deere) are entitled to protection from "overload" above and beyond that provided under the LightSquared-Inmarsat coordination agreement. In the underlying pleadings, Amtech and Skywave made precisely

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40 *Flexibility for Delivery of Communications by Mobile Satellite Service Providers in the 2 GHz Band, the L-Band, and the 1.6/2.4 GHz Bands*, 20 FCC Rcd 4616, at ¶¶ 43-47, 95 (2005) ("*Second ATC Reconsideration Order*").

41 *Flexibility for Delivery of Communications by Mobile Satellite Service Providers in the 2 GHz Band, the L-Band, and the 1.6/2.4 GHz Bands,* 18 FCC Rcd 1962, at ¶ 143 (2003).

42 *Second ATC Reconsideration Order* ¶¶ 43-47.

43 47 C.F.R. § 25.253(a).

those arguments now being advanced by Deere at the Commission.[44] In rejecting these arguments, the Commission noted that "[r]eliance on satellite-operator coordination agreements is an important aspect of a longstanding Commission policy of reliance on marketplace mechanisms to develop solutions to interference concerns, and of refraining from interfering unnecessarily with licensees' business negotiations,"[45] and that such agreements "serve[] the public interest by promoting overall spectrum efficiency and facilitating provision of valuable new services . . . ."[46]

Critically, the Commission acknowledged that giving effect to such agreements could "present challenges to earth station operators using the satellites involved, and *may require modification of operations, deployment of new equipment, or other adjustments*."[47] The Commission found that giving effect to such agreements would serve the public interest notwithstanding these challenges, and that "it would not serve the public interest for the Commission to assume the role of an arbiter of disputes between a satellite operator and its customers . . . ."[48] The Commission should reach the same result here as in the *SkyTerra Order*, and make clear that Deere has no greater rights in the L Band than the right Inmarsat has to provide Deere service under the LightSquared-Inmarsat coordination agreement.

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44 *See* Petition to Deny of Amtech Systems, LLC, IBFS File Nos. SAT-MOD-20090429-00047, SAT-MOD-20090429-00046, SES-MOD-20090429-00536 (filed Jul. 10, 2009); Comments of SkyWave Mobile Communications, Corp., IBFS File Nos. SAT-MOD-20090429-00047, SAT-MOD-20090429-00046, SES-MOD-20090429-00536 (filed Jul. 10, 2009).

45 *SkyTerra Subsidiary LLC*, DA 10-534, at ¶ 29 (Mar. 26, 2010) ("*SkyTerra Order*"); *see also Principles for Promoting Efficient Use of Spectrum by Encouraging the Development of Secondary Markets*, 15 FCC Rcd 24178, at ¶ 8 (2000) ("[I]n general, the best way to realize the maximum benefits from the spectrum is to permit and promote the operation of market forces in determining how spectrum is used").

46 *SkyTerra Order* ¶ 30.

47 *Id*. (emphasis added).

48 *Id.*

3. Even if Deere Still Held a License, Deere's Right to Interference Protection Would Have Terminated By Virtue of Its Apparently Unauthorized Operations

As discussed in greater detail in Section V below, publicly available information strongly suggests that Deere's operations in the 1525-1559 MHz band have been at variance with the terms of its receive-only license—both prior to and following automatic termination of that license in 2002.[49] To the extent this in fact is the case, any remaining interference protection would have terminated automatically by operation of law.

Specifically, Section 25.162 of the Commission's rules provides that the interference protection otherwise enjoyed by a receive-only earth station "*shall be automatically terminated*" where the Commission finds that the actual use of the facility is inconsistent with the Communications Act, the Commission's rules or policies, or the terms and conditions of the underlying authorization.[50] The Commission has explained that Section 25.162 "provide[s] for eliminating protection from interference in cases where a *licensee*" does not utilize its receive-only earth station in the expected manner.[51] Section 25.162 reflects the Commission's policy determination that parties that fail to comply with applicable regulations or license terms should not be rewarded through the perpetuation of

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49 Namely: (i) Deere may be operating outside of the specific frequencies once authorized; (ii) Deere may be operating unauthorized antenna/receiver types; (iii) Deere may be receiving transmissions from unauthorized points of communication; (iv) Deere may be operating more than the 10,000 terminals it was authorized to deploy; (v) Deere may be operating receivers that do not conform to the MSS allocation in the 1525-1559 MHz band, without having first obtained a required waiver of the U.S. Table of Allocations; (vi) Deere may be operating transmit/receive devices that are outside the scope of its authority; and (vii) Deere may have failed to maintain adequate "control" of radiocommunication devices.

50 *See* 47 C.F.R. § 25.162 (emphasis added).

51 *See Satellite Network Earth Stations*, 20 FCC Rcd 5666, at ¶ 115 (2005) (emphasis added); *Maritime Telecommunications Network, Inc.*, 16 FCC Rcd 11615, at ¶ 32 (2001). This is consistent with the fact that Deere would be an earth station registrant but for the fact that it is communicating with non-U.S.-licensed, L-Band Inmarsat spacecraft. *See* 47 C.F.R. § 25.131(j). *See also Earth Station Application Procedures*, 6 FCC Rcd 2806, at ¶ 7 (1991) ("[W]e emphasize that a registration program will afford the *same protection from interference* as would a license issued under our former procedure.") (emphasis added).

their rights to interference protection (*e.g.*, through license renewal)—to the extent that those rights otherwise would exist.

V. THE COMMISSION SHOULD ADDRESS CRITICAL QUESTIONS WITH RESPECT TO DEERE'S UNAUTHORIZED OPERATIONS

Even if the Commission were to determine that Deere's license did *not* terminate automatically in 2002, significant outstanding questions would remain about whether Deere's operations have been consistent with the terms of that license. As explained below, it appears that they have not been. The Commission should conduct a thorough inquiry of these matters to determine whether Deere has in fact operated outside of the terms of its authorization, the Communications Act, and Commission rules and policies.

A. Deere's Actual Operations Appear Inconsistent with the Operating Authority Granted by the Commission

Because Deere's equipment communicates with non-U.S.-licensed spacecraft, Deere must obtain a Commission license prior to commencing operations with any given receiver.[52] Based on publicly available information—including information provided by Deere itself—it appears that Deere has not obtained or maintained sufficient authority to cover its actual operations. Because Deere did not disclose these changes in its renewal application, it also appears that Deere may have certified falsely in that application that the information on file with the Commission at the time remained accurate and truthful without exception.[53] Such behavior calls into question whether Deere is qualified to serve as a Commission licensee. More specifically:

Deere may be operating outside of its authorized frequencies. Deere is *not* licensed to operate throughout the 1525-1559 MHz band, and thus *cannot* operate—and certainly cannot claim interference protection—throughout that band.[54] Rather, Deere has

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52 47 C.F.R. § 25.131(j).

53 *See* FCC Form 312-R, Question 8.

54 The Part 25 earth station registration mechanism is not available for Deere receivers, which communicate with non-U.S.-licensed, non-Permitted List Inmarsat spacecraft in the L Band. *See* 47 C.F.R. § 25.131(j). The Permitted List applies only to standard C- and Ku- and certain Ka-band spacecraft, such that Inmarsat's L-Band spacecraft are categorically excluded.

been licensed to conduct receive operations in, at most, two narrow 2.5 kHz channels, centered at 1545.5440 MHz and 1535.1525 MHz under its last license modification. Nevertheless, Deere asserts that it is entitled to interference protection "across the full range of space-to-earth L-Band frequencies"—*i.e.*, throughout the entire 1525-1559 MHz band.[55] In addition, Deere's recent *ex parte* presentations indicate that Deere is operating in at least *three* channels (and perhaps six)—including at least one channel that does not correspond to frequencies listed on Deere's license.[56] Exhibit A contains an excerpt from one such presentation, depicting what Deere calls its "[c]urrent assignments" at 1535, 1537, and 1545 MHz.[57] There is no indication that Deere ever was licensed at 1537 MHz.

Deere may be operating unauthorized antenna/receiver types. An applicant for an earth station license must specify, with precision, the antenna model(s) to be covered by the requested authorization. Deere's license specified only a single device—the John Deere Model PF80385, which appears to be an early-generation StarFire receiver. Consistent with that application, Deere's license authorized Deere to operate only a single receiver type—the John Deere Model PF80385. Yet, Deere's website indicates that it is manufacturing and marketing for use in the United States a number of additional receiver configurations. These include: (i) the StarFire 3000 Receiver; (ii) the StarFire 300 Receiver; (iii) a number of StarFire ITC Receivers; and (iv) a number of integrated combinations of StarFire receivers and RTK radios. As shown on Exhibit B, these other devices appear physically different than the John Deere Model PF80385, and may be different from an electromagnetic perspective as well—an issue that warrants examination.

Deere may have deployed equipment intended for the reception of communications from foreign radio stations. Under the Commission's rules, an earth station may receive communications from a foreign spacecraft only if it is specifically

55 *See* Reply Comments of Deere & Company, IB Docket No. 11-109, at 23 (Aug. 15, 2011).

56 *See* Letter from Counsel for Deere & Company, to Secretary, FCC, IB Docket No. 11-109, Att. at 19 (Aug. 22, 2011) (page 19 of which is attached as Exhibit A hereto).

57 *Id.*

authorized to do so in the relevant license.[58] The only non-U.S. spacecraft with which Deere was authorized to communicate under the terms of its license were Inmarsat spacecraft. The Commission has been clear that its rules require Deere to obtain a license prior to receiving signals from other foreign spacecraft: "The Federal Communications Commission's (FCC) rules require licensing of non-Federal receive-only equipment operating with foreign satellite systems, including receive-only earth stations operating with non-U.S. licensed radionavigation-satellite service (RNSS) satellites."[59] Contrary to this express requirement, it appears that Deere's newest receivers—and potentially older receivers with wideband "listening" capabilities—are capable of receiving, and are used to receive, transmissions from the GLONASS RNSS system, which is operated under authority of Russia. For example, Deere's product brochures note that the StarFire 3000 receiver offers "increased satellite availability through GLONASS, the Russian satellite constellation," beginning in 2011.[60] The website of NavCom—the Deere subsidiary that manufactures StarFire devices—confirms as much and notes that "[i]n 2011, NavCom launched StarFire™ GNSS, which supports GPS + GLONASS corrections and also provides improved real-time accuracy of five centimeters."[61] The website of a North Carolina-based provider of GPS-based farming equipment suggests that Deere receivers used in the United States are in fact receiving GLONASS signals.[62]

Deere may have deployed more than 10,000 StarFire terminals. Deere's license permitted it to operate no more than 10,000 John Deere Model PF80385 terminals. A

58 *See* 47 C.F.R. § 25.131(j). This rule also allows communication with certain foreign-licensed C, Ku, or Ka band spacecraft that are on the Commission's "Permitted List" (which does not apply to the L Band).

59 *NTIA Provides Information Concerning Executive Branch Recommendations for Waiver of Part 25 Rules Concerning Licensing of Receive-Only Earth Stations Operating with Non-U.S. Radionavigation Satellites*, DA 11-498 (rel. Mar. 15, 2011).

60 *See* John Deere, GreenStar Product Brochure at 8, *available at* http://www.deere.com/en_US/docs/zmags/agriculture/online_brochures/greenstar/static/greenstar_zmags.html (last visited Oct. 6, 2011).

61 *See* StarFire Product Description, *at* http://www.navcomtech.com/StarFire/ (last visited Oct. 6, 2011) ("History" tab).

62 *See* http://vauseequipment.com/vause%E2%80%99s-news.aspx (last visited Oct. 10, 2011).

2007 NavCom white paper explains that far many more have been deployed so far: "[t]here are more than 40,000 StarFire receivers deployed worldwide for use in an increasingly diverse set of applications."[63] Because Deere's net sales revenues for the U.S. and Canada historically have been 2-3 times those for the rest of the world combined,[64] it is reasonable to expect that more than 10,000 StarFire receivers have been deployed in the United States.

Deere may have deployed nonconforming fixed-satellite service devices without requisite authority. The United States Table of Allocations contains a primary allocation for MSS in the 1525-1559 MHz band.[65] MSS is defined as a "radiocommunication service: (1) Between mobile earth stations and one or more space stations, or between space stations used by this service; or (2) Between mobile earth stations by means of one or more space stations."[66] "Mobile earth station," in turn, is defined as: "An earth station in the mobile-satellite service intended to be used while in motion or during halts at unspecified points."[67]

It appears that Deere is marketing a number of integrated combinations of StarFire receivers and RTK radios that can operate as fixed (or temporary-fixed) earth stations that receive a StarFire signal (either through an "RTK" receiver or another StarFire receiver type incorporated into the unit), and use that signal to produce localized GPS correction factors. Notably, the product manual for the StarFire iTC and RTK configuration (an excerpt from which is attached as Exhibit C) provides guidance for users wishing to permanently attach StarFire receivers to barns, towers, and other fixed structures.[68] If so,

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63 *See* Kevin Dixon, *StarFire: A Global SBAS for Sub-Decimeter Precise Point Positioning*, at 7, *available at* http://www.navcomtech.com/Support/DownloadCenter.cfm?category=whitepapers (Jan. 2007).

64 *See* Deere & Company, *Historical Income Statement*, *available at* http://www.deere.com/en_US/docs/Corporate/investor_relations/pdf/factbook/historical.pdf (Dec. 22, 2010).

65 47 C.F.R. § 2.106.

66 47 C.F.R. § 2.1(c). Under the United States Table of Allocations (US380), this includes ATC operations. 47 C.F.R. § 2.106 n.US380.

67 47 C.F.R. § 2.1(c).

68 *See* StarFire and RTK Operator's Manual (2009), *available at* http://stellarsupport.deere.com/en_US/support/pdf/om/en/OMPC21514_StafireiTC_RTK.pdf.

when communicating with spacecraft, these terminals actually are operating in the FSS, and not the MSS—and thus represent a nonconforming use of the 1525-1559 MHz band. Such operations would require a waiver of the United States Table of Allocations, which Deere has neither sought nor obtained, and would not be entitled to interference protection.[69]

Deere may have deployed transmit-receive facilities. At most, Deere's Part 25 receive-only license once authorized Deere to conduct its StarFire service through receive-only terminals. Yet, it appears that Deere is marketing "RTK" implementations that receive the StarFire signal, use that signal to produce localized GPS correction factors, and then *transmit* this information to nearby mobile terminals using frequencies in the 450 or 900 MHz bands. In other words, at least some implementations of the Deere StarFire RTK radio operate effectively as two-way devices that take a communication link *from* Inmarsat (and apparently foreign RNSS) spacecraft and retransmit that communication *to* StarFire mobile receivers. These StarFire RTK implementations thus are more than "receive-only" earth stations, and do not fall squarely within the terms of Deere's prior authority. None of this was disclosed in Deere's 2001 receive-only application, nor was it disclosed in the subsequent modification applications or Deere's 2011 renewal application. This provides yet another reason to conclude that Deere is operating in the L Band at variance from the Part 25, receive-only license it once held.

Deere may not be exercising appropriate "control" over the StarFire receivers it has deployed. Section 25.119 of the Commission's rules provides that prior approval is required for any transfer of control of a Commission licensee.[70] Accordingly, Deere is required to exercise "control" over each of the StarFire terminals that it operates. Moreover, Deere's "blanket" authority was premised on Deere's ability to ensure that its receivers are technically identical to each other, which assumes that Deere can exert sufficient "control" to prevent an end user from modifying a StarFire terminal or using it in a way that does not conform to Deere's authority.

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69 *See, e.g.*, *QUALCOMM, Inc.*, Memorandum Opinion, Order and Authorization, 4 FCC Rcd 1543, at ¶ 11 (1989); *see also id.* ¶ 8 n.14 ("Operations from a fixed earth station to a satellite constitute a fixed-satellite service.").

70 47 C.F.R. § 25.119.

However, the manual for the StarFire RTK 450 Radio allocates these responsibilities to Deere's customers. Namely, Deere requires that each end user of that radio must obtain an individual license from the Commission in order to transmit with that radio in the 450 MHz band.[71] The terms of such a license necessarily require the *end user* to exercise "control" over the device.[72] There is no indication in the Commission's electronic databases that applications seeking authority for any such transfers with respect to Deere's L Band license have been filed. Ambiguities about who actually controls the use of these Deere devices make it even more critical that the Commission clarify that use of these devices is on a strict non-interference basis, and that their use provides no basis to complain about the operation of any authorized radio service.

B. The Commission Should Conduct a Thorough Investigation of Deere's Apparently Unauthorized Operations

As noted above, Section 25.156(a) of the Commission's rules provides that renewal applications may be granted if the Commission finds that: (i) the applicant is legally, technically, and otherwise qualified; (ii) the proposed facilities and operations comply with all applicable rules, regulations, and policies; and (iii) grant of the application will serve the public interest, convenience and necessity.[73] In light of the issues noted above, there are significant reasons to believe that Deere's activities do not comply, and have not complied, with all applicable rules, regulations, and policies, and that grant of Deere's renewal application would not advance the public interest, convenience, and necessity. In addition, Deere's unauthorized operations, which appear to be willful and repeated, call into question whether Deere has the requisite character qualifications to serve as a Commission licensee, and whether it has made false certifications to the Commission.

Accordingly, and as discussed above, the Commission should conduct a thorough inquiry into the nature of Deere's activities and its representations to the

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71 *See* StarFire RTK 900 and 450 MHz Radios Operator Manual, *available at* http://manuals.deere.com/omview/OMPFP10776_19/?tM= (last visited Oct. 13, 2011).

72 *See* 47 C.F.R. § 1.948.

73 47 C.F.R. § 25.156(a).

Commission. At a minimum, the Commission should require Deere to provide specific information with respect to:

1. The exact frequency bands in which it has conducted receive-only operations;

2. The exact antenna/receiver types that it has deployed, the dates of deployment, and the exact number of each type deployed;

3. The exact spacecraft with which its devices communicate with now and have communicated in the past;

4. The specifics of all two-way Deere communications devices; and

5. How Deere exercises the requisite level of control over its devices.

In light of the information presented above, it is appropriate for the Enforcement Bureau to issue such an inquiry and conduct a comprehensive evaluation of information received in response, and determine whether Deere has acted in accordance with the terms of its existing license, as well as the requirements of the Communications Act and the Commission's rules and policies. Any findings that Deere has not done so would warrant denying the renewal application and potentially imposing other sanctions.

VI. ANY RENEWAL OF DEERE'S LICENSE WITHOUT APPROPRIATE LIMITING CONDITIONS WOULD BE CONTRARY TO THE PUBLIC INTEREST, CONVENIENCE, AND NECESSITY

Deere's public statements clearly indicate that it wishes to use the 1525-1559 MHz band in a manner that would undermine the implementation of LightSquared's next-generation 4G LTE wireless network, and the delivery of the benefits of mobile broadband to hundreds of millions of users—including in rural areas—consistent with the *National Broadband Plan.* In order to mitigate the potential for harm that would result if Deere were allowed to foreclose LightSquared's use of the L Band for that purpose, the Commission should impose the following conditions on Deere's license, if it decides to renew the Deere license after concluding, following an investigation, that: (i) Deere's license was not automatically terminated in 2002 and is not now null and void; and (ii) Deere has not in fact engaged in unauthorized operations that warrant declining to renew Deere's authority:

First, the Commission should make clear that all operations under Deere's license are subject to the condition that Deere accept all interference that may be caused by the operation of any other authorized radio station (including those operated by LightSquared or its wholesale customers). An unambiguous condition of this type is needed to disabuse Deere of the notion that it is entitled to interference protection throughout the 1525-1559 MHz band.

Second, the Commission should require Deere receivers to meet minimum standards to ensure compatibility with other users of the 1525-1559 MHz band. Such standards would help to guard against the possibility that Deere would experience actual interference, or that Deere would seek to curtail operations of the LightSquared network or compromise the intended use of the 1525-1559 MHz band at a later date.[74] Notably, in 2003 the Commission imposed similar standards on aircraft-based devices operating in the 108-117.975 MHz band and providing "differential GPS"—a term that encompasses the satellite-based augmentation provided by the StarFire system.[75] More specifically, the Commission required such receivers to meet International Civil Aviation Organization ("ICAO") standards to ensure that their operation was compatible with FM broadcasting systems, and that entities operating those receivers could not seek to foreclose broadcasting operations in the band.[76] Imposing such a condition is also appropriate because the Commission already has noted the need to "look closely at . . . establishing receiver standards relative to the ability [of receivers like Deere's StarFire devices] to reject interference from signals outside [RNSS] allocated spectrum [in the 1559-1610 MHz band]."[77] Deere's license also should be subject to an

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74 LightSquared already has demonstrated that it is possible to design receivers that are compatible with LightSquared's intended MSS/ATC operations. *See, e.g., LightSquared Announces Simple, Affordable Solution to GPS Interference Issues* (Sep. 21, 2011), *available at* http://www.lightsquared.com/press-room/press-releases/.

75 *See Review of Part 87 of the Commission's Rules Concerning the Aviation Radio Service*, 18 FCC Rcd 21432, at ¶ 55 (2003).

76 *Id.* at ¶¶ 53, 55.

77 *See Fixed and Mobile Services in the Mobile Satellite Service Bands at 1525-1559 MHz and 1626.5-1660.5 MHz, 1610-1626.5 MHz and 2483.5-2500 MHz, and 2000-2020 MHz and 2180-2200 MHz,* 26 FCC Rcd 5710, at ¶ 28 (2011), *recon. pending*.

explicit condition requiring Deere to comply with any standards that are adopted in such a rulemaking.

VII. CONCLUSION

For the foregoing reasons, LightSquared urges the Commission to reconsider its grant of Deere's renewal application and deny that application. It appears that Deere's license terminated automatically in 2002, such that Deere holds no license to renew. Even if Deere did continue to hold a license, renewal would be contrary to the public interest, convenience, and necessity given: (i) Deere's intent to claim spectrum rights it does not have and foreclose the implementation of LightSquared's 4G LTE wireless network; and (ii) the significant outstanding questions as to whether Deere's operations have been consistent with the Commission's rules and the terms and conditions of Deere's long-expired license—questions that the Commission should resolve by conducting a thorough inquiry. If, after completing such an inquiry, the Commission nevertheless decides to grant renewal, it should do so only with clear and unambiguous conditions requiring Deere to operate on a strict noninterference basis, while satisfying minimum standards to ensure compatibility with other users of the 1525-1559 MHz band.

Respectfully submitted,

/s/ Jeffrey J. Carlisle

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Reston, VA 20191
703-390-2001

Exhibit A

Deere “Current Operations”

LightSquared Rollout and StarFire Frequencies

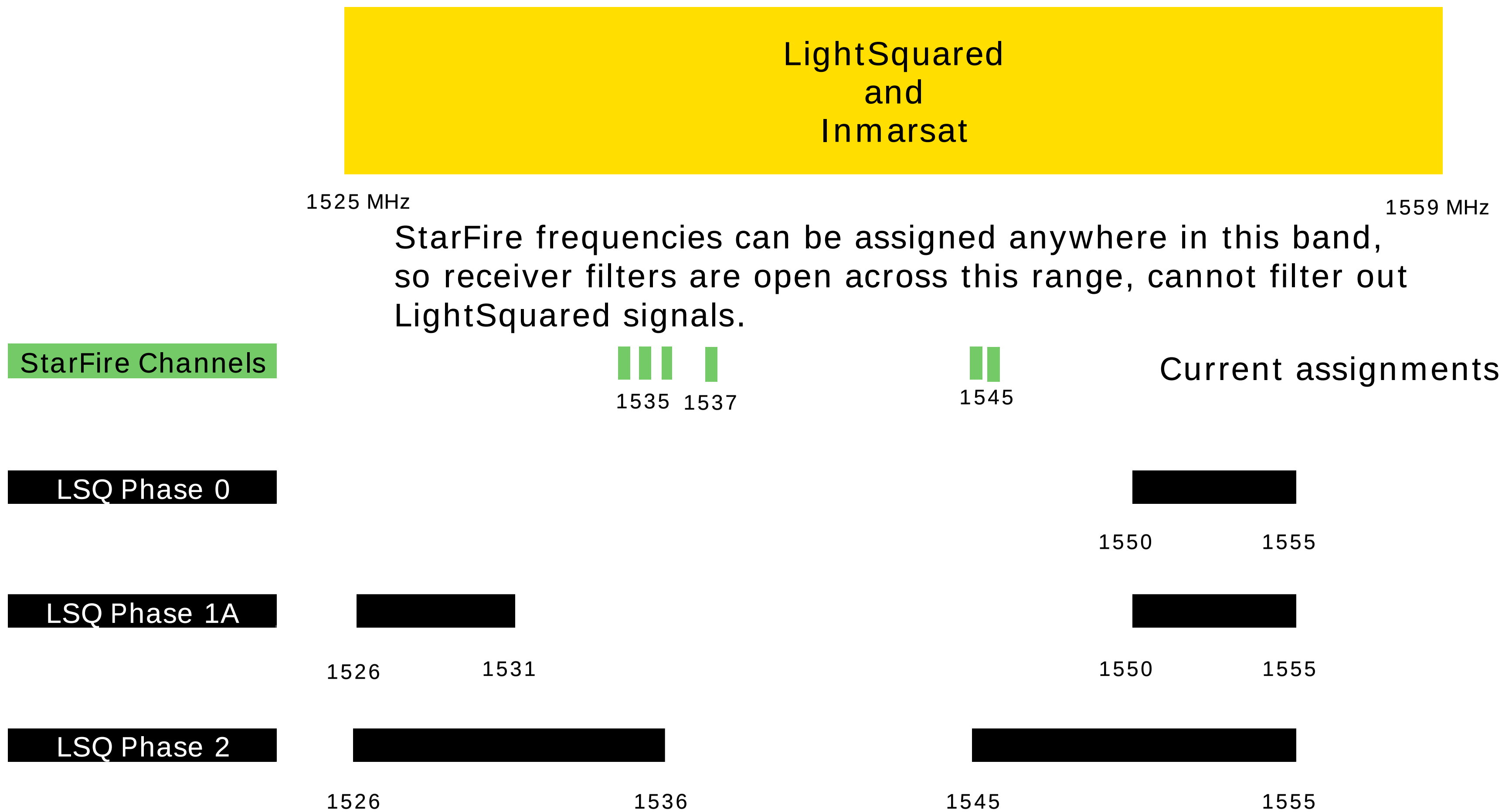

Exhibit B

Selected StarFire Receiver Types

StarFire Model PF80385

Source: http://dozerdeals.com/jd-starfire-receiver-gen2-greenstar-gps/

StarFire 300 Receiver

Source: GreenStar Product Brochure, Page 22

StarFire 3000 Receiver

Source: GreenStar Product Brochure, Page 22

StarFire ITC

Source: http://www.fastline.com/v100/listings.aspx?keywords=starfire

StarFire 450 RTK Radio

Source: http://www.deere.com/en_US/media/corporate_images/2010_press_releases/march/itc_deluxe_450.jpg

StarFire RTK 900 Radio

Source: http://www.deere.com/wps/dcom/en_US/products/equipment/ag_management_solutions/displays_and_receivers/starfire_900_rtk_radio/starfire_900_rtk_radio.page

Exhibit C

StarFire iTC and RTK Manual Excerpt

DCY

StarFire iTC and RTK

OPERATOR'S MANUAL

StarFire iTC and RTK

OMPC21514 ISSUE E9 (ENGLISH)

CALIFORNIA

Proposition 65 Warning

Diesel engine exhaust and some of its constituents are known to the State of California to cause cancer, birth defects, and other reproductive harm.

If this product contains a gasoline engine:

WARNING

The engine exhaust from this product contains chemicals known to the State of California to cause cancer, birth defects or other reproductive harm.

The State of California requires the above two warnings.

John Deere Ag Management Solutions
(This manual replaces OMPC20960)
North American Version
PRINTED IN THE U.S.A.

OMPC21514

Introduction

www.StellarSupport.com

NOTE: Product functionality may not be fully represented in this document due to product changes occurring after the time of printing. Read the latest Operator's Manual and Quick Reference Guide prior to operation. To obtain a copy, see your dealer or visit www.StellarSupport.com

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Contents

Continued on next page

Original Instructions. All information, illustrations and specifications in this manual are based on the latest information available at the time of publication. The right is reserved to make changes at any time without notice.

System Overview

The StarFire™ RTK system consists of a local base station placed in a field or mounted on a structure that transmits high accuracy corrections to the vehicle StarFire™ receiver using RTK radios. The StarFire™ receiver on the RTK-equipped vehicle must have a direct line of sight with the base station in order to receive the RTK signal.

Performance of the RTK system is related to the operating distance from the base station. When operating beyond 20 km (12 miles), degraded accuracy will occur and it may take longer to initially acquire the RTK signal.

A repeater, which is simply an RTK radio supplied with 12 volts of power, can be used to receive the base station signal and establish a new line of sight point. However, performance limitations can still be expected if trying to use the repeater to transmit the RTK signal to a vehicle that is farther than 20 km (12 miles) away from the base station.

Receiver—On Vehicle

Position receiver with integrated RTK radio module is located on top of machine. Position receiver receives global positioning and differential correction signal through a single receiver and integrates signal for use with system.

The receiver has a dedicated operating mode (Vehicle Mode). Refer to “Operating Mode—RTK” in “StarFire iTC” Section for setup of the receiver on vehicle.

IMPORTANT: The antenna must be installed before the radio module is powered ON.

Avoid water intrusion by keeping the antenna attached whenever possible.

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Removing the antenna while transmitting may damage the radio module.

Continued on next page

JS56696,00005D6 -19-13MAY09-1/3

Receiver—On Base Station

The base station is the most critical part of an RTK system. During installation, care must be taken to ensure the base has problem-free operation. There are two issues that are responsible for most problems with a base station: **Shading and Multipathing**. If a base station experiences one of these problems, it could be detrimental to your RTK operation. Although it may not be possible to locate a base station in an ideal location, this guide is aimed at helping to define the best option available.

Base station operating mode can be either Absolute Survey Base Mode or Quick survey Base Mode. Refer to "Operating Mode—RTK" in "StarFire iTC" Section for setup of the receiver on base station.

Refer to "Base Station Operation and Setup" in "StarFire iTC" Section for proper use and setup of the base station.

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Continued on next page

JS56696,00005D6 -19-13MAY09-2/3

Repeater Radio

The radio can be configured to act separately as a repeater. A repeater is required if obstructions (i.e. trees, hills, etc.) exist between the base station and vehicle(s) or if base station is too far away from the vehicles.

A repeater consists of:

- Radio (configured as a repeater)
- Harness
- Mounting Bracket
- 12 Volt Power Source
- Tripod or wall mount cradle

IMPORTANT: A repeater can only be used to repeat a signal from a base station to a vehicle. Therefore, a repeater cannot be used in a ''daisy chain,'' repeating the signal from one repeater to another.

Refer to “Repeater—RTK” in “StarFire iTC” Section to properly configure radio as repeater.

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JS56696,00005D6 -19-13MAY09-3/3

Installation of the RTK radio and antenna

Once you have installed the base station receiver, installing the radio in a location to best maximize the output, can be a challenge. Below are four options currently available through John Deere.

- Leave the RTK radio in its original configuration attached directly behind the base station receiver.
- Use a repeater as part of the base station. Install a radio with the base station receiver. Then install a Repeater radio, available through whole goods or parts, in an elevated location. The base station will then send the RTK data to the repeater and the repeater will then transmit that data out to the vehicle on the network. This will eliminate other repeaters in the system.

  NOTE: It is important to remember that additional repeaters can not be run off of the central repeater. In areas with heavy foliage or uneven terrain, this setup method is not advived

- Use PF80821 extension harness (92 m; 300 foot in length), moving the radio from the back of the base station receiver to an elevated position, and running the harness in between.

  NOTE: It is important to use the PF80821 harness and grounding wire properly according to the installation instructions. This harness has built in protection for both your radio and receiver for unwanted static electricity developed on the harness.

- Attach the RTK radio in a secured location and run coaxial cable between the radio and the antenna.

  IMPORTANT: The antenna must be installed before the radio module is powered ON.

  Avoid water intrusion by keeping the antenna attached whenever possible.

  Removing the antenna while transmitting may damage the radio module.

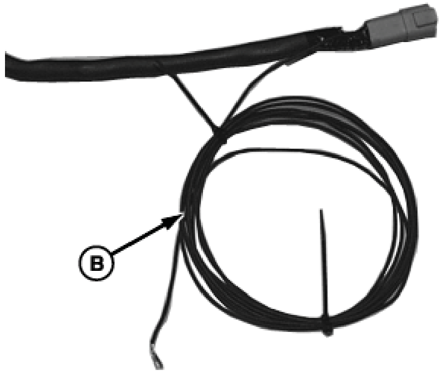
  IMPORTANT: If using a coaxial cable between the radio and the antenna, you need to use the lowest-loss cable available or you may suffer RTK radio link range issues.

  NOTE: When using this option, it may be necessary to install a higher-gain antenna to compensate for loss.

Always mount the radio antenna vertically to make sure that the RTK signal is radiating outwards. If the antenna is at an angle, it may cause the data received at the vehicle to be lower than expected.

JS56696,00005D7 -19-13MAY09-1/1

Attaching RTK Harness



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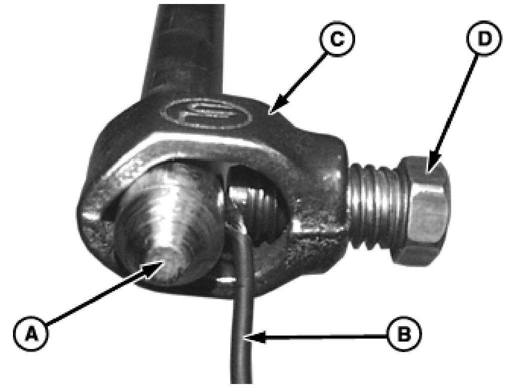

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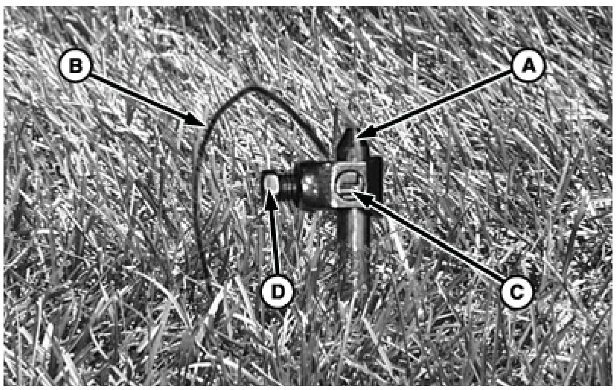
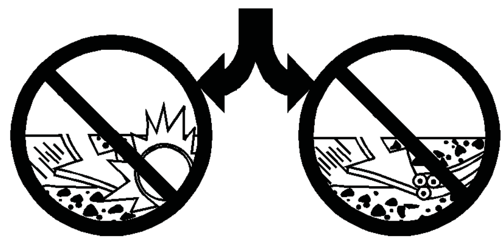


PC8571 —UN—14JUL05



PC8569 —UN—14JUL05

A—Rod **B—Grounding Wire** **C—Collar** **D—Screw**

CAUTION: Avoid serious injury or death to you or others. Contact your local utility companies to determine the location of gas, electric, or water lines. Placement of grounding rod must be a safe distance away from pipelines and cables.

IMPORTANT: Carefully choose location of rod so that it is away from paths where it could damage equipment or be damaged by equipment.

DO NOT route RTK Extension harness along any other power sources. Keep harness at least 2m (6 ft) away from any other AC power lines.

1. Attach harness between radio and receiver.
2. Carefully determine placement of rod (A) a safe distance away from pipelines and cables. Drive into ground leaving one end above surface.
3. Route grounding wire (B) from harness to rod. Grounding wire may be extended if necessary to reach rod.
4. Remove insulation from end of grounding wire.
5. Place collar (C) over end of rod.
6. Place grounding wire between rod and screw (D).
7. Tighten screw.
8. Restrain harness to supporting structures as necessary to keep them away from equipment, damage, and to reduce wire strain.

JS56696,00005D8 -19-13MAY09-1/1

RTK Network Base Station Setup

A—7° Off the Horizon (Mask)

Installing and operation of the Base Station Receiver.

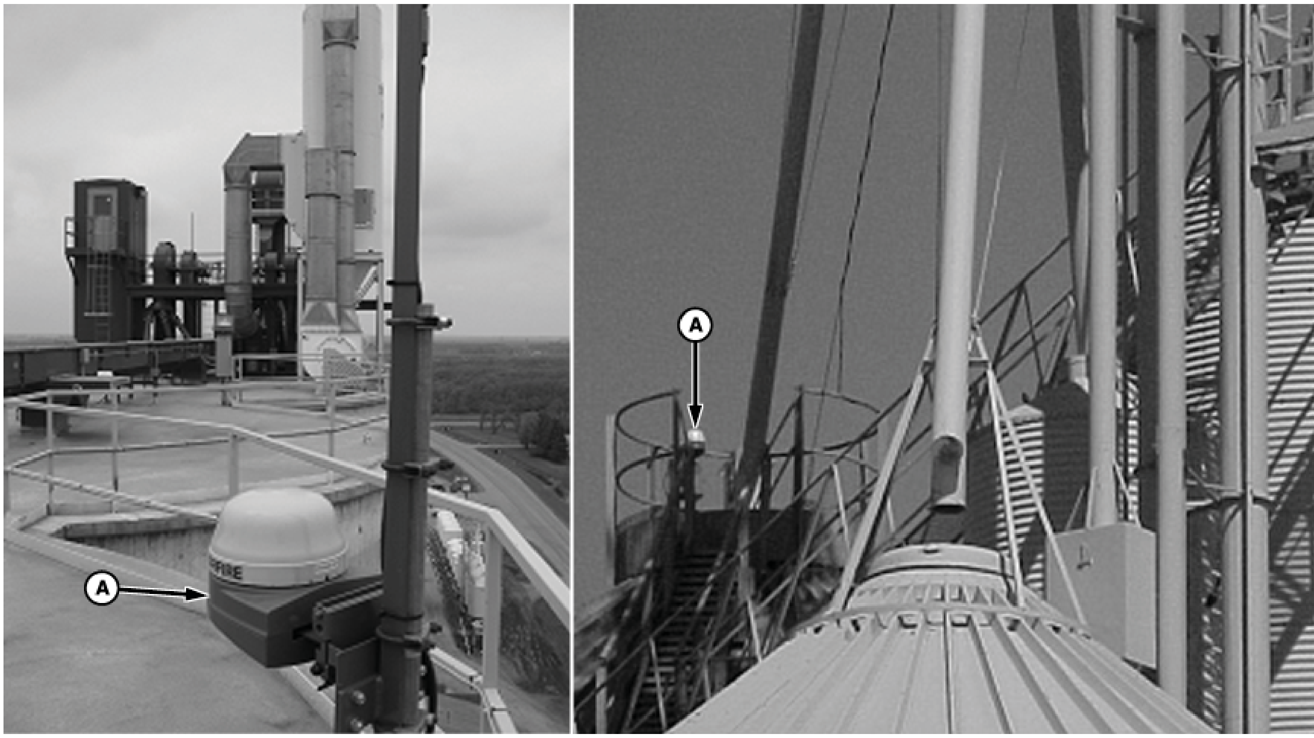
The base station is the most critical part of the RTK operation, so setting up a base station correctly is vital to the operation of the RTK system. If the Base Station Receiver is setup in a questionable location, the receiver could have two separate issues; Shading and Multipathing

Shading:

In order to insure proper operation of a RTK base station, the GPS Receiver must have a clear view of the sky in all directions above 7 degrees off the horizon. Both the base receiver and the vehicle receiver will use any satellites that are above 7 degrees off the horizon. If a base station receiver can't use a satellite above 7 degrees, then all vehicles operating on that base station also can't use that blocked satellite. This is call "Shading" of the base station. If enough of this occurs your RTK system could be inaccurate. Many things can cause shading such as buildings, towers, poles and grain legs.

Continued on next page

JS56696,00005D9 -19-13MAY09-1/4



A—Receiver

NOTE: The closer the receiver is to the tower, the more it will be shaded.

In the pictures above, the base stations are shaded by the surrounding objects.

Picture on the left—the towers in the background and the pole behind the receiver will block GPS satellites as they pass behind it.

Picture on the right—the base station will be shaded by both the grain tubes and bins on the right.

Continued on next page

JS56696,00005D9 -19-13MAY09-2/4

PC8736 —UN—01SEP05

A—Receiver

This receiver could be affected by both Multipathing and by shading. All the grain legs in the picture will shade the receiver from satellites.

Continued on next page

JS56696,00005D9 -19-13MAY09-3/4

A—Receiver

In the pictures above, both receivers will experience shading.

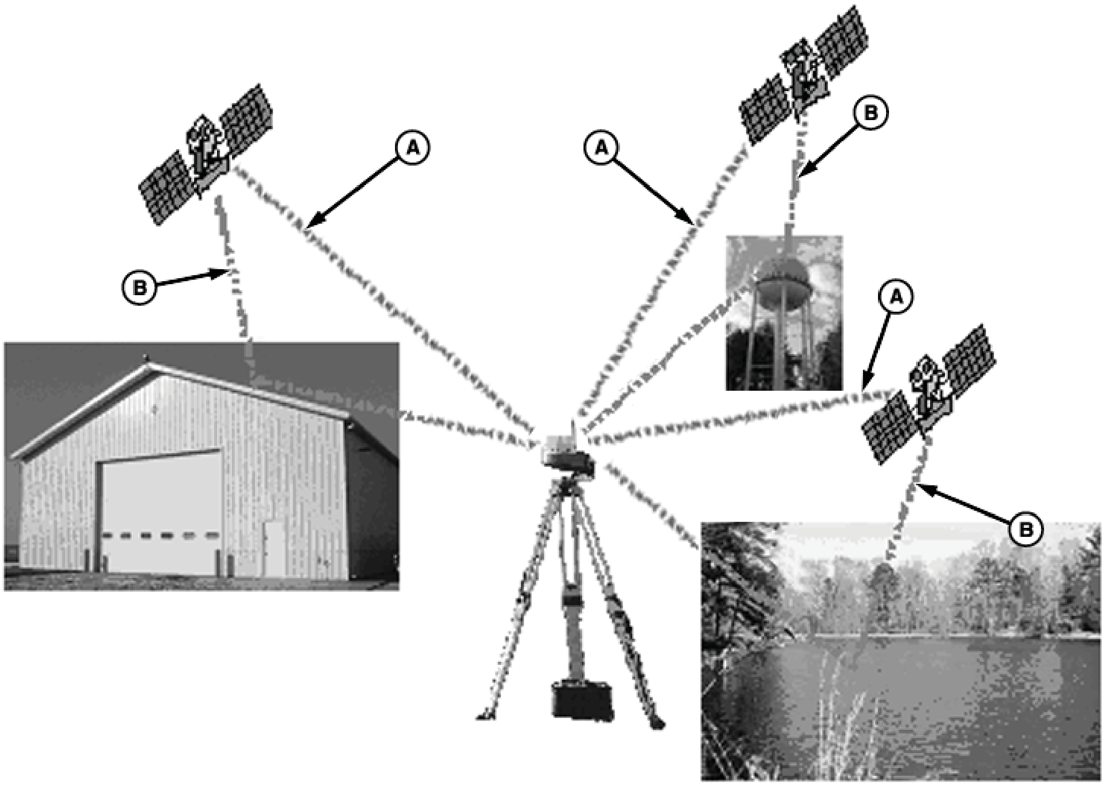
Picture on the left—Shaded by the tower

Picture on the right—Shaded by the pole.

The receiver on the right will have more shading issues than the receiver on the left because the pole is right up against the receiver shading a large portion of the sky. The receiver on the left has been moved further away from the tower to reduce shading issues.

JS56696,00005D9 -19-13MAY09-4/4

Multipathing



A—Good Sources **B—Multipath Sources**

Before explaining how to protect against Multipathing, let's discuss exactly what Multipathing is: Each satellite sends down time coded messages for any receiver to pick up. If a receiver sees multiple time coded messages from the same satellite, it determines there is a problem with the satellite and discontinues using that satellite until it determines the problem is corrected. This could take up to minutes before the situation corrects itself. The following are some examples of what causes multipath.

- Metal roofs
- Center pivots
- Water towers
- Pickup trucks
- Grain bins
- Bodies of water

In the following pictures, we have provided illustrations to help show how Multipathing occurs. The time coded signal from the GPS satellite is being beamed down in all directions, so if the same time coded signal is reflected off of an object back towards a receiver, the receiver will see the same message many times. If this occurs, you could see A/B line jumps while operating in the field

Continued on next page JS56696,00005DA -19-13MAY09-1/6

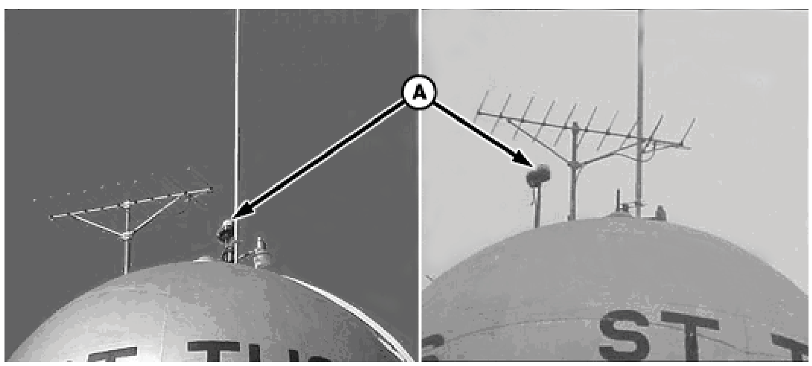

PC8743 —UN—01SEP05


PC8744 —UN—01SEP05

Even though the multipath signal may be reflected in below the 7 degree elevation mask, the receiver may still use this message because the time coded message tell the receiver that the satellite position is above 7 degrees (i.e. Sat 1; Elev. 35 degrees, Azimuth 255 degrees).

Both the roof of the car and the building are causing multipath to occur at the base station receiver. The signals is bounce along the car or building and enter the receiver at a slight delay from when the direct satellite message is received.

JS56696,00005DA -19-13MAY09-2/6



PC8745 —UN—01SEP05

A—Receiver

Picture on the Left: The base station, with receiver attached 1 foot off the top of the tower, was being affected by multipath from the dome of the water tower. The vehicle receiver running off this base station experienced different symptoms:

- Two vehicles would be operating at the same time. One vehicle would go from RTK into RTK-X and see a line jump of up to 6 inches for a couple of minutes, while the other vehicle would be operating without incident.
- At a later time, the situation would reverse, and the vehicle without incident earlier would go into RTK-X and experience a line jump, while the other vehicle wouldn't.

The reason the vehicles behaved differently was because each vehicle may have been using a different set of satellites at a given time due to shading and vehicle location.

Picture on the Right: Base station was elevated 5 feet off the top of the tower. Raising the receiver greatly reduced the multipath effects observed on this RTK system.

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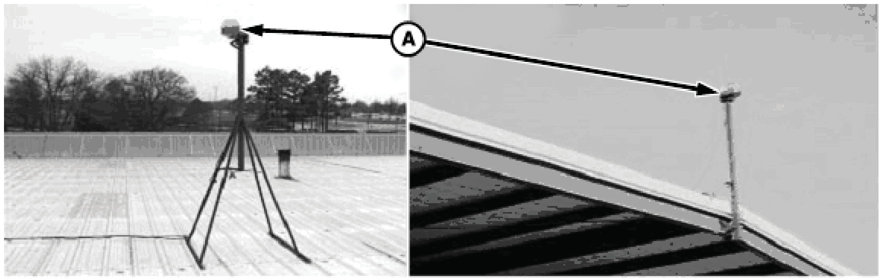
JS56696,00005DA -19-13MAY09-3/6



PC8746 —UN—01SEP05

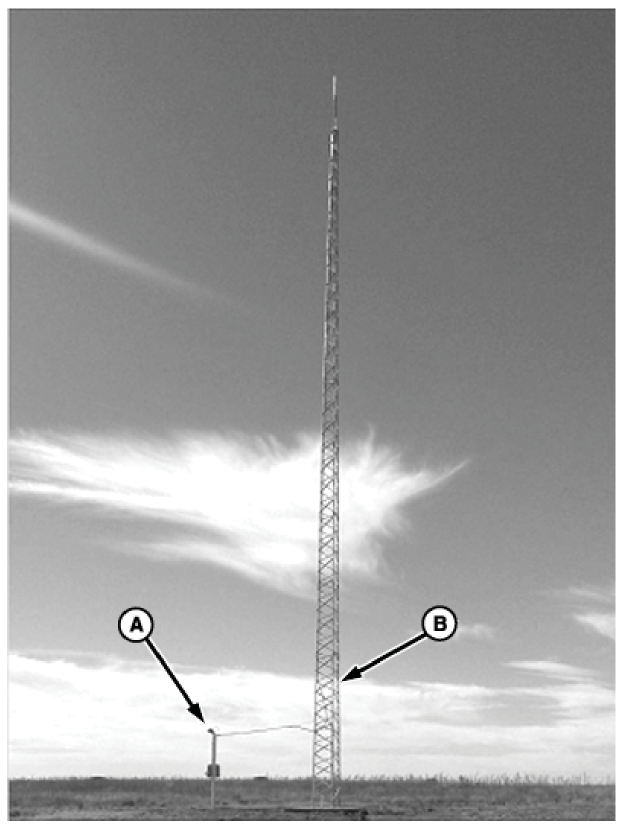
A—Receiver

To reduce both multipathing and shading, elevate the base station receiver above any structure to which it is attached. For best results, two meters or more from the highest point of the structure is recommended. The higher the better, but you must also ensure that the base station receiver is attached solidly so there is no movement of the receiver. Movement of the base station receiver will result in the same movement in your vehicle. The two base stations shown above are examples of good base station locations, because the trees are below the 7 degrees elevation mask and the roof is not made of metal which helps to reduce multipathing.

JS56696,00005DA -19-13MAY09-4/6

When setting up a tower network, ensure that the receiver (A) is 9.1 m (30 ft) away from the base of the tower (B) to protect your system from multipath.

A—Receiver **B—Tower**



PC9391 —UN—23OCT06

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JS56696,00005DA -19-13MAY09-5/6

When installing a receiver (A) on a shed, grain leg, water tower, or other tall structure, ensure the receiver is 2 m (6 ft) above the peak of the structure. This placement will help prevent multipathing of the receiver.

A—Receiver

PC9392 —UN—23OCT06

JS56696,00005DA -19-13MAY09-6/6

RTK using Straight, Curves or Circle

RTK Base Station Network Areas Utilizing Straight, Curves or Circle AutoTrac

Symptoms:

- Customer changes base stations and/or fields and the vehicle does not align to the previous track or bed.
- Customer utilizes multiple base stations for the same field and does not see the desired AB line repeatability among vehicles or field passes.

NOTE: When the term AB line is used, it also encompasses Circle track and Curve track lines.

Solution:

RTK is designed to provide repeatability pass after pass and from season to season. This repeatability is a function of the Base Station location and it's correlation to a field specific AB line driven by the vehicle.

AB lines and field operations must be linked to the specific base station that they were originally created with. Every AB line in the field is created while utilizing a specific RTK base station. Every pass in that field for a particular season or set of beds must utilize the same original base station and location that was used to create that specific AB line(s).

JS56696,00005DB -19-13MAY09-1/1

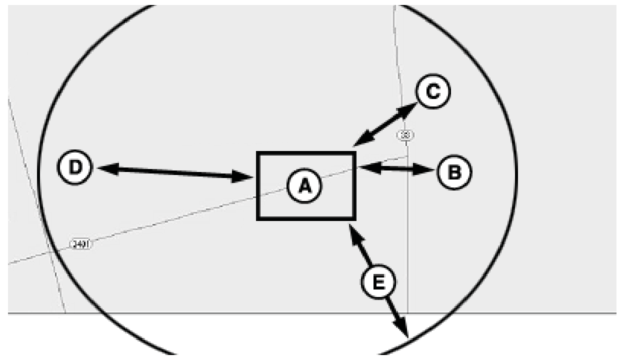
Example A

As you see in the picture, Field A (A) has 3 base stations located within a 9.7 km (6 miles) radius of the field. Although 3 base stations could be used to operate vehicles within this field, one base station must be selected to perform all field operations for that season and assigned/created AB lines. In this instance, the customer selected base station # 1 as it was centrally located to other farms.

This means that when AB lines are being created, all vehicles and operations for that cropping season MUST use the same base station and location. Also, if AB lines were set up during subsequent seasons, the same original base station that was utilized in subsequent seasons must be used again at the same base location.

AB lines must be assigned and associated to a specific base station in order to achieve absolute accuracy and repeatability. This absolute accuracy and repeatability is obtained during the base stations 24 hour absolute survey.

Any time a base station is used to perform a field operation and it IS NOT the base station that was used to create that original AB line, errors will exist in the AB line position. These errors will vary from location to location, but may be as much as 3 to 5 inches off.



A—Field A
B—Base Station 1 — 6.4 km (4 miles)
C—Base Station 2 — 4.8 km (3 miles)
D—Base Station 3 — 4.8 km (3 miles)
E—9.7 km (6 miles) radius

A recommended practice is to assign every field to a specific base station. This will ensure that every operation performed in that field, including AB line creation, is utilizing the most accurate and repeatable correction signal possible.

JS56696,00005DC -19-13MAY09-1/1

Operating Parameters

StarFire iTC or Gen II Receiver Operating Parameters for ALL AutoTrac, SF1, SF2, and RTK

Several factors can attribute to a less than optimal performance of the GPS receiver, whether it is operating in SF1, SF2 or RTK mode. Any lack of performance while operating in RTK mode will display symptoms sooner then operating with SF1 and SF2. RTK operations require higher precision and many applications are in preexisting tracks, so the operator will notice unsatisfactory performance sooner by visually comparing against the previous tracks.

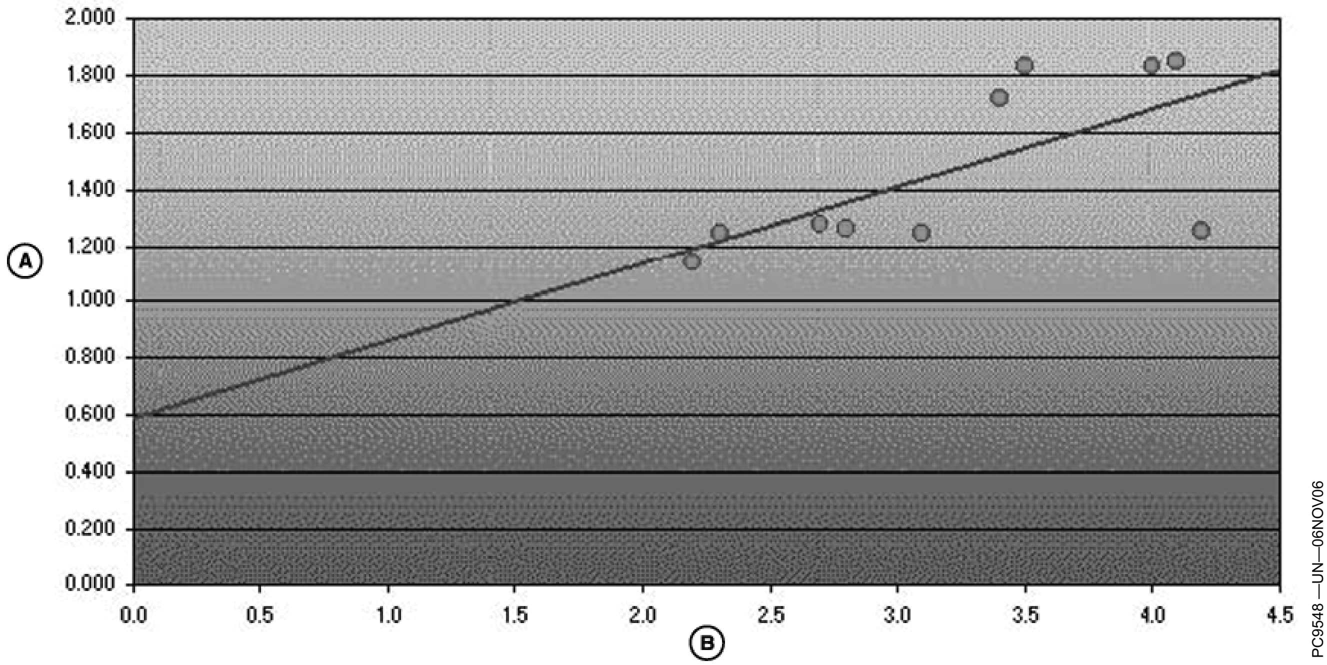
When operating with RTK, there are always 2 critical components that come into play:

1. Base Station Setup and any possible obstructions
2. Vehicle Setup and any possible obstructions

RTK vehicle operation is directly affected by the quality of the base station location and setup, not just vehicle GPS receiver interferences. The base station is feeding satellite correction information to the vehicle (rovers) at all times. If any of the GPS signals being received at the base station are distorted or corrupted in any way, that incorrect information will in turn be fed directly to the vehicle (rover) leading to a loss in accuracy and repeatability.

JS56696,00005DD -19-13MAY09-1/1

PDOP Definition



A—Horizontal Precision (m) **B—Maximum PDOP Value**

The Position Dilution of Precision (PDOP) is likely one of the most critical GPS AutoTrac values to monitor. As the PDOP value increases, both the horizontal and vertical precision (guidance accuracy) of your data points decreases.

To help illustrate this relationship, please review the graph, which plots the PDOP value against the horizontal precision points collected on and around the University of Montana campus. Ten locations were collected to serve as ground control points to register an April 4, 1999 aerial photograph of the University area. You can see that as the PDOP value climbs from a minimum of 1.15 to a maximum of approximately 4.5, the horizontal precision and accuracy decreases from about 1.15 meters to about 1.9 meters. PDOP values below 7 are generally required to collect data at a 1 meter accuracy range (as determined by the PDOP mask set on your data logger) and any value below 3.5 is considered in-range for AutoTrac applications.

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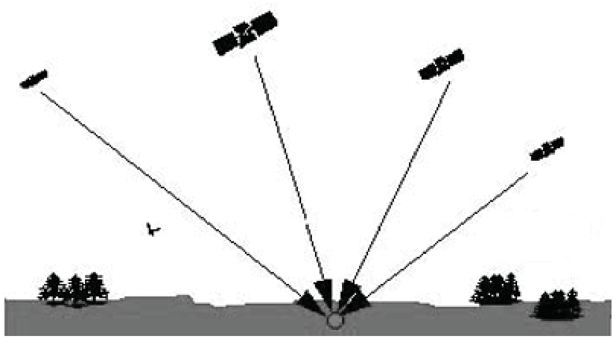
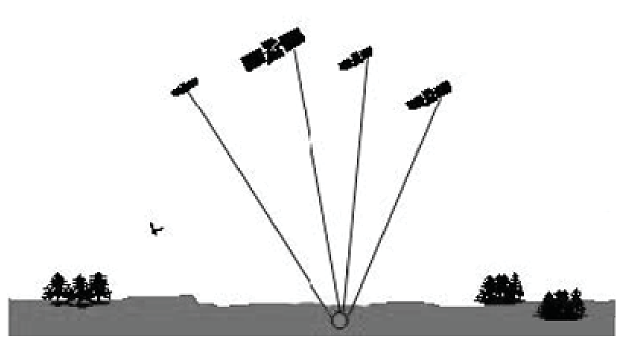
JS56696,00005DE -19-13MAY09-1/2



GOOD



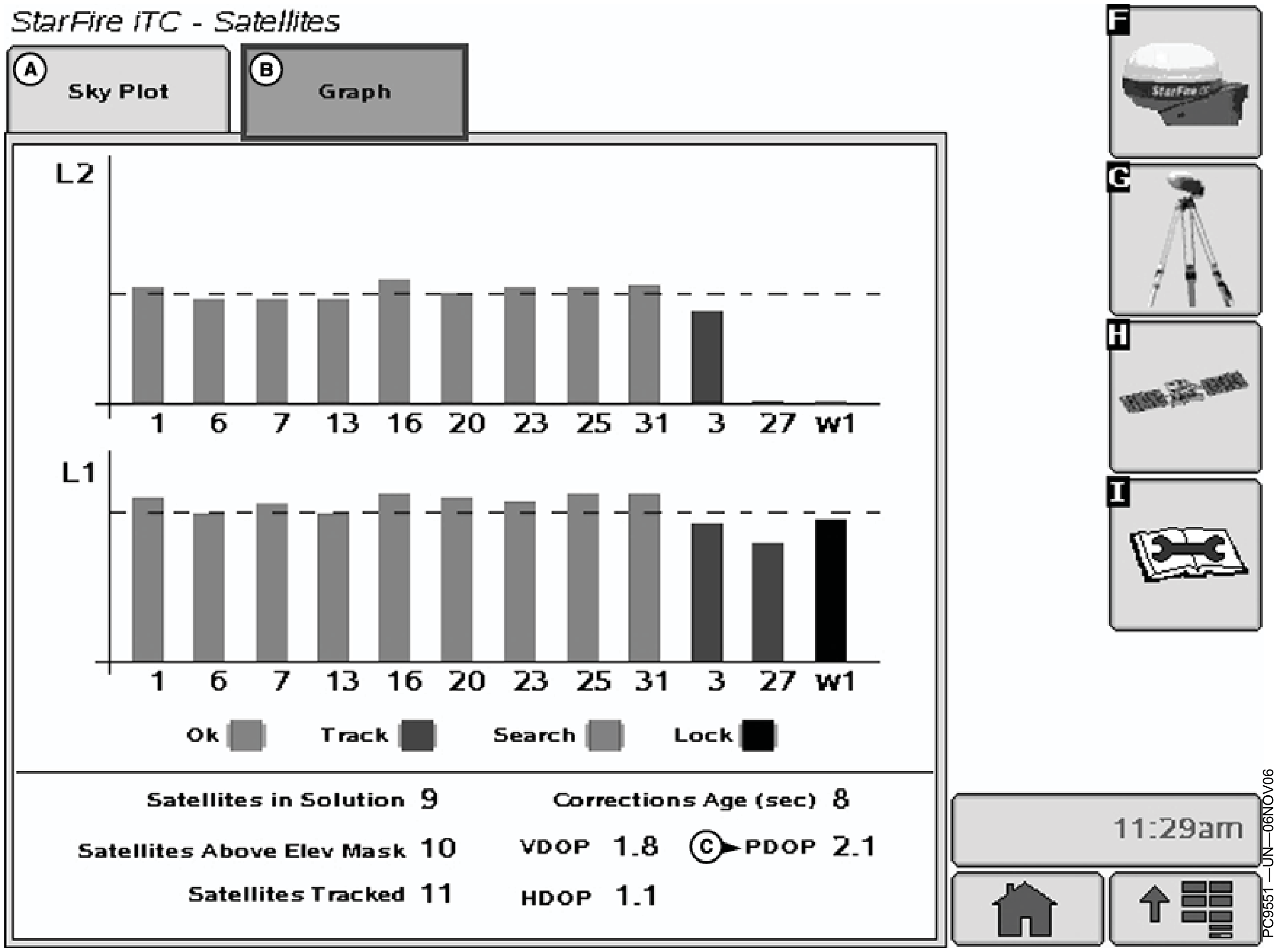
BAD

Keep in mind that PDOP (Position Dilution of Precision) is the measure of the geometrical strength of the GPS satellite configuration. As a general rule, any PDOP value below 3.5 is acceptable to use while operating AutoTrac but, the lower the number, the more precise the steering accuracy will be.

During vehicle operation, the PDOP can be viewed under the StarFire information pages in both the Original GreenStar Display and GS2 Display

JS56696,00005DE -19-13MAY09-2/2

PDOP Operating Values

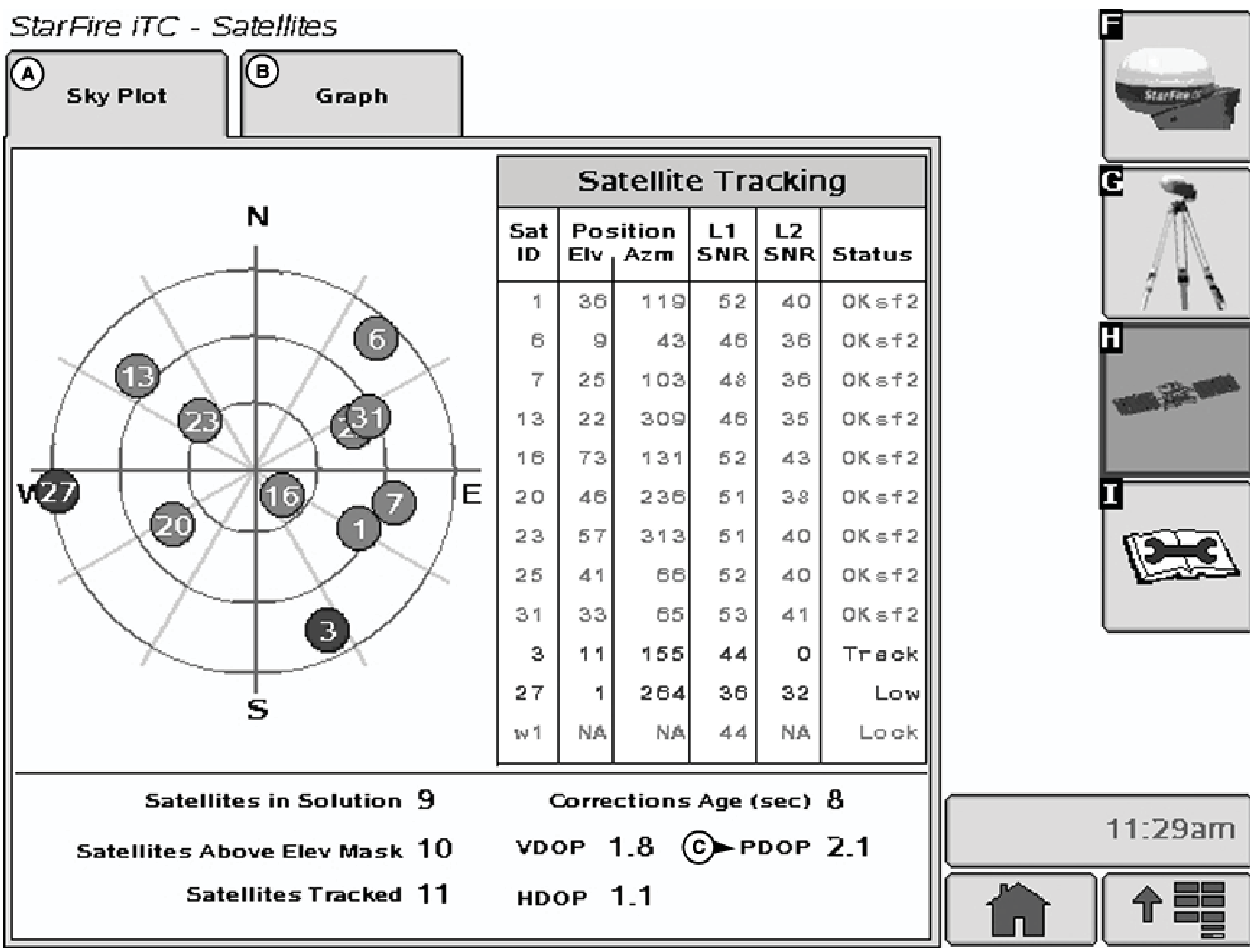


StarFire iTC - Satellites

A—SkyPlot **B—Graph** **C—PDOP**

Continued on next page

JS56696,00005DF -19-13MAY09-1/2



PC9552 —UN—06NOV06

StarFire iTC - Satellites

A—SkyPlot **B—Graph** **C—PDOP**

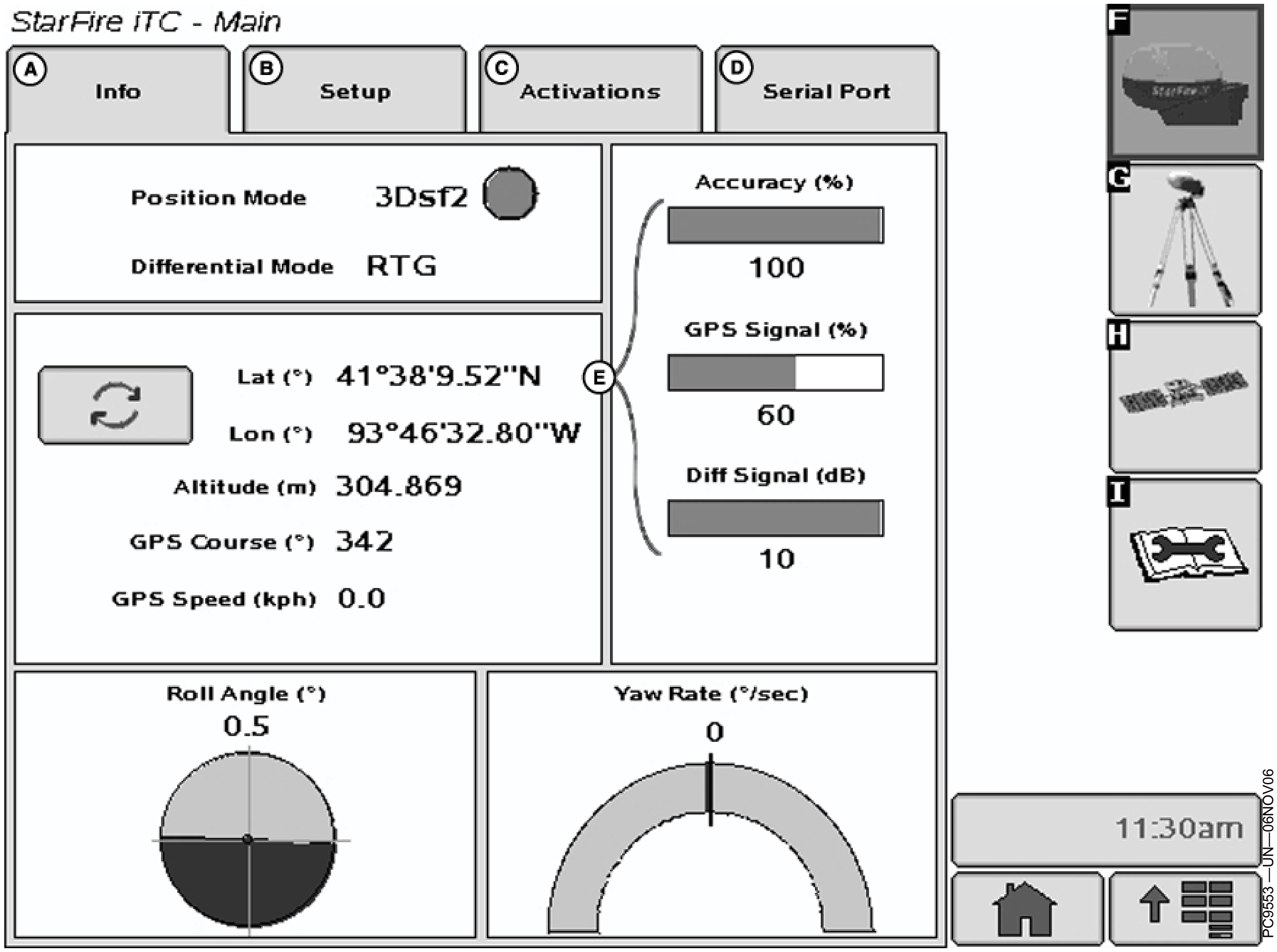
PDOP operating values should remain BELOW 3.5 DURING ALL AUTOTRAC OPERATIONS, especially RTK high precision operations. As the value of PDOP rises above 3.5, position accuracy will be compromised.

As a rule, when the GPS receiver is warming up from being in a powered off state and gathering satellite signals high PDOP values (4 to 20+) will be experienced for upwards of 15 minutes (under normal conditions).

It is important to monitor PDOP along with GPS signal quality while performing field operations.

JS56696,00005DF -19-13MAY09-2/2

StarFire Signal Monitoring System

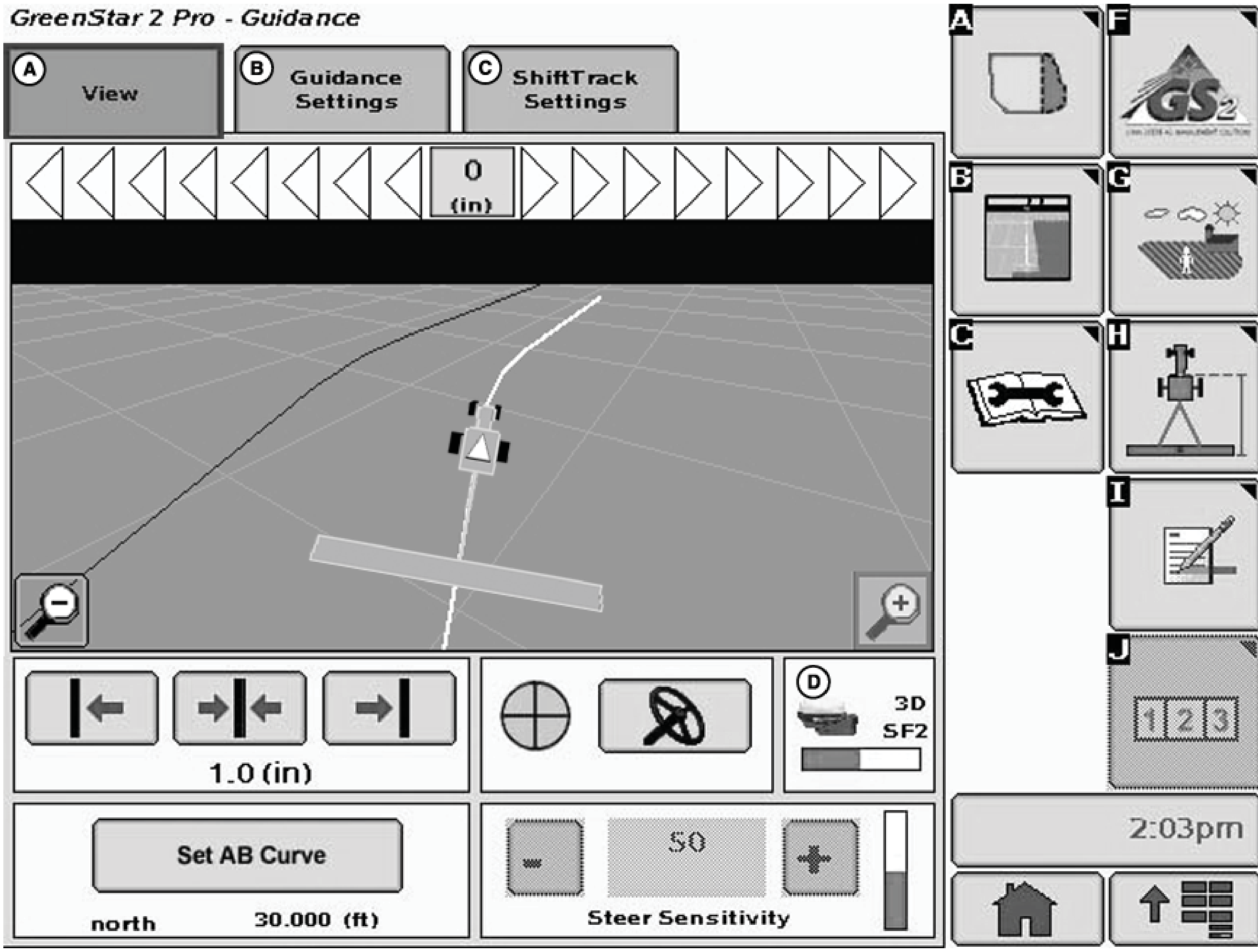


StarFire iTC Main

A—Info
B—Setup
C—Activations
D—Serial Port
E—Accuracy (%), GPS Signal (%), Diff Signal (dB)

Continued on next page

JS56696,00005E0 -19-13MAY09-1/5



GreenStar2 Pro - Guidance

A—View **B—Guidance Settings** **C—ShiftTrack Settings** **D—Signal Quality**

The GS2 alerts the operator when the current StarFire signal is not accurate. There are three levels of this warning system (Normal, Marginal, and Poor). The levels are determined both by the StarFire Receiver's PDOP value and the number of satellites being tracked. It is recommend that if the StarFire receiver is being used in high accuracy operations that care be taken when the StarFire Signal Monitoring system indicates that the current status is Marginal or Poor, as accuracy degradation may occur.

NOTE: Operating in RTK or RTK-X, both PDOP and "Number of Satellites" are used to determine the level of warning.

Operating at a signal level less than RTK (SF2, SF1, WAAS, ect.) only PDOP will be used to determine the level of warning.

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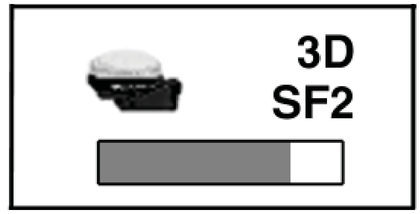
JS56696,00005E0 -19-13MAY09-2/5

Normal

PC9387 —UN—17OCT06

- Green Bar
- Normal Operating Range
- Acceptable range for high accuracy operations
- PDOP value: 0 - 3.5
- 6 or more satellites in solution



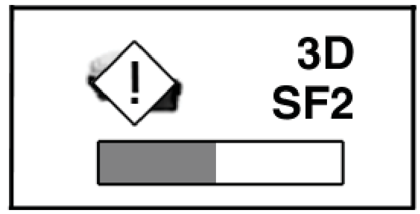
Normal

JS56696,00005E0 -19-13MAY09-3/5

Marginal

PC9388 —UN—17OCT07

- Orange Bar with Permanent Caution Sign
- Marginal Operating Range
- Moderate risk of accuracy degradation - caution is advised
- PDOP value: 3.5 - 4.5
- 5 satellites in solution



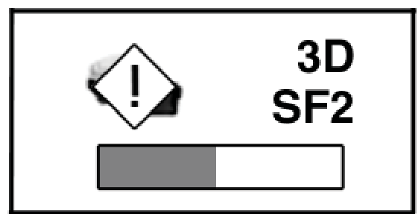
Marginal

JS56696,00005E0 -19-13MAY09-4/5

Poor

PC9388 —UN—17OCT07

- Red Bar and Flashing Caution Sign
- Poor Operating Range
- Significant risk of accuracy degradation - high accuracy operations are not advised
- PDOP value greater than 4.6
- 4 satellites or less in solution



Poor

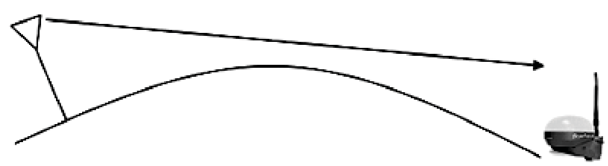
JS56696,00005E0 -19-13MAY09-5/5

Antenna Height

RTK Shared Base Station: Antenna Height

PC9393 —UN—23OCT06

In order to maintain a good RTK Radio link, the antenna must be mounted high enough to radiate over the earth's curvature and any obstacles. As shown in the figure, the curve of the earth can block the signal from the RTK link. If the radiating base station radio antenna is mounted too low, the broadcasting range will be drastically reduced.



JS56696,00005E1 -19-13MAY09-1/1

Specific Tower Setup Information

It is recommended that the receiver be, at minimum, 9.1 m (30 ft) away from the tower to prevent both Shading and Multipathing. This distance may vary depending on the frame design of the tower or structure that you are mounting it around.

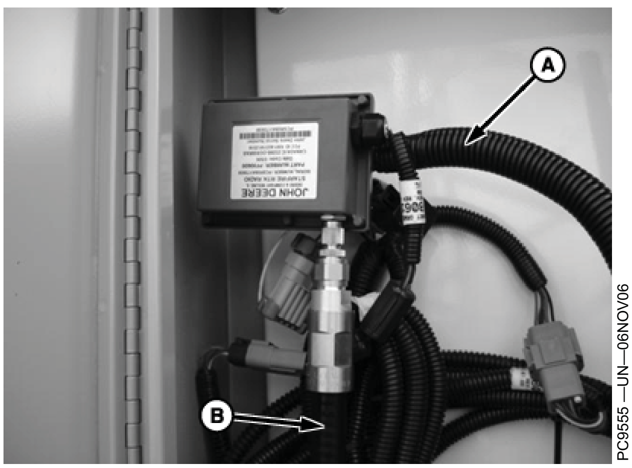
When using the 91 m (300 ft) extension harness, do not cut the harness to the length needed. This harness has built in voltage protection and is shielded. Cutting the harness will limit the effectiveness of the harness and will cause failures of either the radio or the receiver due to static electricity build up on the harness. This harness was built to be buried underground, so it is suggested to bury all extra harness underground to protect the harness.

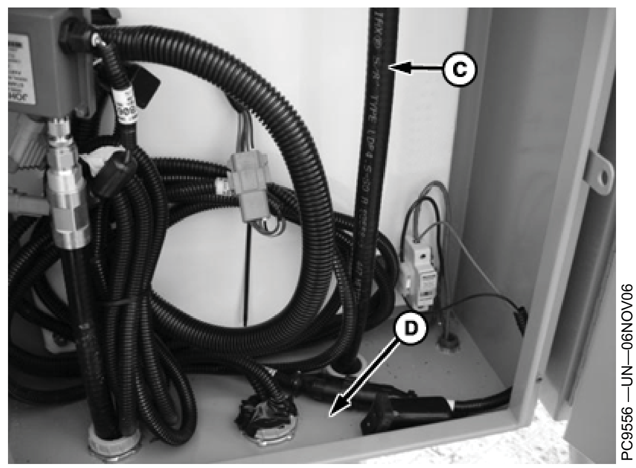
After deciding what structure that you will be mounting your base station on, there are five different ways to set up your base station.

- Utilizing Both The 91 m (300 ft) RTK Extension Harness And Low Loss Coax Cable
- Utilizing The RTK Extension Harness
- Utilizing A Repeater
- Utilizing Just Low Loss Coax Cable
- Leaving The Radio And Receiver As A Single Unit

JS56696,00005E2 -19-13MAY09-1/1

Utilizing Both The 91 m (300 ft) RTK Extension Harness And Low Loss Coax Cable





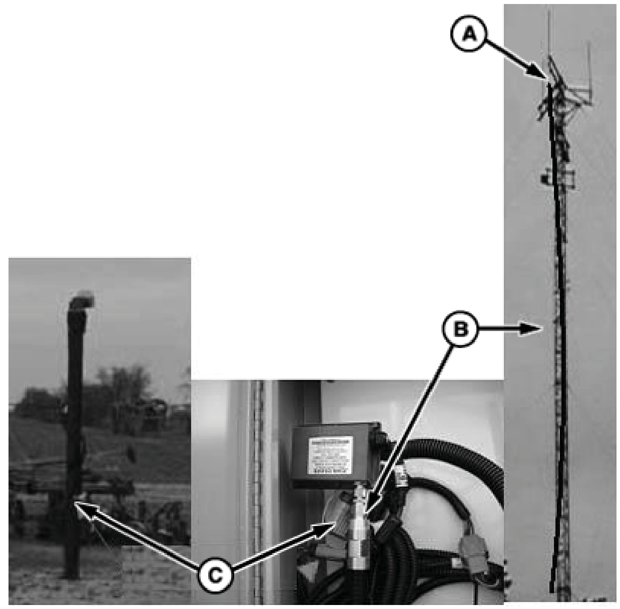
A—91.4 m (300 ft) RS232 Cable from receiver **B—Coax cable connection from antenna** **C—Coax running up tower to antenna** **D—Coax looped under electrical box**

This base station setup allows the placement of the receiver to be up to 91.4 m (300 ft) away from the radio, giving the base station an absolute clear view of the sky.

Continued on next page JS56696,00005E3 -19-13MAY09-1/2

The radio, usually installed in a secure location at the bottom of a tower, is then connected to low loss coax that is ran up the tower to the antenna.

A—Antenna
B—Low-Loss Coax Cable
C—91.4 m (300 ft) RS232 Cable



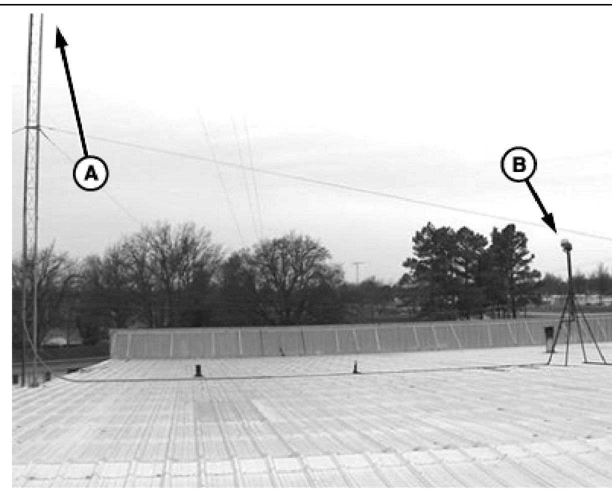
PC9557 —UN—06NOV06

JS56696,00005E3 -19-13MAY09-2/2

Utilizing The RTK Extension Harness

This base station setup allows you to mount the receiver at a secure location and mounting the radio, with antenna, to an elevated position, and utilizing 91 m (300 ft) of RS232 cable between the receiver and radio.

A—Radio mounted on tower
B—Base Station Receiver



PC8762 —UN—16SEP05

JS56696,00005E4 -19-13MAY09-1/1

Utilizing A Repeater

This base station setup allows the placement of the receiver and radio in a location with no obstructions. A repeater, with its own power source, is placed at an elevated location. The base station radio sends its signal up to the repeater and the repeater then sends out the signal.

NOTE: With this type of base station setup, no other repeaters can be used with the base station.

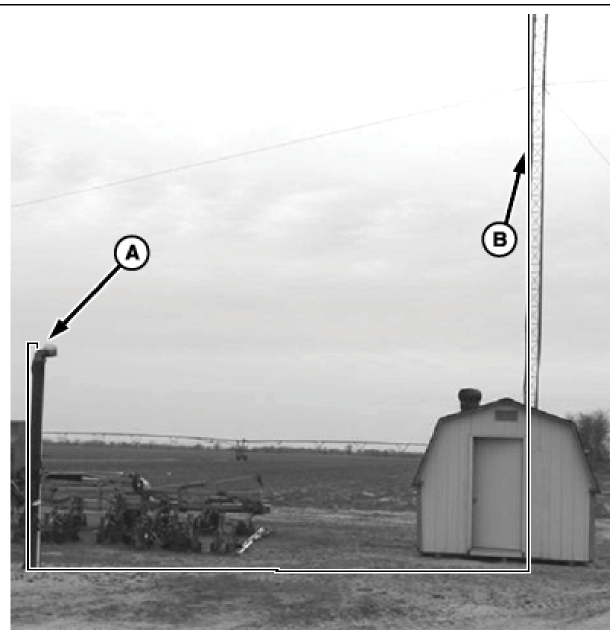
PC8761 —UN—16SEP05

JS56696,00005E5 -19-13MAY09-1/1

Utilizing Just Low Loss Coax Cable

This base station set up leaves the receiver and radio in a secure location and using low loss coax cable running to the antenna at an elevated position.

A—Receiver and Radio **B—Coax Cable**



PC8763 —UN—16SEP05

JS56696,00005E6 -19-13MAY09-1/1

Leaving The Radio And Receiver As A Single Unit

This base station setup keeps the receiver and radio as a single unit usually mounted in an elevated location.

IMPORTANT: Receiver must have a clear view of the sky and must be free of Multipathing.

The receiver must not move. Any movement of the receiver will result in movement of the vehicle receivers.

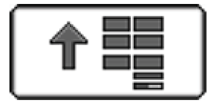
PC9558 —UN—06NOV06

JS56696,00005E7 -19-13MAY09-1/1

Accessing GREENSTAR 2 Diagnostic Addresses

PC8664 —UN—05AUG05

MESSAGE CENTER button (showing time)



PC8663 —UN—05AUG05

MENU button

Message Center screen can be reached by pressing MESSAGE CENTER button (showing time) or MENU button then MESSAGE CENTER button (With Info Icon).

PC8655 —UN—05AUG05

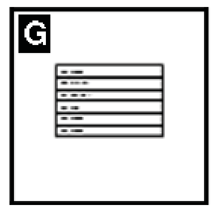
MESSAGE CENTER button (With Info Icon)

JS56696,00005E8 -19-13MAY09-1/3

Select Diagnostic Address icon (softkey G)

Message center will display all active warning, alert messages and icons.

PC8668 —UN—05AUG05



DIAGNOSTIC ADDRESSES softkey (G)

Continued on next page

JS56696,00005E8 -19-13MAY09-2/3

DECLARATION OF JEFFREY J. CARLISLE

I, Jeffrey J. Carlisle, hereby make the following declarations under penalty of perjury.

1. I am Executive Vice President, Regulatory Affairs and Public Policy of LightSquared Inc. ("LightSquared"). In that capacity, I am responsible for all domestic and international regulatory and policy matters on behalf of LightSquared, including those at the FCC.

2. I have reviewed the foregoing Petition for Reconsideration, and certify that, to the best of my knowledge and belief, the factual assertions in the Petition are truthful and accurate.

/s/ Jeffrey J. Carlisle
Jeffrey J. Carlisle

Executed: October 14, 2011

CERTIFICATE OF SERVICE

I, Curleen Brothers, hereby certify that on this 14th day of October, 2011, I caused a true copy of the foregoing "Petition for Reconsideration" to be served by first class mail, postage pre-paid, upon the following:

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EXHIBIT 6

DR. COLEMAN BAZELON,
IMPLICATIONS OF REGULATORY INEFFICIENCY FOR INNOVATIVE WIRELESS INVESTMENTS

Implications of Regulatory Inefficiency For Innovative Wireless Investments

Coleman Bazelon

The Brattle Group, Inc.

March 15, 2012

Acknowledgments: This research was sponsored by LightSquared and draws heavily on two previous papers of mine, "GPS Interference: Implicit Subsidy to the GPS Industry and Cost to LightSquared of Accommodation," July 22, 2011 and "Cost of Regulatory Risk for Wireless Spectrum Values," August 23, 2011. I would like to thank Florin Dorobantu, Annie Valkova, Jenna Yang, and Giulia McHenry for their invaluable help in preparing this paper. All errors remain mine.

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I. INTRODUCTION

Radio spectrum is a scarce resource and care must be taken to ensure that it is put to its highest valued uses.[1] The actual value of spectrum licenses—either at auction or in secondary markets—is driven by the expected value derived from this future use. To allow market forces to help facilitate spectrum deployed to its highest valued purpose, the right to its use must be traded at a value reflecting the economic and social value of that service. Any impairment to the rights associated with a spectrum license, or any government support to a lower valued service, will limit the extent to which spectrum is used for its highest valued uses.

For this reason, maintaining regulatory transparency and objectivity, and minimizing regulatory risk, is crucial to preserving the substantial value of radio spectrum licenses needed to ensure private investment maximizes its value. Furthermore, fair and equal treatment of both incumbent users and new potential users is necessary to ensure that spectrum continues to be allocated to its highest valued uses. One important aspect of this is ensuring that when new uses of spectrum are more valuable than old, new users are able to gain access to spectrum and obtain capital to build out new networks.

Setting aside the significant direct economic harm to LightSquared and U.S. wireless broadband consumers caused by derailing LightSquared's deployment of LTE,[2] this

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1 See the Principle of Spectrum Reallocation as discussed in "Oral Testimony of Coleman Bazelon," *The Brattle Group, Inc.* U.S. House of Representatives, Committee on Energy and Commerce Subcommittee on Communication and Technology (April 12, 2011). Found at: http://democrats.energycommerce.house.gov/sites/default/files/image_uploads/Testimony_04.12.11_Bazelon.pdf (last visited June 20, 2011).

2 By making intensive use of otherwise underused spectrum, LightSquared would introduce wireless broadband services into the marketplace that create approximately $12 billion in value to the economy and potentially 10 times that amount or $120 billion in benefits to consumers.

Further, LightSquared has already made substantial investments in infrastructure to integrate its existing satellite services with a nationwide 4G LTE network in the L-Band. Through a series of secondary market trades, LightSquared has accumulated the license rights to 46 MHz of spectrum in the L-Band. Additionally, as of February 15, 2012 the company had invested $4 billion to build and launch a next-generation satellite system for integrated satellite and 4G terrestrial LTE network, and invested heavily in developing and deploying a terrestrial network as part of an integrated, nationwide network. Without authority to provide terrestrial and satellite service in the L-Band, however, LightSquared's plans will be halted and its investments will be lost. See paper addresses two critical ways in which, by preventing LightSquared from deploying a terrestrial wireless broadband network in the L-Band for the foreseeable future, the FCC will distort future reallocations of radio spectrum and limit further investment in valuable new spectrum related services. In particular, I focus on the cost imposed on future investment by the regulatory uncertainty caused by effectively revoking LightSquared's Ancillary Terrestrial Component ("ATC") license authority[3] This inefficiency is compounded by the market distortion resulting from the continued support of the commercial GPS industry in the form of subsidy and effective rights to the L-Band. This subsidy offers support to less valuable services that would otherwise not be undertaken. By allowing GPS users to occupy the L-Band the FCC is also incentivizing incumbent users to not make important investments to accommodate new users.

Furthermore, permitting the GPS industry to effectively occupy spectrum that it is not authorized to use creates a serious "moral hazard." If incumbent GPS manufacturers and users are allowed to continue occupying spectrum that is not licensed for their use, even at the expense of another licensee, they have little incentive to invest in technology to mitigate the potential interference problem their unauthorized use creates. To the extent that additional users in neighboring spectrum bands would cause some inconvenience to GPS users, blocking such users actually rewards the GPS industry for not cooperating. The GPS industry could mitigate any potential harm and effectively limit its spectrum usage to the GPS assigned spectrum by deploying more robust receiver technology, developing better filters, and otherwise using the spectrum more efficiently. However,

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"LightSquared Response to FCC Public Notice Statement from Sanjiv Ahuja, Chairman and CEO of LightSquared," LightSquared Press Release, February 15, 2012. Found at: http://www.lightsquared.com/press-room/press-releases/lightsquared-response-to-fcc-public-notice/ (last visited February 26, 2012).

For a complete discussion of the benefits of LightSquared's plan and related issues, see Coleman Bazelon "GPS Interference: Implicit Subsidy to the GPS Industry and Cost to LightSquared of Accommodation," *The Brattle Group*, June 22, 2011.

3 On February 15, 2012, the International Bureau of the FCC proposed to (i) vacate the Conditional Waiver Order that would have permitted LightSquared to deploy a terrestrial-only service on a wholesale basis, and (ii) suspend indefinitely all or a substantial portion of LightSquared's underlying ATC authorization, amounting to effective revocation of this license. See, "International Bureau Invites Comment on NTIA Letter Regarding LightSquared Conditional Waiver," *FCC Public Notice*, DA 12-214 (February 15, 2012). Found at: http://apps.fcc.gov/ecfs/document/view?id=7021860418 (last visited March 15, 2012).

without recourse for not attempting to mitigate its interference issues, the GPS industry has no incentive to make such investment.

By revoking LightSquared's license for a terrestrial build-out, the FCC will increase regulatory uncertainty regarding the security of rights tied to FCC licenses. This regulatory uncertainty would, in turn, increase the attendant costs and reduce the value of holding radio spectrum licenses. As a result, these added costs would decrease the potential receipts from spectrum auctions, as well as the value of spectrum traded on the secondary market. In fact, early results on the volatility of firms investing in spectrum related services, such as Clearwire, suggests that the market has perceived additional uncertainty that did not exist prior to the FCC's announcement.

Meanwhile, the free use of the GPS system by the commercial GPS industry represents a service offered free of charge—at a subsidy—to a select group of firms. This distorts the true cost of investment to offer particular services and renders certain low value services, which would not otherwise be worthwhile, as profitable to the service operator. By effectively reducing the cost of operations exclusively for commercial GPS service providers, this benefit represents a form of "price support" to this industry alone.

More generally, by relenting to GPS industry requests and rescinding LightSquared's license despite the substantial value it is expected to create, the FCC might create—or reinforce—an expectation that the political process could be used to influence policy and prevent spectrum from being reallocated to its highest valued use. The FCC should operate in a fair-minded way by focusing on policies that benefit the consumer, while also ensuring that spectrum is used for its highest valued use whenever possible. The FCC's review process is typically understood to be a way for the FCC to gather information on the costs and benefits of a particular policy, and then make an informed decision, presumably on the facts. By allowing political interests to influence allocation decisions well outside the normal deliberative process, the FCC would create even more uncertainty and exacerbate the element of political strategy into what should otherwise be a fact driven regulatory process.

A. SOURCES OF SPECTRUM VALUE

Transferring spectrum licenses to firms and investors interested in building wireless networks maximizes both social welfare and economic value. For spectrum licenses to maintain their highest value they must meet at least two criteria: (1) that they are easily transferable and (2) that the bundle of rights tied to a spectrum license is not diminished. Similar to any asset, if the value of the spectrum license can not be traded and its usefulness diminishes over time, then the asset loses value. Wireless broadband service is currently one of these highest valued uses of radio spectrum—both in terms of economic value and social welfare. Deploying an ATC to a satellite network is one such opportunity to assure spectrum is put to its highest valued use.

Since the expected value of radio spectrum licenses is driven by the present value of future expected cash flows from the services enabled, any factor that decreases the value of those expected cash flows has a negative effect on spectrum value. For instance, license restrictions imposed by the FCC and various other encumbrances to the spectrum can have a substantial impact on the value of spectrum by increasing deployment costs, and decreasing capacity and revenues. Similarly, any factor that increases the risk or uncertainty related to deploying spectrum or receiving revenue will reduce the current value of its expected revenue and cash flow.[4]

B. IMPLICATIONS OF UNCERTAINTY FROM SUSPENDING LIGHTSQUARED'S SPECTRUM AUTHORITY

One potential source of uncertainty for the expected revenues of a spectrum license is regulatory risk. In addition to the conventional sources of risk related to the telecom industry and wireless broadband spectrum business overall—such as uncertainty about future demand and technology—government regulation can be another serious source of

[4] Other factors that either increase costs or decrease expected revenues include the quality and physical characteristics of the spectrum, the cost of clearing incumbent users from the spectrum, and the cost of network build-out. For further discussion of factors that impact spectrum value, see Coleman Bazelon, "The Economic Basis of Spectrum Value: Pairing AWS-3 with the 1755 MHz Band is More Valuable than Pairing it with Frequencies from the 1690 MHz Band," The Brattle Group (April 11, 2011). (Herein "Bazelon, "Economic Basis of Spectrum Value," 2011"). Found at: http://www.brattle.com/NewsEvents/NewsDetail.asp?RecordID=945 (last visited July 17, 2011).

added uncertainty and reduced revenue expectations.[5] In fact, regulatory risk is not unique to the telecom industry, and is likely to decrease values in a variety of regulated industries, including natural gas pipelines, energy utilities, and various other regulated industries.[6]

Historically the FCC has been attentive to the costs that can be imposed by increased regulatory risk. For instance, it has exercised its authority to revoke licenses sparingly.[7] Similarly, most licenses auctioned come with "a high renewal expectancy,"[8] even though the licenses are based on a fixed term and the FCC is not obliged to renew them. This "expectancy" was created by the FCC in an attempt to reduce uncertainty about what would happen at the end of a license term and, thereby, increase the value to bidders of licenses at auction. Such long-term certainty provides the incentives for licensees to continue to invest in their networks even as the license expiration approaches.

Until now, license holders have not anticipated the FCC revoking licenses as a significant concern, as they do in some industries. License holders relied on the certainty that if they purchase a spectrum license and invest in the infrastructure required to transmit services,

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5 The Chairman of the FCC recently recognized this very point. See FCC Chairman Julius Genachowski Remarks As Prepared for Delivery, GSMA Mobile World Congress, Barcelona (Feb. 27, 2012), 3-4 (recognizing that that "[w]ireless infrastructure doesn't build by itself. It requires many billions of dollars in investment – overwhelmingly by private companies. . . . In our work, we've recognized that regulatory certainty and predictability promotes investment.").

6 For further discussion on regulatory risk, see Laurence A. Kolbe, William B. Tye, and Stewart Myers. *Regulatory Risk: Economic Principles and Applications to Natural Gas Pipelines and Other Industries*. Kluwer Academic Publishers. Massachusetts: 1993.
For a European perspective, see Burkhard Pedell, *Regulatory Risk and the Cost of Capital*, Springer 2006.

7 There are cases of FCC licenses revoked for failing to meet the criteria of a license. For instance, in September 2010 MSS provider Globalstar lost its ATC authority for failing to meet gating criteria for ATC deployment in a timely manner. See *Globalstar Licensee, LLC Application for Modification of License to Extend Dates for Coming into Compliance with Ancillary Terrestrial Component Rules,* DA 10-1740, Order, 25 FCC Rcd 13114 (2010). Available at: http://transition.fcc.gov/Daily_Releases/Daily_Business/2010/db0914/DA-10-1740A1.pdf (last visited March 15, 2012).

8 Gregory L. Rosston and Jeffrey S. Steinberg, "Using Market-Based Spectrum Policy to Promote the Public Interest," *White Paper* (January 1997). Available at: http://wireless.fcc.gov/auctions/data/papersAndStudies/spectrum.txt (last visited March 14, 2012).

the rights associated with their license will be maintained. Further, buyers on the secondary market have had the same assurance that the rights associated with any license they purchase will be maintained once the license is transferred. This certainty has likely resulted in relatively lower costs of borrowing for license holders, increased the expected cash flow from licenses, and allowed for greater transparency in the secondary market—all of which likely increased the value of spectrum licenses.

By effectively revoking LightSquared's ATC authority in the L-Band the FCC would signal a new level of uncertainty in FCC policy. Such action would introduce the possibility that other current and future license assignments may also be revoked or suspended. Even more, such revocation would be caused not by actions that the licensee has taken, or even could take, but rather by other users (who in this case are not even spectrum licensees) who are not living within the boundaries of their authorized parameters.[9] Furthermore, by revoking LightSquared's ATC authority the FCC will effectively suggest that there is potential for such action regardless of investments made, or of the consumer and social benefits associated with a given new or innovative use of a band of spectrum.

If the FCC were to signal a willingness to suspend or revoke spectrum licenses in such circumstances, this new uncertainty could reduce the expected value of *all* spectrum licenses in two important ways. First, given the risk that the FCC could revoke or

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9 These interference issues are not the result of LightSquared signals intruding into GPS spectrum, but rather they are due to existing GPS devices that do not filter spectrum beyond the GPS allocated spectrum bands. LightSquared has ensured that their spectrum will not interfere with GPS frequencies by developing base station filters that effectively cut off all signals above 1559 MHz. GPS users acknowledge there is no problem with out-of-band emissions. See Coleman Bazelon, "GPS Interference: Implicit Subsidy to the GPS Industry and Cost to LightSquared of Accommodation," *The Brattle Group White Paper* (June 22, 2011). Found at http://www.lightsquared.com/wp-content/uploads/2011/06/LightSquared625pm.pdf (last visited July 30, 2011). (Herein "Bazelon, "GPS Interference," 2011"). This cites Tim Farrar, "Fixing the GPS interference problems," TMF Associates MSS blog (April 6, 2011). (Herein "TMF Associates, April 6, 2011"). Found at: http://tmfassociates.com/blog/2011/04/06/fixing-the-gps-interference-problems/ (last visited June 20, 2011). According to John Deere, "[out of band emissions] is not a problem in the GPS band if LightSquared filters their signals as they have committed." See John Deere Presentation to FCC, attached to Electronic Filing regarding Notice of Ex Parte Presentation in LightSquared Subsidiary LLC Request for Modification of its Authority for an Ancillary Terrestrial Component. IBFS File No. SAT-MOD-20101118-00239 (March 21, 2011).

suspend a license there would be some probability that any project could be stopped in its tracks. Without a license, services that relied on that spectrum would have to be halted, and future revenues and cash flows would be lost. Second, the possibility that cash flow might be zero increases the probability that, with zero cash flow, the license holder will default on its debt obligations.[10] A higher likelihood of default, in turn, would increase the cost of debt.

C. GPS Industry Lack of Mitigating Investment Despite Implicit Subsidy[11]

By allowing commercial users free use of the GPS satellite system, the U.S. government further distorts the true market value of GPS services and makes them appear to be more valuable relative to other services associated with spectrum. Because they do not pay for the service, commercial GPS users do not incur the full cost of network investment associated with their services. Low valued services that appear to be profitable under the current subsidies would not be offered if commercial users incurred their true cost. This distorts the true value of GPS services, making them appear relatively more profitable than they otherwise would relative to other types of spectrum services.

Furthermore, GPS users have enjoyed an additional benefit—the cost savings by not deploying filtering technology so that they can exist with higher powered signals in the adjacent band. As a result, GPS users have not been incurring the true cost of providing their services. Rather than investing in the technology so that GPS devices only operate

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[10] There is a third potential impact of increased risks on spectrum value—the potential to change the 'beta' of a company and, therefore, its cost of equity. It is unclear if this channel would be applicable here, or even the direction of the impact if there was one, so it will not be considered in what remains.

[11] According to the GAO, a subsidy includes:

> A payment or benefit made by the federal government where the benefit exceeds the cost to the beneficiary. Subsidies are designed to support the conduct of an economic enterprise or activity, such as ship operations. They may also refer to (1) provisions in the tax laws for certain tax expenditures and (2) the provision of loans, goods, and services to the public at prices lower than market value.

See Government Accountability Office, "A Glossary of Terms Used in the Federal Budget Process," GAO-05-734SP (September 2005), p. 92. Available at: http://www.gao.gov/new.items/d05734sp.pdf (last visited August 12, 2011).

in the spectrum they have been allocated, GPS users have been using the adjacent spectrum in the L-Band without proper compensation to the rightful license holders of the spectrum.

In addition to distorting the true cost of the spectrum, by allowing GPS users to continue occupying spectrum they are not authorized to use, the FCC ruling would create a moral hazard, disincentivizing the efficient use of spectrum. Incumbent users have reduced incentives to mitigate potential harms if the fact that they will be harmed—even if as a result of their own inaction—can be a basis for blocking efficiency-enhancing spectrum reallocations. Such action by the FCC would signal to incumbent users that they should forego investments that might help accommodate new spectrum users. Just as fire insurance reduces the incentive to install sprinklers and make other fire mitigation investments, the FCC's acceptance of the GPS industry's unmitigated interference claims creates a moral hazard that diminishes the incentive for efficiency enhancing investments.[12]

By offering services and applications that utilize the GPS satellite network, commercial GPS device manufacturers enjoy a substantial implicit subsidy from the U.S. government. Unlike most commercial users of radio frequencies, commercial GPS users enjoy the privilege of using the GPS satellite network at no cost. In contrast, once they acquire FCC spectrum licenses, commercial wireless broadband providers must invest billions of dollars to build and maintain a network of transmission sites or satellites in order to provide services to customers. If the GPS satellite network was privately held or not provided to users for free, GPS service providers would either have to pay for some sort of GPS service license, or build and maintain such a satellite navigation system privately. Below, I estimate the total value of this subsidy to be worth $18 billion to U.S. commercial GPS users.

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[12] This moral hazard in the FCC interference resolution process has been identified previously by Professor Thomas Hazlett. Professor Hazlett wrote that the FCC rules process "create[s] a moral hazard for incumbents who are rewarded for raising interference complaints simply to block competition." For further discussion of the issue of moral hazard in the FCC's rules process see Thomas W. Hazlett, "Liberalizing US spectrum allocation," *Telecommunications Policy*, 27 (2003), pp. 485 – 499 (herein "Hazlett (2003)"), at p. 486.

The next section discusses the costs associated with the added regulatory uncertainty that would be imposed if the possibility of license revocation or suspension increases. Section III discusses the subsidy enjoyed by the commercial GPS users who offer products that use the GPS satellite network free of charge. Finally, Section IV addresses how these two distortions are likely to affect the value of spectrum and the implications of lower spectrum values.

II. THE COST OF REGULATORY RISK

By effectively revoking all or a substantial portion of LightSquared's ATC authority and L-Band spectrum license, the FCC is effectively signaling a willingness—absent licensee malfeasance—to revoke spectrum licenses even after capital investments have been made on projects that had substantial consumer and societal benefit. The analysis below assumes that by revoking a wireless broadband license the FCC increases the perceived probability that it will take such measures on any wireless spectrum license. It is very difficult, and largely speculative, to estimate the exact change in perceived risk that would result if the FCC increases market uncertainty by revoking a spectrum license. I employ a simple cash flow model similar to one that might be used to evaluate the costs and benefits of investing in a wireless broadband network. To illustrate that even a small increase in the probability of losing a license has significant impact, this analysis assumes a 5% increase in risk of license revocation. Sensitivity analyses show how these results are reasonably robust to the level of risk induced by any FCC action and various other parameters of our model.

My results suggest that an added 5% risk of the FCC revoking a spectrum license and stopping a project after 2 years decreases its value by just over 10%. My model shows that this added risk has two separate impacts on value. Because the value of a wireless broadband spectrum license is equal to the present value of future expected cash flows, an additional 5% chance that the services will be stopped and net revenue will fall to zero results in a lower present value. This direct effect from the change in expected cash flows alone reduces the value of the spectrum license by 6%.[13]

There is also an indirect impact of increased risk on the discount rate used to calculate the present value of cash flows accounts for the additional 4% reduction in value. This additional risk works through the firm's ability to borrow money to finance its activities. If the project is halted and net revenue is then zero, the debtors are at risk of not being repaid.[14]

A. VALUE OF A SPECTRUM LICENSE

As with any capital investment, the net return of investing in a band of spectrum will be realized over time. The upfront capital investment in a spectrum license is expected to result in a stream of annual cash flows (revenue, minus capital expenditures and operating costs) over time. The value of the investment and expected stream of profits depends critically on the timing of these returns. The present value of any future payment is equal to the amount you would need to invest today to receive that future payment. For instance, given an interest rate of 5%, the present value of $105 next year is $100 today. This value today of this stream of revenues and costs is captured by the net present value (NPV) of an asset.

The NPV of a capital investment represents the cash value today of the expected stream of net returns (revenues minus costs) that an investment is expected to yield over its lifetime. The present value of any investment is equal to the sum of the present value of each annual net return or cash flow (*CF*), discounted by the rate of return for that year.[15]

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[13] As discussed below, this loss is a little over 5% because there is a 100% probability of negative cash flows due to infrastructure investments in the first two years.

[14] The legal issue of 'regulatory takings' and any constitutional requirement for compensation is beyond the scope of the current analysis. There is no way to know how the FCC would behave in this situation.

[15] Aswath Damodaran, *Investment Valuation 2nd Edition*, New York, NY: John Wiley and Sons (2001).

$$NPV = \sum_{t=0}^{n} \frac{CF_t}{(1+R_t)^t}$$

Investments that have higher levels of risk must have higher expected rates of return (*R*) or, equivalently, higher discount rates. As a result, if the rate of return on an investment is higher, the NPV of each anticipated cash flow is more heavily discounted, and therefore lower, today.

If regulatory uncertainty results in a higher risk that there will be no future cash flows there will be two effects. First, expected cash flow from that project will be lower due to the probability that there are no net revenues after year-2. Second, the present value will be more heavily discounted through the use of a higher discount rate.

B. IMPACT OF REGULATORY UNCERTAINTY

To quantify the effects of decreased expected cash flow and added uncertainty that might result if the FCC begins revoking licenses, I employ a simple cash flow model. The assumptions in this model are based on observed cash flows of wireless broadband providers, as reported in company Annual Reports and other filings.[16] The model supposes an initial capital investment in network build-out estimated to take 4 years. The cost per year of this initial investment is equal to one third of the expected revenues in year-5 when the entire network is operational and a customer base has been established.[17]

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16 In particular, I reviewed the 2008 through 2010 Annual Reports of Verizon Wireless, U.S. Cellular, and Sprint.

17 Linking the amount of capital expenditure to the value of full service revenue ensures that capital investment for build-out is related to the revenue of the full capacity network. Assuming annual capital investment for the first 4 years is one-third of year-5 revenues implies that, based on the assumptions here, total capital expenditure is 40% of the total spectrum value with no regulatory uncertainty. This assumption is validated by LightSquared's own experience. LightSquared signed a deal with Nokia Siemens to build its LTE network for $7 billion. See Stacey Higginbotham, "Nokia Siemens Networks Wins $7B Contract to Build Harbinger's LTE Network," *Gigaom* (July 20, 2010). Found at http://gigaom.com/2010/07/20/nokia-siemens-networks-wins-7b-contract-to-build-harbingers-lte-network/ (last visited July 30, 2011). It is likely that $5 billion of this investment is upfront capital expenditures, which represents 42% of the total $12 billion value of the L-Band spectrum available to LightSquared for network build-out. See Bazelon, "GPS Interference," 2011.

Cash flows during this build-out phase are expected to be negative and operating costs are ramping up annually with service and build-out.[18]

Beginning in year-5, the model assumes a fully operational network, receiving full revenues and incurring operating expenses equal to 63% of capital investment.[19] After year-5, annual revenue growth is 5% and there are no further capital investments in infrastructure. In contrast to a typical balance sheet, but consistent with the typical cash flow of capital investments, the model assumes the cash outlay for capital investments is incurred in the first 4 years. Since we are modeling the possibility that the entire project is shut-down half-way through build-out, this assumption is a critical feature of the model. Finally, I assume that, unless the project is canceled after 2 years due to a revoked license, the project will generate revenue through year-30.[20]

i) Lower Expected Cash Flow

Based on these assumptions, there are two cash flow scenarios to consider. First, in the absence of regulatory uncertainty (*i.e.*, assuming there is no increased chance the FCC will revoke the license), the expected cash flow for any year is simply the expected revenue, less capital investment and operating expenditure. Second, if the FCC were to revoke the license, cash flows would be equal to the cash flows in absence of uncertainty

[18] In year-1, revenues and operating costs are equal to $0. In year-2, gross revenues and operating costs are 25% of year-5 revenues. In year-3 gross revenues and operating costs are 50% of year-5. Finally, in year-4, gross revenues and costs are assumed to be 75% of year-5. Operating expenses are 63% of total revenue per year, starting in year-2.

[19] This assumption allows me to model various expenses, such as consumer equipment subsidies, as a fixed share of revenues, thus significantly simplifying the calculations. Cash flow and operating cost assumptions based on observations from public income statements of three wireless carriers' (*i.e.*, Verizon, Cellco, Sprint and U.S. Cellular) for 2007 through 2009. I made similar modeling assumptions in a previous paper released in April 2011. See Bazelon, "Economic Basis of Spectrum Value," 2011.

[20] Because costs are tied to revenue, and revenue is assumed to grow at a constant rate, each annual cost and cash flow are essentially a multiple of year-5 revenues. With no loss in generality, I consider the case in which revenue in year-5 is equal to 1. The model can be scaled appropriately by multiplying revenues in year 5 by any estimate of revenues for a fully operational wireless network.

in years 1 and 2, but thereafter cash flows are equal to zero.[21] Assuming regulatory uncertainty creates a 5% chance the FCC will revoke any license, the expected cash flow under regulatory uncertainty is equal to the sum of a 95% chance of business as usual cash flows and a 5% chance of no cash flows after year-2. As a result, after year-2 the expected cash flows under uncertainty are 5% lower than the expected cash flows were in absence of this uncertainty. Total cash flows for all 30 years are a little more than 5% lower under regulatory uncertainty.[22] These calculations result in a stream of expected annual cash flows for 30 years.

ii) Higher Cost of Capital

In the absence of regulatory uncertainty, the only risks incurred should be associated with existing business related factors. Certainly, every enterprise incurs some risk of doing business. Some portion of this risk is inherent to the entire economy, while the rest is unique to the industry or sector. Sector specific risks often include market failures, technological uncertainties related to research and development, and the possibility of accidents. These general market and sector specific risks and uncertainties are reflected in the industry cost of capital, defined as the weighted average return from debt and equity by firms in the sector. The cost of capital, therefore, reflects general economic risks and sector specific business risks.[23]

For the purposes of this analysis, I use the weighted average cost of capital (WACC) for companies in the wireless networking sector of 8.8% to calculate the present value of 30 years of cash flows.[24] Based on my initial assumptions, if year-5 revenue is $1 billion,

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21 Based on the capital investment costs, cash flows in the first 2 years are negative, but although cash flows would continue to be negative in year 3 if the project continues, no costs are incurred once the project is halted. This assumption is conservative to the extent operators have signed development contracts with cancelation penalties.

22 A little more than 5% because the first 2 years of negative cash flows occur with 100% probability.

23 This includes any existing regulatory risks associated with spectrum licenses.

24 Cost of equity is 9.56% and cost of debt is equal to 5.29%, or 4.48% after tax. These costs are based on 48 telecommunications companies in the wireless networking sector. For detailed cost of capital information on a variety of sectors, and the companies included in the wireless

for instance, the total value of a spectrum license is $3.3 billion with no increased regulatory uncertainty. Using the existing industry discount rate, but assuming the expected cash flow is based on a 5% probability the FCC might revoke a license, the present value of spectrum is 6% lower, or $3.2 billion. See Table 1 below.

Because long-lived assets such as spectrum licenses are typically financed with debt, I assume that the average debt to equity ratio is 75/25, as opposed to 15/85 estimated more generally for the wireless networking sector. Assuming that the WACC remains 8.8%, I recalculate the cost of debt and equity to be 5.4% and 21.0%.[25] I use this cost of debt and debt to equity ratio to calculate the total debt payments associated with investing in a spectrum license.

This particular regulatory risk associated with the FCC revoking an existing spectrum license is different from normal business cycle related risks, in that it is asymmetric. That is, this uncertainty introduces the possibility that, if a license is revoked, there will be zero return on investment, without any offsetting increase in the possibility that cash flows and profits will be higher.

The regulatory uncertainty likely induced by the FCC if it suspends LightSquared's ATC authority in the L-Band could increase the cost of debt by introducing the probability of default (modeled here as occurring in year-3) if the FCC revokes the license. The cost of debt must ensure that debtors are indifferent between lending under no uncertainty and lending in the presence of regulatory risk. Assuming a 5% regulatory risk and a 75/25 debt to equity ratio, the cost of debt (before taxes) increases to 5.84%, nearly 8% higher than under regulatory certainty.[26] As the cost of debt increases the weighted average cost

networking sector see Aswath Damodaran, "Cost of Capital by Sector," webpage on Damodaran Online. Updated as of January 2011. Found at: http://pages.stern.nyu.edu/~adamodar/New_Home_Page/datafile/wacc.htm (last visited July 29, 2011). (Herein "Damodaran Online").

25 Calculations based on unleveraged beta of 1.08, a risk free rate of 4.2% and a risk premium of 4.3%. See Damodaran Online.

26 In order to calculate the updated costs of debt, I assume that the debt is a lump sum equal to 75% of the present value of the spectrum license over 30 years, as calculated with the no additional uncertainty WACC (8.8%). I apply the original cost of debt (5.29%) to the expected payment

of capital also increases to 9.08%. In turn, the higher cost of capital (higher discount rate) pushes the present value of cash flows down to $3 billion. See Table 1 for a summary of results. Combined with the lower expected cash flow, the present value of spectrum drops by 10% over the case of no additional regulatory uncertainty.

Table 1. Impact of Regulatory Risk on Spectrum Value Assuming 5% Increase in Probability License is Revoked

		Cost of Debt (Percent) [1]	WACC (Percent) [2]	Present Value of Spectrum Cash Flow ($Billions) [3]	Discount on Present Value of Spectrum Cash Flow Due to Regulatory Risk (Percent) [4]
[A]	No Regulatory Risk	5.29%	8.80%	$3.35	
[B]	Regulatory Risk of License Revocation Increased by 5% in Cash Flow with No Change in WACC	5.29%	8.80%	$3.15	6%
[C]	Regulatory Risk of License Revocation Increased by 5%	5.84%	9.08%	$3.01	10%

Sources & Notes:
[1][A], [1][B]: Cost of Capital for Wireless Networking sector found at Damodaran Online, <http://pages.stern.nyu.edu/~adamodar/New_Home_Page/ datafile/wacc.htm>.
[1][C]: The Brattle Group Calculation.
[2]: [1]*75% + Cost of Equity*25%, where cost of equity (9.02%) is found on Damodaran Online, <http://pages.stern.nyu.edu/~adamodar/New_Home_Page/ datafile/wacc.htm>.
[3]: The Bratle Group Calculation.
[4]: 1 - [3] / [3][A], for the respective case.

The analysis above assumes that if the FCC suspends LightSquared's license as proposed, the probability that the FCC will suspend or revoke a license in the future will increase by 5%. This magnitude of the increase in risk is largely speculative; that some increase in risk will result, however, is not speculative. It would likely be difficult to determine what the impact would be until it occurs. The results of this model remain reasonably consistent to a range of potential risks. In particular, for any increase in the probability of a revoked spectrum license, the percent change in spectrum value is close to double that probability or added risk. Furthermore, the base cost of debt and equity, as well as the

streams in the case of no regulatory uncertainty. This yields a stream of annual payments such that the entire debt and interest is repaid at the end of 30 years. Next, using the total payment to debtors from this stream of payments under no added regulatory risk, I calculate the cost of debt and expected stream of payments under each risky scenario that will yield the same expected total sum of payments to the debtor.

revenue and cash flow assumptions of the stream of payments are much less influential. The appendix includes a more complete discussion of these sensitivities.

C. Early Signs of Added Uncertainty

Beyond the impacts on LightSquared, however, the FCC's tentative decision is expected to increase uncertainty about the security of future spectrum allocations and assignments. Although many factors affect the value of spectrum, there is some evidence that the recent FCC proposed decision was perceived by the market to increase the uncertainty in the security of rights to future spectrum assignments.

If the FCC's announcement regarding LightSquared were to increase the perceived uncertainty associated with the certainty of spectrum access rights, one would expect to see an increase in the implied volatility measure[27] for stocks of firms that rely heavily on wireless licenses. More specifically, this increase in volatility should be particularly strong for firms that, like LightSquared, have nascent new business models for deploying spectrum in the near future. For example, Clearwire might be particularly vulnerable to this type of regulatory uncertainty, because it is currently planning its wireless broadband build-out and relying on repurposing existing spectrum licenses.

In fact, recent stock activity since the FCC's tentative decision was announced does suggest increased volatility in spectrum related stocks. At the time the FCC issued its Statement in response to the NTIA letter on February 14, 2012 and its *Public Notice* the next day, the implied volatility of ClearWire increased markedly more than both the overall market and firms that rely on older and/or more established/firmer spectrum bands. See Figure 1. Although many things effect the perceived volatility of an investment, the sharp uptick in the implied volatility of ClearWire's stock when the recent LightSquared announcement was made is certainly indicative of the negative impact on investments discussed herein.

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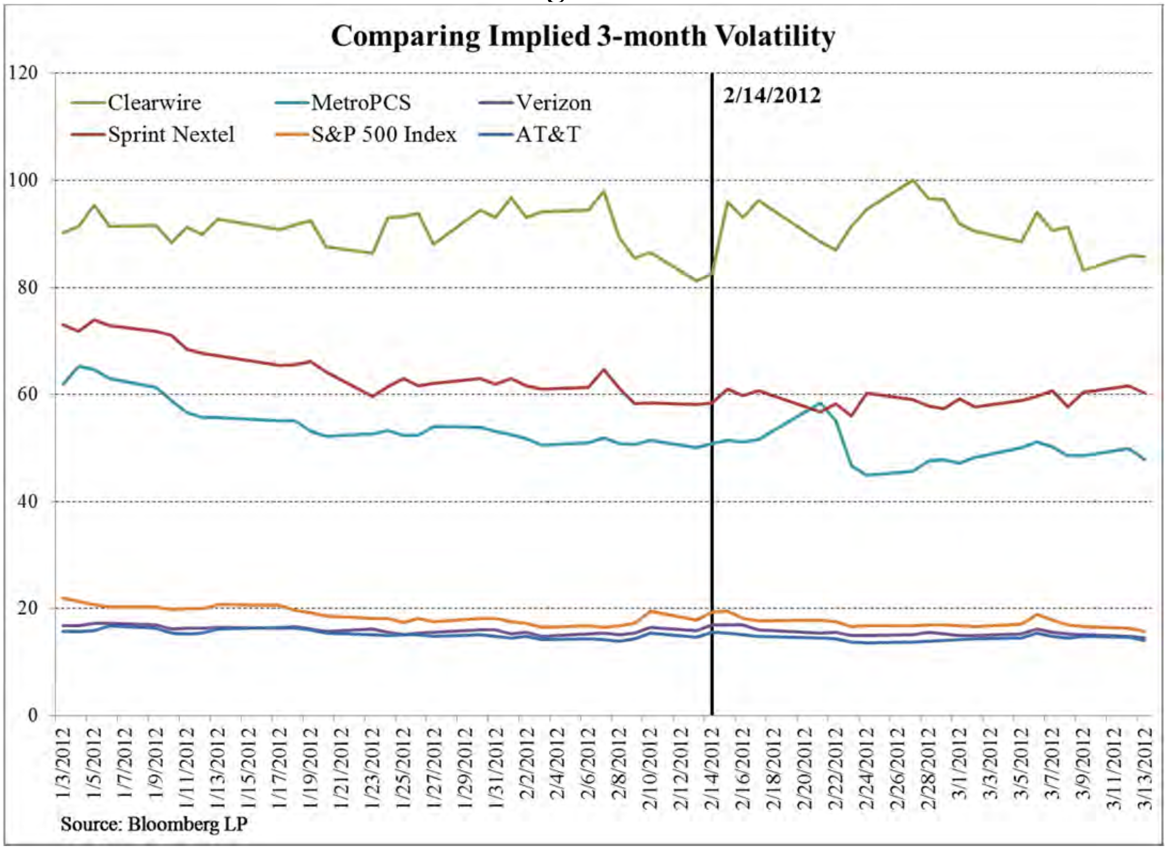
[27] This is the measure of future volatility in the underlying security implied by the value of options to buy or sell the underlying security, as calculated by Bloomberg for the 3-month implied volatility. Bloomberg calculates the 3-month implied volatility as the weighted average of the two put options closest to the at-the-money strike. See Bloomberg.

Figure 1



D. IMPLICATIONS OF LOWER SPECTRUM VALUES

Clearly, any factor that reduces the value of licensed spectrum will impact future investments in the wireless industry in a number of ways. For instance, lower spectrum values would result in lower FCC auction receipts. If the expected value of the NBP's suggested 500 MHz of spectrum was worth $100 billion,[28] a 5% increase in license revocation risk could reduce the value of that spectrum by as much as 10% or $10 billion. Perhaps more important than the direct impacts on federal auction receipts, however, is the impact of lower expected returns on private sector investment in wireless broadband.

Any investment project, either deploying wireless networks or some alternative, is a balance of revenues and costs. If the expected revenues exceed the expected costs, then an investment is profitable and worth undertaking. Higher expected cash flows imply

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28 See, for example, Coleman Bazelon, "Expected Receipts From Proposed Spectrum Auctions," *The Brattle Group* (July 28, 2011). Found at: http://www.brattle.com/_documents/UploadLibrary/Upload964.pdf (last visited August 9, 2011).

greater expected profits and more attractive investment opportunities. Added regulatory uncertainty implies that some previously profitable projects will no longer be undertaken. Even for wireless broadband projects that continue to be profitable under such uncertainty, lower returns will make investing less attractive than alternative investments not impaired by increased license revocation risk. In turn, finding investors will be more difficult and even profitable projects will be delayed.

III. IMPLICIT SUBSIDY TO GPS INDUSTRY

By using the GPS satellite network free of charge, commercial GPS device manufacturers enjoy substantial benefits at no cost, effectively reducing their network investment costs to zero and distorting commercial GPS users' investment decisions.

In order to offer the same geo-location services they do today without the U.S. Government's GPS satellite network, these commercial users would have to rely on some equivalent system. This is a cost that the commercial GPS users do not face, because the Federal Government allocates valuable spectrum for GPS transmissions and invests in GPS satellite infrastructure and operations, but does not charge commercial users for the use of the spectrum or these GPS services. The implicit subsidy to commercial GPS users is then the opportunity cost they would face in order to offer the same services to their customers if they could not use the U.S. Government's GPS satellite system or the spectrum for transmission for free. Since there are no commercial alternatives presently available, commercial users would have to build a satellite system capable of offering commercial geo-location services.

A commercial system would certainly require some backup service, but might not find the same level of reliability required by the DOD economical to provide. Though many GPS devices are designed to work worldwide, for the purposes of this analysis, I assume that a commercial GPS system would only need to cover the continental U.S.[29] An

[29] Certainly there are some U.S. commercial GPS services abroad—for example tracking cargo—but these uses are limited and it is likely not worth the incremental value of building a global satellite network. To be conservative, therefore, this analysis assumes these users pursue alternative technologies, and a more limited U.S. only network is sufficient. This estimate is even further discounted by not including Alaska or Hawaii.

alternative, commercially focused GPS system would likely require fewer satellites than the current GPS network provided by the U.S. military. As discussed below, in order to build a GPS satellite system sufficient for U.S. commercial purposes only, a reasonable estimate is that it would require at least 18 functioning satellites.

For a GPS receiver to provide an accurate estimate of its position on the Earth's surface, it must be able to receive signals from 4 separate GPS satellites.[30] These signals together are sufficient to identify the receiver's time, latitude, longitude, and altitude. A GPS satellite system that provides service anywhere in the United States must be able to offer a user full view of at least 4 satellites at any given time and location. Satellites rotate around the earth in orbital planes that must pass over the equator. Placing at least 4 satellites in an orbit ensures that, if you are within range of an orbit from a given position on the earth's surface, you will be in view of a satellite in that orbit.

For a configuration similar to the existing U.S. NavStar-GPS satellite constellation, ensuring complete coverage in the continental U.S. would require at least 18 satellites, including 16 in operation and 2 spares in orbit.[31] The existing U.S. NavStar-GPS satellite constellation is comprised of 6 orbital planes, each of which requires a minimum complement of 4 satellites[32] in medium-altitude orbit.[33] This guarantees the user a view

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[30] See "NAVSTAR GPS User Equipment Introduction," *United States Coast Guard Navigation Center*. September 1996, p. 13. Found at: http://www.navcen.uscg.gov/pubs/gps/gpsuser/gpsuser.pdf (last visited June 20, 2011).

[31] In addition to the possibility of satellite failure, GPS satellites must regularly be temporarily taken off line in order to make adjustments to their orbits. A constellation, therefore, should be designed to work with 1 satellite offline for maneuvering even when another satellite has failed. This suggests a minimum of 2 spare satellites. This is consistent with the 2008 Department of Defense Performance Standards, which consider the failure of up to 2 satellites in their calculations of GPS receiver accuracy. See GPS Service Performance Standard, 2008, p. B-14.

[32] For official U.S. Government Information about the Global Positioning System and related topics see "Space Segment," webpage at GPS.gov. Found at: http://www.gps.gov/systems/gps/space/ (last visited June 20, 2011).

[33] Some systems deploy a handful of geo-stationary high-orbit satellites, such as the Chinese COMPASS GPS network. However, a full network of geo-stationary satellites could not be designed, as all of these satellites must occupy a single orbital plane. See "Astrophysicist Q&A," *NASA Goddard Space Flight Center*. April 1997. Found at: http://imagine.gsfc.nasa.gov/docs/ask_astro/answers/970408d.html (last visited June 20, 2011).

of at least 4 satellites from almost any point on the Earth's surface. For a similar configuration, a continental U.S.-only GPS system could continue to have at least 4 satellites in an orbital plane, but would likely require fewer than 6 orbital planes to ensure U.S. coverage. At a minimum, such a system would require at least 4 orbital planes, because a user would need to see at least 4 satellites at any time from the earth's surface in the continental U.S. (a user cannot be guaranteed a view of more than 1 satellite per orbital plane).[34] These 4 orbital planes with 4 satellites each would therefore require at least 16 total satellites functioning at any given time. Further, a U.S. commercial system would need a minimum of at least 2 spare satellites in orbit in addition to the baseline 16 in order to make the system reasonably robust to satellite failure.[35]

Table 2 shows that the estimated present value of expenditure for building and operating a commercial GPS satellite system for 30 years is $18 billion. Building and operating a satellite system requires an initial capital expenditure, ongoing operating expenses and an additional capital expenditure in 12 to 15 years to replace aging satellites.[36] The value of satellite spectrum licenses that might be needed by a private system in order to transmit signals is an additional cost. The initial capital expenditure includes research and development, satellite builds, launch costs and launch insurance, and building ground systems and related infrastructure to operate the satellites.

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[34] This can be seen by comparing the distribution of the 4 satellites in an orbital plane with the "footprint," or visible range on the earth's surface, of each satellite See GPS Service Performance Standard, 2008, p. A-4.

[35] There are alternative constellation configurations that could also operate with 18 – 20 satellites. For instance, GLONASS uses more than 4 satellites per orbital plane to reduce the number of planes from 6 to 3. The system can provide global positioning for Russia exclusively with a total of 18 satellites. See Polischuk, G. M.; *et al.* "The Global Satellite Navigation System GLONASS: Development and Usage in the 21st Century, Russian Aerospace Agency. 2002. Found at: http://www.dtic.mil/cgi-bin/GetTRDoc?Location=U2&doc=GetTRDoc.pdf&AD=ADA484380 (last visited June 20, 2011). See also Novosti, Ria. "Russia to Set World Record with 39 Space Launches in 2009," 2008. Found at: http://en.rian.ru/russia/20081229/119210306.html (last visited June 20, 2011).

[36] Life expectancy for the GPS IIF satellites initially launched in 2010 is 12 years, while the life expectancy of the new IIIA satellites in development is 15 years. See Space Segment, GPS.gov.

The estimated cost of building the original 18 satellites is $3.6 billion, with an additional $1 billion for R&D and $1.1 billion for launch and insurance costs. In 2008 Lockheed Martin won the contract to develop and build the next generation constellation of GPS III satellites. The value of the contract included an initial $1.5 billion for R&D and two satellites, as well as the option to procure an additional 10 satellites for another $2.1 billion.[37] Based on this contract, the cost of an individual satellite is a little over $200 million, with an initial R&D cost of just over $1 billion. In addition to the initial 18 satellites, the replacement cost of each satellite in 15 years will be an additional $200 million per satellite. In 2010, Arianespace of France was contracted to launch all 14 EU Galileo satellites for €397 million.[38] Based on the current exchange rate, this translates into $40 million per satellite launch. A commercial launch would also require launch insurance, which is typically 10% of the insured satellite value.[39] Based on these estimates, the total cost for building and launching satellites for a commercial GPS network would be approximately $5.7 billion. See Table 2.

Further, the cost of infrastructure investment and annual operations over 30 years are expected to be close to $1.1 billion each. In 2007, building the ground base infrastructure to accompany the Galileo satellite system—including ground control infrastructure,

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37 See Gibbons, Glen. "Lockheed Martin Wins GPS IIIA Contract," *Inside GNSS*. May 16, 2008. Found at: http://www.insidegnss.com/node/681 (last visited June 20, 2011). (Herein "*Inside GNSS*, May 16, 2008"). See also Hedgepeth, Dana and Zachary A. Goldfarb. "Lockheed Wins GPS Satellite Contract," *Washington Post*. May 16, 2008. Found at: http://www.washingtonpost.com/wp-dyn/content/article/2008/05/15/AR2008051504007_pf.html. (last visited June 20, 2011).

38 See "EU Awards Galileo Satellite Navigation Contracts," *BBC News*. January 7 2010. Found at: http://news.bbc.co.uk/2/hi/science/nature/8442090.stm (last visited June 20, 2011). (Herein "*BBC News*, January 7, 2010"). For general information on the Galileo navigation system, see the Galileo Navigation website maintained by the European Space Agency (ESA). Found at: http://www.esa.int/esaNA/galileo.html (last visited June 21, 2011).

39 By one estimate, satellite insurance can be as low as 10% - 13% of insured satellite value. See Selding, Peter B. de. "Insurance Premiums Stay Float Despite W3B Satellite Failure," *Space News*. May 20, 2011. Found at: http://www.spacenews.com/satellite_telecom/110520-insurance-premiums-flat.html (last visited June 20, 2011). (Herein "*Space News*, May 20, 2011"). For the purposes of this paper, I assume that the entire satellite value is insured.

systems engineering and procurement—was expected to cost €745 million.[40] According to 2010 estimates by UK think tank, *openeurope*, the cost of annual operations after deployment is expected to be €750 million a year.[41] Again applying the current exchange rate, I estimate the cost of infrastructure and the cost of annual operations to be $1.1 billion each.[42] Assuming a 15% rate of return on such a risky venture, the present value of 30 years of maintenance is close to $8 billion. The present value of replacement satellites, including launch and insurance costs, is $576 million.

Finally, a commercial GPS satellite network would likely require additional satellite licenses worth about $2 billion. The U.S. Government's GPS system uses a dedicated band of spectrum that is more than 50 MHz.[43] In order to transmit signals, a commercial GPS network may also need approximately 50 MHz of commercial satellite spectrum.[44] Since spectrum is a scarce resource, it would be difficult to get access to the wide bands of spectrum needed for such a venture. While commercial satellite spectrum licenses are not frequently traded, comparable spectrum is generally valued around $2 billion. For instance, Sirius XM Radio holds about 50 MHz of contiguous satellite spectrum licenses

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40 This excludes an additional $1.5 billion in cost overruns that were estimated by 2010, as well as governmental administrative costs and the costs of running GALILEO's satellite navigation predecessor, EGNOS. See "Galileo: Recent Developments," House of Commons Transport Committee. November 7, 2007. Found at: http://www.publications.parliament.uk/pa/cm200708/cmselect/cmtran/53/53.pdf (last visited June 20, 2011). (Herein "House of Commons Transport Committee, November 7, 2007"). See also "Lost in Space: How the Cost of the EU's Galileo Project Has Skyrocketed," Open Europe. October 17 2010. Found at: http://www.openeurope.org.uk/research/galileo2010.pdf (last visited June 20, 2011). (Herein "Open Europe, October 17, 2010").

41 See Open Europe, October 17, 2010.

42 I consider these estimates conservative since, by some reports, these figures are optimistic and the cost associated with GALILEO continue to rise. See Galileo (satellite navigation) on Wikipedia. Found at: http://en.wikipedia.org/wiki/Galileo_(satellite_navigation) (last visited June 18, 2011).

43 This is not considering the additional spectrum GPS devices are using by not ensuring that GPS devices adequately filter L-Band transmissions beyond the GPS allocation, the GPS industry has been effectively using 10 MHz of adjacent L-Band spectrum.

44 A commercial satellite system will require spectrum for a wideband transmission signal and some amount of adjacent guard bands. The total amount of spectrum required is equal to the amount of spectrum not available to other users as a result of the commercial GPS system. It may be the case that the total requirements for a commercial system are less than 50 MHz. If so, the value of their allocation would be reduced proportionately.

for transmission of its satellite radio services. These licenses are similar to the type of spectrum a commercial GPS system would require. According to company filings, these licenses are worth just over $2 billion.[45] This is consistent with other satellite spectrum transactions. For instance, the bankrupt MSS provider TerreStar Networks Inc. is expected to be bought at auction for $1.37 billion.[46] Assets of a similar bankrupt MSS operator, DBSD North America, were purchased for $1.4 billion in March 2011.[47] The major assets of both companies are licenses for 20 MHz of S-Band spectrum.[48]

All told, the system is expected to cost $18 billion in present value terms. This is 56% of the value currently estimated of operating the Galileo system for 20 years.[49] This value represents the total investment in a U.S. commercial network, rather than the value to any one user. This analysis does not attempt to determine how such costs would be distributed to individual users. While there are various ways the GPS commercial industry might arrange to invest in such a network, the critical point is that such expenditure would have to be made by the industry players. By enjoying free access to the U.S. Government GPS network, these users are able to forgo this cost and likely receive better service than on a commercial network.

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[45] This estimate is based on the asset value of commercial satellite spectrum licenses held by Sirius/XM. See "Sirius XM Radio Inc. and Subsidiaries Notes to Consolidated Financial Statements," Sirius XM 10-K. 2010, p. F-19.

[46] Humer, Caroline; Nick Brown. "Exclusive: Terrestar nears bid pact," *Reuters*. June 14, 2011. Found at: http://www.reuters.com/article/2011/06/14/us-terrestar-exclusive-idUSTRE75D6AA20110614 (last visited June 22, 2011).

[47] Humer, Caroline. "Dish approved to buy satellite company DBSD," *Reuters*. March 15, 2011. Found at: http://www.reuters.com/article/2011/03/15/us-dish-dbsd-idUSTRE72E61N20110315 (last visited June 22, 2011).

[48] Goldstein, Josh. "Harbinger, Solus challenge Dish's Ergen for spectrum assets," *FierceWireless*. March 3, 2011. Found at: http://www.fiercewireless.com/story/harbinger-solus-challenge-dishs-ergen-spectrum-assets/2011-03-03#ixzz1Q1xrslWp (last visited June 22, 2011).

[49] As of October 2010, the total cost of building and operating Galileo for 20 years was estimated to be €22.2 billion ($32 billion). See Open Europe, October 17, 2010.

Table 2. Estimated Satellite Network Cost for Commercial GPS System

[1]	Satellite Research and Development	$	$1,000,000,000
[2]	Cost of Satellite	$	$200,000,000
[3]	Total Cost of 18 Satellites	$	$3,600,000,000
[4]	Satellite Launch Cost	$	$40,000,000
[5]	Total Launch Cost for 18 Satellites	$	$720,000,000
[6]	Total Launch Insurance Cost	$	$360,000,000
[7]	**Total Cost of Building and Launching GPS Satellites**	**$**	**$5,680,000,000**
[8]	Ground Infrastructure and Operation	$	$1,100,000,000
[9]	Annual Operating Cost of Maintaining Satellite Network	$	$1,100,000,000
[10]	Rate of Return	%	15%
[11]	Net Present Value of Operating Cost (30 Years)	$	$8,322,577,600
[12]	Net Present Value of Satellite Replacement	$	$575,146,191
[13]	Potential Cost of Satellite Spectrum Licenses for GPS Network	$	$2,000,000,000
[14]	**Total Cost of Building and Operating a Commercial GPS Network**	**$**	**$17,677,723,791**

Sources and Notes:
[1] & [2]: Estimate based on Inside GNSS, May 16, 2008
[3]: [2] x 18
[4]: Estimate based on BBC News, January 7, 2010
[5]: [4] x 18
[6]: [3] x 10%; based on Space News, May 20, 2011
[7]: [1] + [3] + [5] + [6]
[8]: Estimate based on House of Commons Transport Committee, November 7, 2007
[9]: Estimate based on Open Europe, October 17, 2010
[10]: Assumption
[11]: Net Present Value of [9] based on [10] over 30 years
[12]: Net Present Value of replacement satellites, launch and insurance costs ($4.68 billion) in 15 years based on [10]
[13]: Estimate based on value of licenses for Sirius XM spectrum
[14]: [7] + [8] + [11] + [12] + [13]

IV. IMPLICATIONS FOR INNOVATIVE USERS OF SPECTRUM

The combined impacts of added regulatory uncertainty and the implicit subsidy to commercial users of the GPS satellite network reduces the likelihood that spectrum will be allocated or assigned to the highest valued uses. Increased regulatory uncertainty created by effectively revoking LightSquared's ATC authority in the L-Band is likely to reduce future investment opportunities for new users of spectrum. Additionally, commercial GPS users' lack of preparation for other users in its neighboring L-band hinders welfare enhancing spectrum policy.

The impact of regulatory uncertainty on investments in innovative, valuable new uses of spectrum is twofold. As illustrated above, increased risk of license suspension or revocation first reduces the expected gross revenues of services. Added uncertainty also indirectly reduces cash flows by increasing the cost of financing the project. With returns diminishing and the cost of financing increasing, the expected profits of *every* wireless broadband project will be lower.

While some projects will still be profitable enough to attract investors, other projects that would have been profitable in the face of regulatory certainty would be less attractive to investors, or could even be unprofitable. These decreased profits could affect either an entire project or a portion of a project. For example, a new network deployment that would otherwise be undertaken will no longer be an attractive investment. Alternatively, added uncertainty could make network expansion, such as deploying an existing network further into rural areas, less attractive. This could result in either delayed or canceled expansion, and more limited access to services for consumers.

This added uncertainty is even more problematic because it is the result of actions of incumbent spectrum users that are not even authorized to use the band at issue. GPS users could have prepared for new higher valued neighbors, but chose not to. Any added costs to do so would have been small compared to the huge subsidy the industry receives through the free use of the GPS network of signals.

Furthermore, a decision by the FCC to revoke LightSquared's terrestrial authority in the L-Band exacerbates the moral hazard for incumbent users. The FCC's decision provides disincentives for incumbent users to invest in new technology that might accommodate new users. By suspending LightSquared's ATC authority, the FCC will then effectively give commercial GPS users the right to operate in the L-Band spectrum outside of the GPS allocation at no charge. Since the FCC initially decided to grant ATC authority to license holders in the L-Band, GPS users could have begun to prepare for the time when adjacent spectrum bands would be occupied by high power users. However, many GPS device manufacturers chose not to incur these additional costs of developing adequate filters on their devices. Instead, they chose to occupy spectrum that was not rightfully theirs.

By allowing GPS users to effectively occupy this spectrum, the FCC is condoning this behavior by incumbent users and reinforcing a serious moral hazard in its interference dispute resolution process.[50] A decision by the FCC to suspend LightSquared's ATC authority would further reduce the incentives of incumbent users to make investments to accommodate new, valuable users of wireless broadband spectrum. That GPS device manufacturers did not make such efficiency enhancing investments after receiving such a substantial subsidy only reinforces the disincentive to other incumbent spectrum users.

The reduced network investments that would result from less profitable spectrum deployment opportunities would have ripple effects throughout the economy. It is well known that wireless broadband investments have significant economic multipliers. For example, former Treasury Secretary Lawrence Summers has stated, "[e]ach dollar invested in wireless deployment is estimated to result in as much as $7 to $10 higher GDP."[51] It is difficult to estimate exactly the reduced investment that would result, but with a multiplier of $7 to $10, it does not take much lost investment for serious economic harm to result. Added uncertainty about the security of license rights would make many wireless broadband investments less attractive to investors than they would otherwise be. Furthermore, some wireless investments that would have otherwise been undertaken will now be unattractive, resulting in delays and canceled opportunities. Consequently, these

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50 As explained by Hazlett (2003):

> The essential problem with interference dispute resolution at the FCC is moral hazard. Incumbents are permitted to oppose applications for new entry virtually without cost, imposing delays that deter competition. Regulatory proceedings to protest interference form and 'attractive nuisance' that existing operators inevitably use to fend off newcomers who threaten to lower prices and steal market share. (See Hazlett (2003) at pp.493-494.)

51 Remarks of Lawrence H. Summers, New America Foundation, *Technological Opportunities, Job Creation, and Economic Growth* (June 28, 2010). Found at: http://www.whitehouse.gov/administration/eop/nec/speeches/technological-opportunities-job-creation-economic-growth (last visited July 30, 2011).

negative economic impacts on wireless industry growth would be amplified throughout the economy.

V. APPENDIX

A. SENSITIVITY OF REGULATORY UNCERTAINTY RESULTS

The analysis above assumes that if the FCC revokes or suspends all, or a significant portion, of LightSquared's ATC authority, the probability that the FCC will revoke a wireless or satellite license in the future will increase by 5%. This magnitude of the increase in risk is illustrative, and the actual amount of risk could be higher or lower. That some increase in risk will result, however, is not speculative. It would likely be difficult to determine what the impact would be until it occurs. The results of the model above remain reasonably consistent to a range of potential risks.

As Table A1 illustrates, for any increase in the probability of a revoked spectrum license, the percent change in spectrum value is close to double that probability or added risk. For instance, a 1% increase in the probability that the FCC will revoke a license results in just over a 2% decrease in the present value of spectrum. For a 20% increase in the probability of a license being revoked, the present value decreases by 39%.

Table A1. Sensitivity of Spectrum Value to Regulatory Risk

Regulatory Risk	Change in Present Value
1%	2%
2%	4%
3%	6%
4%	8%
5%	10%
10%	20%
15%	30%
20%	39%

Source: The Brattle Group Analysis.

The model remains robust to similar sensitivity tests of a range of debt to equity ratios, and costs of debt and equity. For instance, by changing the debt to equity ratio from 75/25 to 25/75, the change in present value drops from 10% to 7%. This impact is largely due to the fact that a lower proportion of spectrum asset value would be financed by debt if the debt to equity ratio were lower.[52] Increasing the revenue growth rate from 5% to 8% decreases the change in present value by less than 1%. Finally, adjusting the year that the license is revoked also has little effect on the results.

Table A2. Sensitivity of Spectrum Value to Various Costs of Borrowing Assuming 5% Increase in Probability License is Revoked

	Change in Present Value
Debt/Equity at 75/25	10.2%
Debt/Equity at 50/50	8.8%
Debt/Equity at 25/75	7.3%
Debt/Equity at 75/25	
Growth Rate at 5%	10.2%
Growth Rate at 8%	10.2%
Year License Revoked	
1	9.9%
3	10.2%
5	10.2%

Source: The Brattle Group Analysis.

As the results in Table A1 and Table A2 indicate, the major factors that largely determine the impact of regulatory risk on spectrum value are the actual change in risk of regulatory action, and the extent to which the purchase of a spectrum asset is financed by debt. The base cost of debt and equity, as well as the revenue and cash flow assumptions of the stream of payments are much less influential.

52 I note that the probability of revoking the license only affects the cost of debt, so the WACC will differ across capital structures.

Technical Appendix

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EXHIBIT B

SUMMARY

This Technical Appendix reviews the support NTIA puts forward for its determinations regarding compatibility of GPS receivers and the feasibility of various mitigation strategies, primarily focusing on its adverse determinations regarding personal/general navigation and FAA-certified aviation devices.

As discussed in more detail below and in Exhibit A, the evidence is overwhelming that the testing and analysis of personal/general navigation devices failed to comply with widely-accepted, reasonable standards and failed to reflect LightSquared's stated deployment plans, with the result that the tests cannot be used to support any rational conclusion regarding the general population of such devices.

In addition to many flaws in the tests themselves, the analysis of the test results was based on an obsolete model of LightSquared's deployment plan. If NTIA had given proper consideration to LightSquared's proposal for deployment, it would have concluded that over 80 percent of the devices tested passed even the unreasonable 1 dB C/N_0 test that NTIA imposed. Accounting for yet other flaws in the tests and analysis would result in potentially all of the personal/general navigation devices "passing."

At the time the NPEF report was issued, LightSquared had agreed both to reduce the maximum power of its base stations as a function of their height and to guarantee not to exceed a given power on the ground at the location of practically any GPS receiver. The guarantee to a limited power on the ground would be provided either by: (i) designing and deploying the network based on the use of a light-clutter propagation model or (ii) using a post-deployment measurement program with sufficient spatial resolution to identify any hotspots that would be eliminated by further modification of base station power. NPEF failed to credit these commitments in its tests and NTIA, in its letter to the FCC, fails to either acknowledge LightSquared's proposals or address them in its consideration of mitigation options.

Similarly, with respect to aviation devices, as discussed below and in more detail in Exhibit B, the evidence shows that mitigation proposals were rejected before FAA requirements were even established or feasible mitigation proposals could even be considered.

Exhibit C of the Technical Appendix discusses a key technical issue that NTIA neglects to analyze or credit, despite its importance: the ability of GPS manufacturers to build receivers that are compatible with LightSquared operations without any loss in performance or material increase in cost or size. NTIA fails to note that all classes of GPS devices include at least some devices that, as manufactured and without modification, pass even the flawed process by which NTIA judges them. Exhibit C rebuts the various technical arguments that commercial GPS manufacturers have made that high performance capabilities require GPS devices to be incompatible with LightSquared's operation and shows that there is no reason why all GPS devices could not have been designed and built to be compatible with LightSquared operations.

EXHIBIT A

NTIA'S CONCLUSIONS REGARDING PERSONAL/GENERAL NAVIGATION DEVICES ARE NOT SCIENTIFICALLY VALID

This exhibit evaluates the National Telecommunication and Information Administration's (NTIA) testing and analysis[1] of potential overload of personal/general navigation devices in proximity to LightSquared base stations and concludes that there were major flaws in both the tests and the analysis. The failures in the test process, which are described in Section I, include a biased device selection process, shoddy test practices, and woefully incomplete data collection and presentation, among other things. Section II describes major failures in the analysis of the test data involving the use of the wrong power level for the LightSquared signal. Section III focuses on the improper use of a loss of 1 dB C/N_0 as the measure of overload, despite the absence of any evidence that such a loss provides any meaningful indication of loss of position accuracy or any other significant impact on the end-user experience.[2]

As discussed further in Section IV, when the results are normalized to account for the more obvious failures in the testing and analysis, it is apparent that none of the devices tested is incompatible with LightSquared's operations. Most of the devices would have passed even the flawed 1 dB C/N_0 threshold if NTIA had used -30 dBm for the power at the receiver, instead of the -15 dBm level in its analysis. An additional nine devices would have passed if NTIA had used a more appropriate level of 6 dB C/N_0 as its pass/fail criterion. (LightSquared does not accept that even this is an appropriate method to determine loss of position accuracy, but it is more reasonable than a 1 dB loss.) Still more would have passed if NTIA had recognized the impact of LightSquared operating with Left Hand Circularly Polarized antennas. Moreover, many of the devices that "failed" appear to have been improperly included in the testing, either because they were high-precision devices, incomplete devices (i.e., subsystems or modules), or cellular devices. On top of that, many of the test results showing "failure" should be discarded based on irregularities in their testing, represented by either unexplained inconsistent results or an abnormally low quiescent C/N_0 that suggests the antenna was mis-oriented or the device was malfunctioning.

Attachment A-1 describes why NTIA's concerns about potential overload from LightSquared user devices are unfounded.

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[1] Also hereinafter referred to as the National Space-Based Positioning, Navigation, and Timing Systems Engineering Forum (NPEF) tests or testing.

[2] According to NPEF, Idaho National Labs reviewed the testing requirements and test set-up and observed the test execution and data collection and MIT Lincoln Laboratory reviewed the testing methods and findings. National Space-Based Positioning, Navigation, and Timing Systems Engineering Forum (NPEF), Follow-on Assessment of LightSquared Ancillary Terrestrial Component Effects on GPS Receivers, at 3 (January 6, 2012) ("NPEF Report [1]").Both entities prepared reports that NPEF cites in support of its process and findings. NPEF Report [1], at 3. LightSquared, however, despite its requests, so far has been denied access to these reports.

I. NTIA RELIED ON TESTS THAT WERE NOT PROPERLY DESIGNED OR CONDUCTED

All told, the NPEF tests deviated from internationally accepted testing standards[3] in a number of critical ways, including the following:

- The process for selecting devices was deeply flawed and biased the outcome.
    - NPEF failed to establish any clear criteria for selecting devices.
    - Instead of a well considered plan for obtaining a representative sample of the total population of general navigation GPS devices, participants, including vendors that opposed LightSquared, were simply invited to bring and test whichever devices they wished.
    - Many of the devices included in the tests and the reported results do not appear to qualify as general navigation receivers.
    - No effort was made to determine whether the models tested were widely sold or in use.
    - Some of the devices were not production units.
    - The devices were not pretested to validate that they were operating correctly and had not been modified.

- Critical variables were not controlled during the tests, including the antenna orientation and spacing of devices, and partisan participants were allowed to modify devices during testing.

- The tests produced a large amount of data showing problems with the tests' validity; these problems should have been examined and explained:
    - There is unexplained and inconsistent data for the same devices tested by both the Technical Working Group (TWG) and NPEF;
    - There is unexplained and inconsistent data for the same device from just the NPEF tests, including missing blocks of data and abnormal behavior of C/N_0 during the tests; and

[3] The evaluation focuses on two international standards for test laboratory practices and coexistence analysis:

(i) ISO/IEC 17025:2005, "General requirements for the competence of testing and calibration laboratories" ("ISO 17025 [12]") and

(ii) IEEE 1900.2:2008, "IEEE Recommended Practice for the Analysis of In-Band and Adjacent Band Interference and Coexistence Between Radio Systems" ("IEEE 1900.2 [13]").

ISO 17025 [12] is the internationally recognized standard for laboratory practice. Accreditation to ISO 17025 [12] is required of laboratories that perform regulatory compliance tests by many agencies, including the FCC. The principles contained in ISO 17025 [12] apply to labs generally but also to specific testing efforts, which is how the standard is applied here.

IEEE 1900.2 [13] was written specifically to guide a coexistence analysis, such as this. It was developed to make coexistence analysis more objective and supportive of innovation and improved use of the spectrum.

- There is a much greater variation of quiescent C/N_0 (without LightSquared signals) among different devices than would be expected from the device locations on the test bench.

- Key data was not reported by the participants to NPEF and by NPEF to LightSquared and the public; the availability of this data is critical for a transparent process that permits public review and independent validation of the tests and their results.

- NPEF's analysis does not properly account for environmental noise.

A. The selection process failed to even attempt to identify a representative or otherwise qualified sample of devices

For the purposes of this testing, NPEF should have established a sampling plan in order to understand the potential impact to the mainstream population of general navigation receivers. Some of the device selection criteria should have been: (i) whether the device was a mainstream Personal/General Navigation device in commercial use; (ii) whether the devices were still in production; (iii) the current market share of the device; and (iv) the likelihood of the device being used near a LightSquared base station.

In contrast, NPEF did not establish any objective baseline criteria for selection of testing devices or provide information about the models tested in its Report. In the Report, NPEF states that "[d]ue to the time constraints for test completion, the NPEF did not limit federal or commercial participants' requested receivers from participating in the testing. In addition . . . other receivers were tested (at each participating organization's discretion)."[4] It seems contradictory to allow unlimited submission of devices due to time constraints on the testing. One would expect just the opposite, that if test time was limited, device selection would have been done with great care to make best use of the time and ensure that the devices tested best represented the population of devices in use. But the government entities and GPS manufacturers participating in the tests were able to include any device(s) of their choosing in the tests.

Many of the devices categorized as Personal/General Navigation devices appear not to qualify as devices sold to the general public. Fourteen of the "devices" were not actually complete GPS devices at all, but were GPS modules and evaluation kits intended as components of completed devices.[5] The performance of those devices would have been affected by the antenna and other essential RF components added to the module. Four devices were cell phones or other devices that did not qualify as Personal/General Navigation devices.[6] Finally, two of the devices tested are high precision devices.[7] Some of the devices tested also appear to be targeted to niche markets, such as hiking or boating, that are unlikely to be used near LightSquared base stations.

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4 NPEF Report [1], at 3.

5 Those devices were device numbers 247, 235, 333, 360, 232, 105, 307, 204, 383, 327, 127, 395, 322, and 373.

6 Those devices were device numbers 102, 315, 377, and 398.

7 Those devices were device numbers 350 and 341.

Because the report provides no further details about the device characteristics, there is no evidence of whether the devices tested are in current use (as opposed to out-of-date models), their intended use, or how many devices have been sold.

The sample of devices tested was non-conformant to ISO 17025 [12], subclause 5.7, sampling:

> ***5.7 Sampling***
>
> ***5.7.1*** The laboratory shall have a sampling plan and procedures for sampling when it carries out sampling of substances, materials or products for subsequent testing or calibration. The sampling plan as well as the sampling procedure shall be available at the location where sampling is undertaken. Sampling plans shall, whenever reasonable, be based on appropriate statistical methods. The sampling process shall address the factors to be controlled to ensure the validity of the test and calibration results.

B. Samples were not properly controlled and participants were allowed to modify devices

In addition to ceding control of the selection process to participants, NPEF also put participants in charge of test set-up. According to the report, test participants were "entirely responsible for setup and data recording."[8] "Few constraints were placed on the data collection process" other than the use of standardized data messages to support "automated data reduction and presentation."[9]

In fact, according to a LightSquared observer, participants had near-total command over device set-up and configuration and the recording of data.[10] The vendors monitored their own devices, gathered performance data and delivered a subset of that data, the 1 dB C/N_0 values, to the Air Force's laboratory staff. There were few controls for critical testing elements such as antenna configuration and orientation. All of this is contrary to ISO 17025 [12]:

> ***5.8 Handling of test and calibration items***
>
> ***5.8.1*** The laboratory shall have procedures for the transportation, receipt, handling, protection, storage, retention and/or disposal of test and/or calibration items, including all provisions necessary to protect the integrity of the test or calibration item, and to protect the interests of the laboratory and the customer.
>
> ***5.8.2*** The laboratory shall have a system for identifying test and/or calibration items. The identification shall be retained throughout the life of the item in the laboratory. The system shall be designed and operated so as to ensure that items cannot be confused physically or when referred to in records or other documents. The system shall, if appropriate, accommodate a sub-division of groups of items and the transfer of items within and from the laboratory.

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[8] NPEF Report [1], at 26; *see also* NPEF Report [1], at 9.

[9] NPEF Report [1], at 26.

[10] *See* Declaration of Steve Holley, Attachment A-2.

> ***5.8.3*** Upon receipt of the test or calibration item, abnormalities or departures from normal or specified conditions, as described in the test or calibration method, shall be recorded. When there is doubt as to the suitability of an item for test or calibration, or when an item does not conform to the description provided, or the test or calibration required is not specified in sufficient detail, the laboratory shall consult the customer for further instructions before proceeding and shall record the discussion.

NPEF has also provided no records of the actions performed by the participants and no certifications from participants or the Test Director that devices were not materially altered between tests. This is clearly in violation of ISO 17025 [12], subclause 5.3.4:

> ***5.3.4*** Access to and use of areas affecting the quality of the tests and/or calibrations shall be controlled. The laboratory shall determine the extent of control based on its particular circumstances.

The Report claims that "[n]o access to the antenna farm was permitted during the test events to ensure the test setup was not impacted . . . In between test events some access to the antenna farm was granted under the supervision of the Test Director to restart devices, log data files, and replace batteries."[11] This is contradicted, however, by a LightSquared observer, who saw what appeared to be the modification, reorientation, and replacement of at least one device antenna.[12]

A number of critical variables were not recorded or controlled during the testing. The potential for the devices to affect each other was not sufficiently checked.[13] It appears from Figure A.I.1 below, taken from the NPEF Report [1], that some devices were spaced more closely than provided in the plan, which may have been close enough so as to degrade each other's performance, either by their emissions or coupling between devices. This is in contrast to the plan used by CTIA for testing cellular devices, which directs:

> A test site shall provide at least the specified minimum measurement distance for all tests and validation procedures described in this test plan. Alternatively, a minimum measurement distance of 1.2 m may be used, provided the appropriate uncertainty term is included in the uncertainty budget for the test case.[14]

With respect to orientation of the device antennas, rather than establishing defined positions and antenna orientations, the NPEF tests "assumed that the participants configured their systems and antenna such that their receivers were operating in a typical manner."[15] The NPEF Report [1] does not cite any measures that were taken to communicate that expectation to government and commercial test participants, or to confirm the veracity of that assumption. It

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[11] NPEF Report [1], at 27.

[12] *See* Declaration of Steve Holley, Attachment A-2.

[13] *See* Declaration of Steve Holley, Attachment A-2. Although a "sniff" test was performed before testing began, it was not repeated before individual test events. Nor was there any testing for "coupling" of devices.

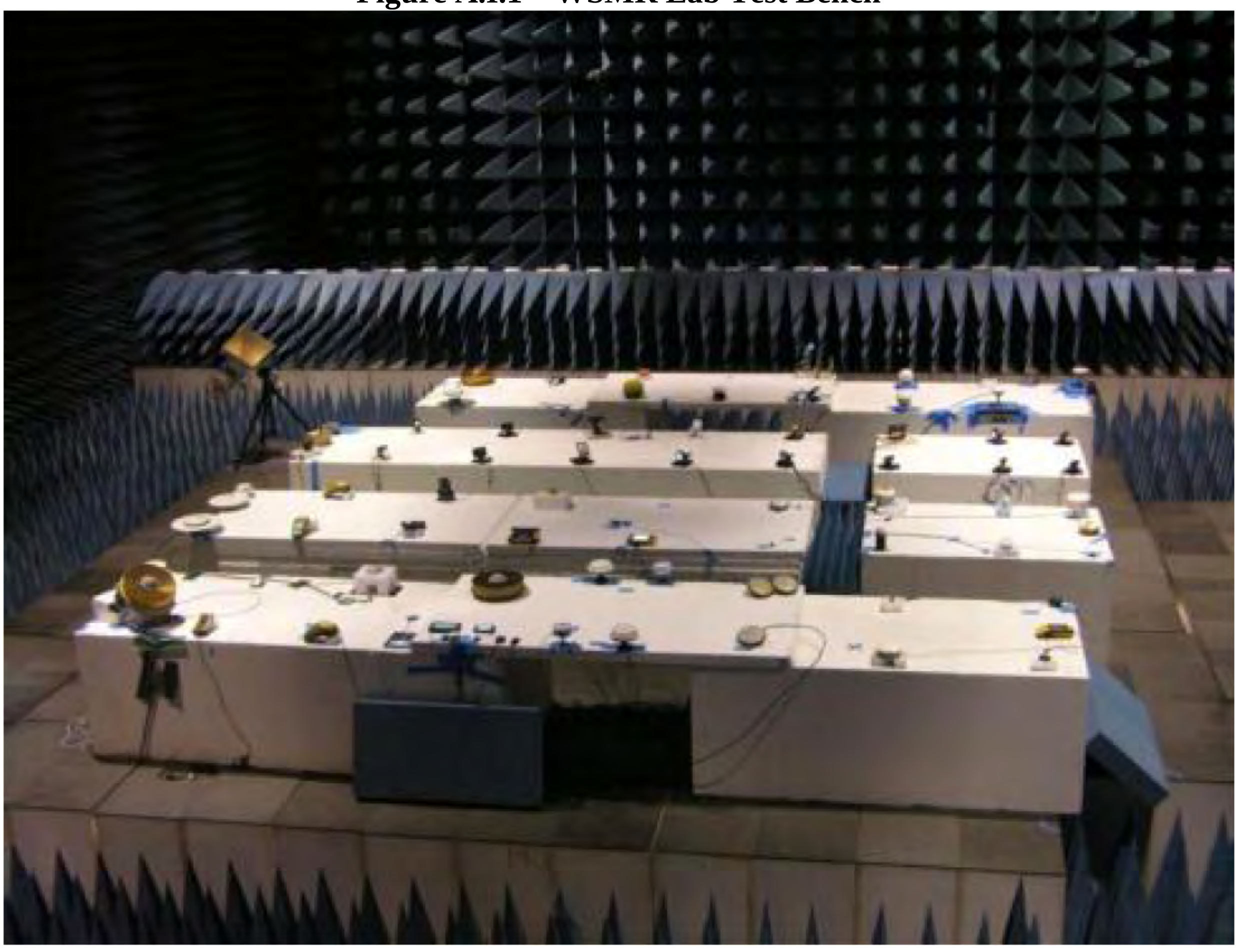
[14] CTIA Certification Test Plan for Mobile Station Over the Air Performance, Rev. 3.1, at p. 34 (January 2011) ("CTIA Test Plan [2]").

[15] NPEF Report [1], at p. 25; *see also* NPEF Report [1] at p. 26.

therefore cannot be concluded that systems and antennas, in fact, were set up to operate as they would in a real world environment.

In fact, Figure A.I.1 actually shows that many devices were oriented so that the peak of the antenna pattern was pointed at the base station antenna, whereas during typical operations most GPS receivers would encounter the LightSquared base station signal at an angle of approximately 10 degrees at the point of greatest power on the ground.[16] The selective orientation of the boresight of the antenna towards the base station antenna, which was at a nominal elevation of 20^0 relative to the test bench, also reduced the antenna gain towards the GPS signal radiator, which was at an elevation of 90^0 (directly overhead). These material deviations are not explained and together could account for 3-6 dB greater interference/signal ratio than would be normally encountered.

Figure A.I.1 – WSMR Lab Test Bench



These factors and others bring into question conformance with ISO 17025 [12], subclause 5.4.2:

[16] This follows from the path geometry, given a typical antenna height of 30 m and LightSquared's base station antenna pattern. The elevation angle to the GPS receiver is not a strong function of the base station antenna height between 15 m and 50 m.

> ***5.4.2 Selection of methods***
>
> The laboratory shall use test and/or calibration methods, including methods for sampling, … which are appropriate for the tests and/or calibrations it undertakes.

ISO 17025 [12] further direction in subclause 5.4.2:

> The laboratory shall confirm that it can properly operate standard methods before introducing the tests or calibrations. If the standard method changes, the confirmation shall be repeated.

It is the laboratory's responsibility to ensure that it is properly equipped to handle the testing being requested. In this case, it appears that the chamber used was not equipped with automated devices for positioning the equipment under test, resulting in lack of control over critical variables. Anechoic chambers that evaluate a device's performance with appropriate automation to control relative positioning in three dimensions are commonly available. In fact such a chamber was used for both the TWG and the recent NTIA-sponsored cellular testing. In that case, each device was characterized for its three dimensional antenna performance, as an early step in the testing process. If the anechoic chamber initially selected for this testing was inadequate then another, qualified, chamber should have been used so that the testing could be performed properly, given its important purpose.

In the context of non-standard tests such as these, it is particularly important to validate that the methods selected are correct for the purpose and will provide objective evidence of device performance. ISO 17025 [12] requires:

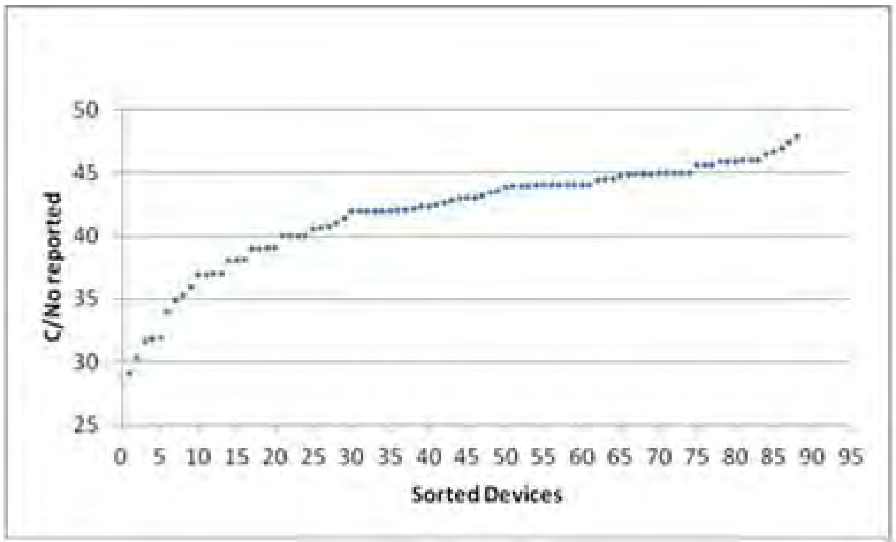
> ***5.4.5 Validation of methods***
>
> ***5.4.5.1*** Validation is the confirmation by examination and the provision of objective evidence that the particular requirements for a specific intended use are fulfilled.
>
> ***5.4.5.2*** The laboratory shall validate non-standard methods, laboratory-designed/developed methods, standard methods used outside their intended scope, and amplifications and modifications of standard methods to confirm that the methods are fit for the intended use. The validation shall be as extensive as is necessary to meet the needs of the given application or field of application. The laboratory shall record the results obtained, the procedure used for the validation, and a statement as to whether the method is fit for the intended use.
>
> ***5.4.5.3*** The range and accuracy of the values obtainable from validated methods (e.g. the uncertainty of the results, detection limit, selectivity of the method, linearity, limit of repeatability and/or reproducibility, robustness against external influences and/or cross-sensitivity against interference from the matrix of the sample/test object), as assessed for the intended use, shall be relevant to the customers' needs.

As discussed above, NPEF seems to have ignored this requirement. There is no evidence of the stability and repeatability of the testing performed or its correlation to field performance.

C. Inconsistent data should have triggered further examination of the test data

One of the most troubling aspects of the testing is the failure to recognize or account for various inconsistencies that should have been "red flags" that the tests were not producing reliable results. A prime example of this is the variation in quiescent C/N_0, the measurement of the carrier-to-noise ratio without any LightSquared signal or potential for overload, as shown in Figure A.I.2.

Figure A.I.2 - Variation of Quiescent C/N_0 reported by GLN devices (value reported in the absence of LightSquared signals)



The C/N_0 that should be reported by a device is a predictable quantity, if the incident GPS signal power, antenna gain and noise figure are known. The relationship is given by

C/N_0 (dB.Hz) = GPS_signal_power_in_isotropic_antenna (dBm) + antenna_gain – receiver_noise_figure (dB) + thermal_noise_PSD (dB.Hz)

Assuming typical values

44.5 dB.Hz = -128.5 dBm + 3 – 4 dB + 174 dB.Hz

According to NPEF Report [1], the test bench was calibrated to provide a nominal, time-invariant GPS signal level of -128.5 dBm for L1 C/A code signals, measured with a 0 dBi reference antenna, for all satellites.[17] There was approximately 5 dB variation as a result of the locations of the receiver on the test bench having different distances from the GPS transmit antenna on the roof. As described in the Report, C/N_0, referenced to a 0 dBi antenna, was

[17] NPEF Report [1], at Appendix E.2. The P code signal was 3 dB lower but is not relevant to a discussion on GLN devices.

expected to be between 42 and 47 dB.Hz. As part of the NPEF calibration process, the C/N_0 was verified by measurements on two receivers and conformed to this expectation. Yet, in Figure A.I.2 above, variability between devices is between 28 and 47 dB.Hz – a range of 19 dB. While up to a 5 dB variation may be attributed to the location of the receiver and perhaps as much as 3 dB to variations in antenna gain and noise figure, there is still an unexplained variation of approximately 11 dB. This may have been because of (i) the deliberate and arbitrary orientating of the devices practiced by the manufacturers to maximize the response towards the base station antenna, and in the process reducing the gain towards the GPS signals, (ii) a fundamental flaw in the calibration of the test set up or (iii) a device was damaged, modified or for some other reason not operating properly, or all of these reasons.

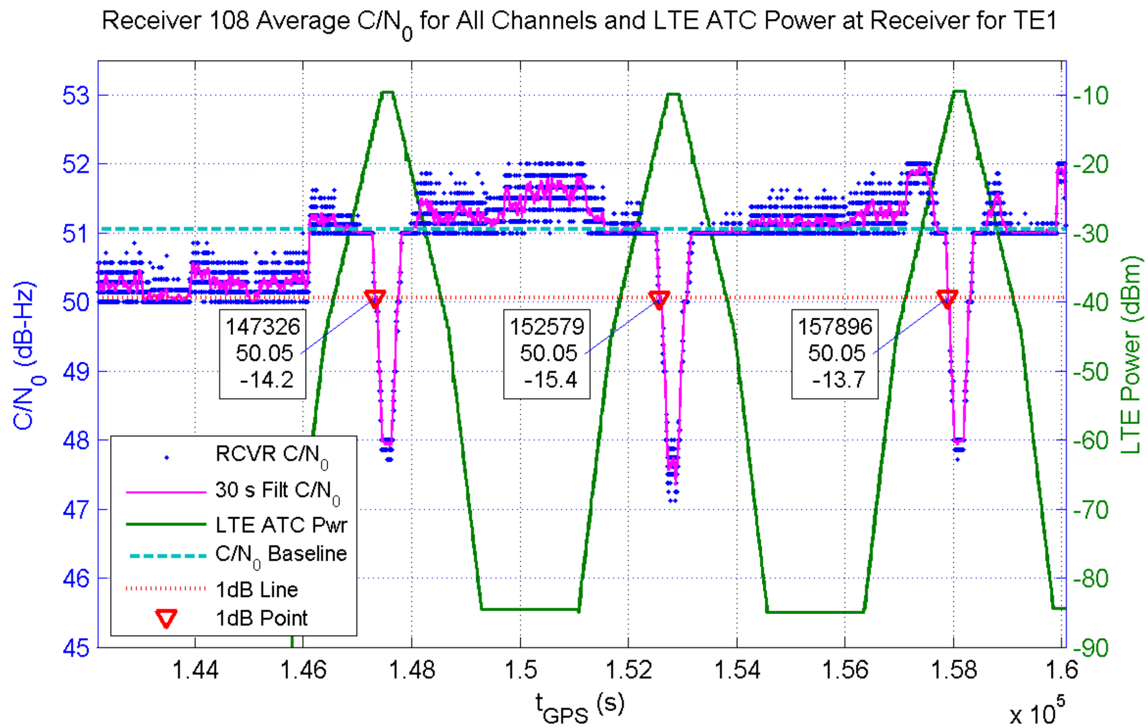
Regardless of the cause, when abnormally low values of C/N_0 were observed during the initial test set up, the testing should not have commenced until the C/N_0 values reached predictable levels and devices gave stable readings in the test setup with only the GPS signal present. Some of the quiescent C/N_0 levels are so low that it is questionable whether the receivers were consistently in lock during the tests.

A closer look at the individual test events reveals other troubling anomalies and holes in the data which should have served as “red flags” and which NPEF did not attempt to explain in its report. These data are described below.

1. Receiver 108 in TE1

In the highlighted plot from Test Event 1, Receiver 108 starts logging in the absence of LTE power, but does not report C/No at the expected baseline levels prior to the introduction of the LTE interferer. An abrupt change in the C/No values can be observed just at the start of the test. Clearly something changed but what changed is not reported. After the LTE interferer is started, Receiver 108’s C/No starts reporting at the expected levels prior to degrading. For the subsequent LTE power ramps, the C/No baseline levels are achieved in the absence of LTE power. One can perhaps infer that Receiver 108 was not ready for the test start, that Receiver 108’s Baseline C/No value is suspect or that the GPS simulator Carrier power rose after the start of logging. Any of these conditions would constitute an invalid test execution meriting a retest.

Figure A.I.3

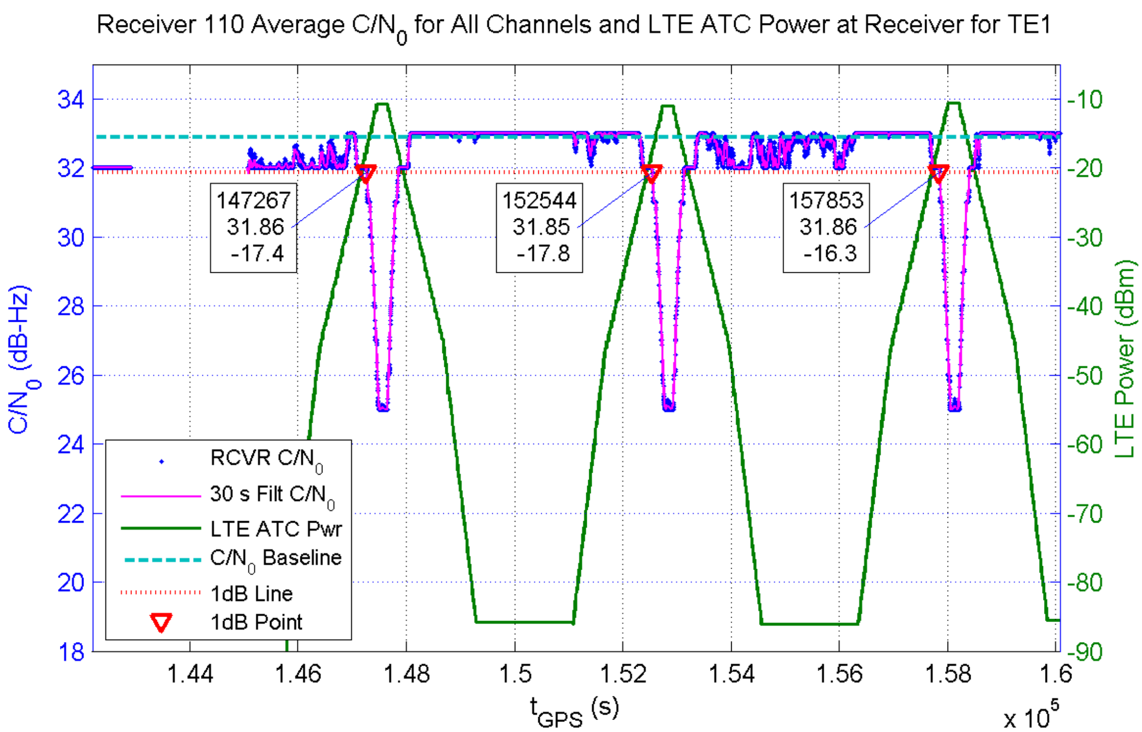


Receiver 108 Average C/N0 for All Channels and LTE ATC Power at Receiver for TE1
C/N0 (dB-Hz)
LTE Power (dBm)
tGPS (s)
x 10^5
147326
50.05
-14.2
152579
50.05
-15.4
157896
50.05
-13.7
RCVR C/N0
30 s Filt C/N0
LTE ATC Pwr
C/N0 Baseline
1dB Line
1dB Point

2. Receiver 110 in TE1

In the review of Receiver 110, the plot anomalies are similar to those of Receiver 108, but not exactly the same. For Receiver 110, the initial C/No logging prior to the LTE power ramp displays almost a 1 dB degrading from the baseline as well as a data gap. It is not clear why this receiver's chart has a data gap.

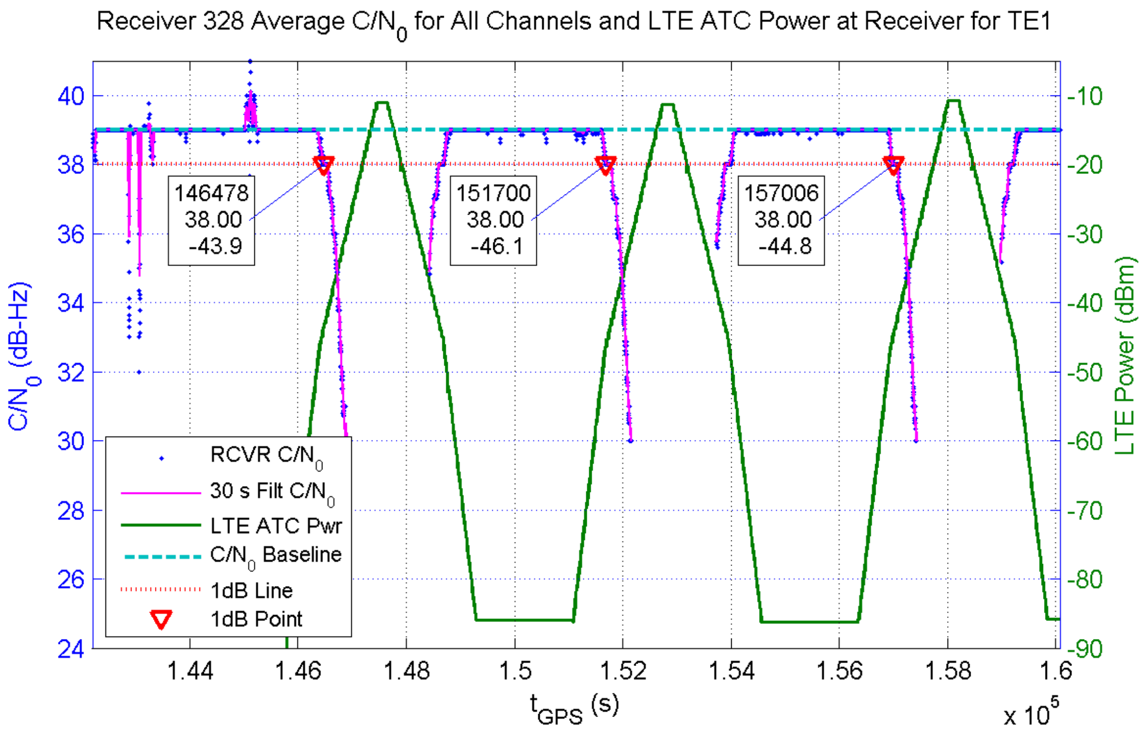
Figure A.I.4



3. Receiver 328 in TE1

The plot for this receiver shows considerable differences in detected 1dB C/No points between each of the three power ramps. To clearly establish C/No criteria, the device should have reported the C/No with less than 1dB variations between all three measurement samples.

Figure A.I.5



The same receiver was tested twice coded as 123 and 111 in TE1 and TE10. The plots for devices 123 and 111 show that although the results were quite consistent during the tests, there is close to 10 dB difference in reported C/No between TE1 and TE10. There is also a very large time variation in the quiescent C/N_0 (in the absence of the LTE signal) which is unexplained, especially given the high mean value of C/N_0.

Figure A.I.6

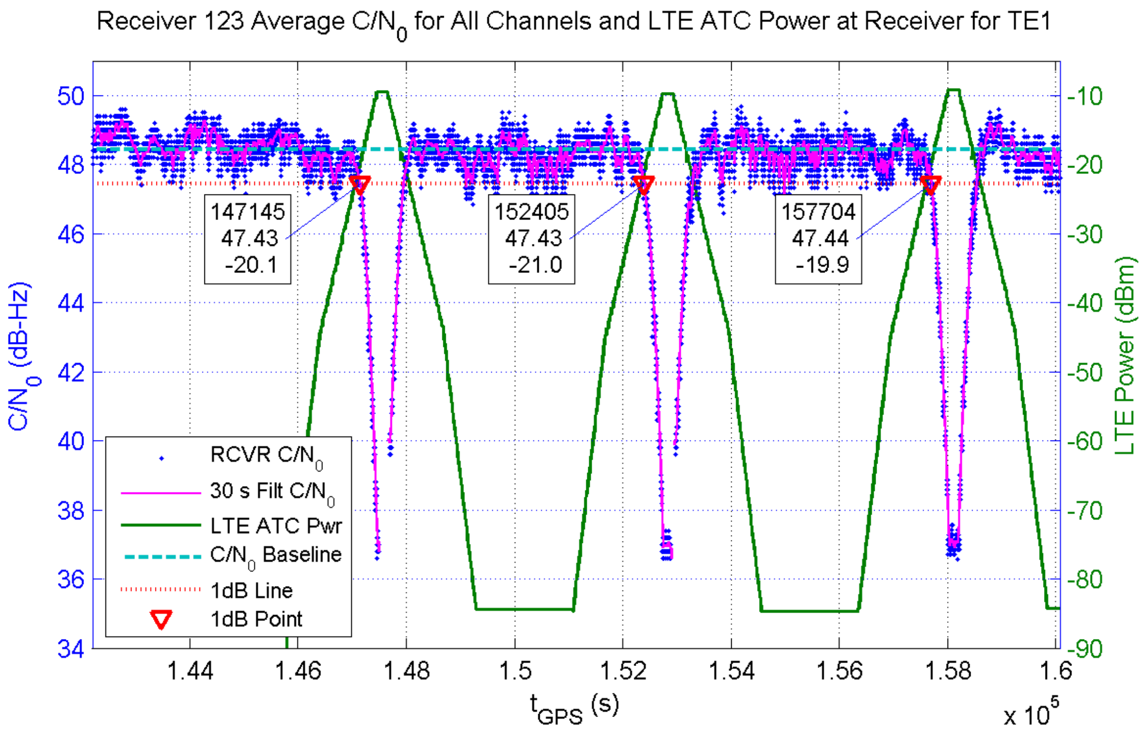
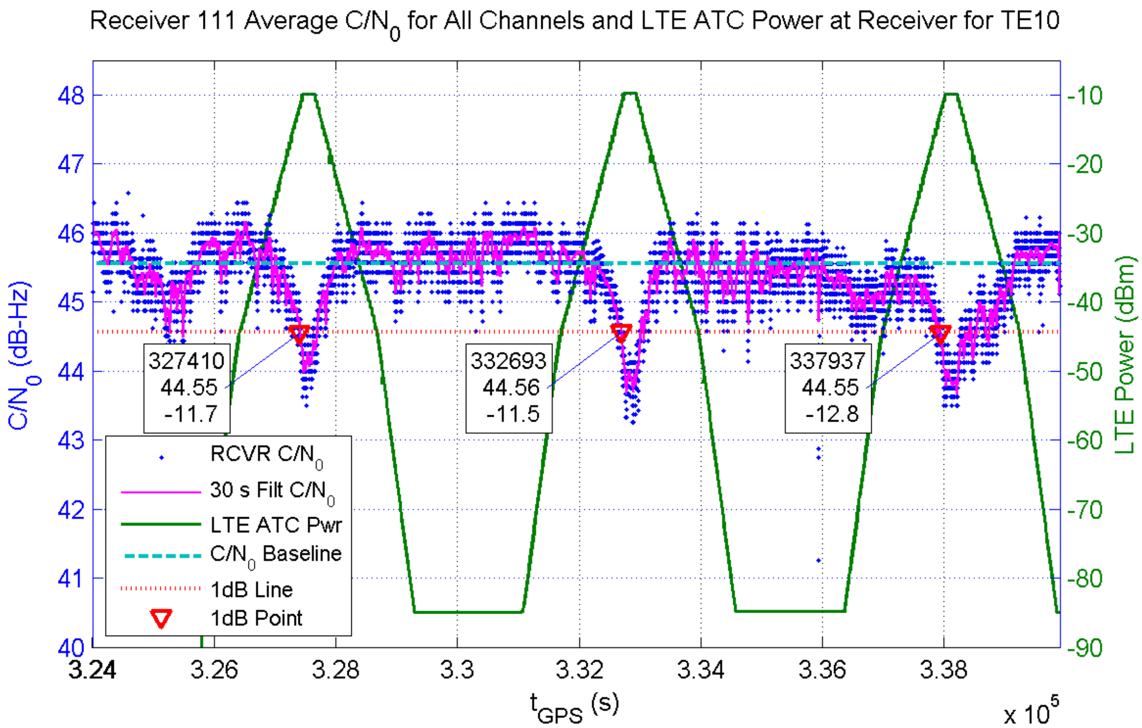


Figure A.I.7



Another revealing inconsistency is between the TWG tests and the NPEF tests. At least seven devices, belonging to three different GPS manufacturers, were subject to both TWG and NPEF tests.[18] Each of these seven devices generated data in the NPEF test that is inconsistent with TWG test results, as depicted below in Table A.I.1.

[18] To maintain the anonymity of the manufacturers, LightSquared is using only the TWG and NPEF device numbers.

Table A.I.1

	TWG Test			WSMR Test			Differential Results	
Device Name	**TWG Id**	**1dB de-sense**	**C/No**	**WSMR Id**	**1dB de-sense (dBm)**	**C/No (dB.Hz)**	**1dB de-sense diff (dB)**	**C/No diff (dB)**
Manufacturer A, 1	G15343	-32	42.8	211	-29.5	38.08	2.5	4.72
Manufacturer A, 2	G10607	0	41	375	-16.4	46.03	16.4	5.03
Manufacturer B, 1	G12867	-13.3	47	113	No results	No results		
Manufacturer B, 2	G17783	0	40	356	-16.3	46.7	16.3	6.7
Manufacturer B, 3	P17655	-2	42.2	124	-16.1	44.06	14.1	1.86
Manufacturer C, 1	G16382	-22	36	110	-17.8	31.85	4.2	4.15
Manufacturer C, 2	G16382	-22	36	313	-33.5	34	11.5	2

Variation in the 1 dB de-sense testing between the two experiments ranged from a difference of 2.5 dB up to 16.4 dB. Variation in the quiescent C/N_0 testing ranged from a difference of 2 to 6.7 dB. These inconsistencies are neither mentioned nor explained in the analysis of the NPEF Report [1]. While differences in the test signals used or test methodology may account for some difference, the differences are substantial enough that they should have raised serious questions and resulted in additional testing to explore why the variations occurred.

In addition, test results for the devices of at least two GPS device manufacturers have confirmed that there were internal inconsistencies in NPEF's data. NPEF's test included eight GPS receivers made by the same manufacturer, as depicted in Table A.I.2 below.

Table A.I.2

Device Name	*WSMR ID*	*1dB de-sense (dBm)*	*C/No(dB.Hz)*
Category 1 Devices			
Manufacturer X Device A	105	-23	41.38
Manufacturer X Device B	383	-15.9	36.93
Category 2 Devices			
Manufacturer X Device C	395	No results	25
Manufacturer X Device D	307	-18	34.96
Manufacturer X Device E	327	-15.4	37.01
Manufacturer X Device F	333	-27	44.99
Manufacturer X Device G	360	-26.7	45
Manufacturer X Device H	373	-30.1	45

Two of the receivers, Device A and Device B, were identical in all features except software, yet experienced degradation levels that differed by 7.1 dB. They also showed quiescent C/N_0 values that differed by a factor of roughly 4.5 dB. The manufacturer's other six receivers also had identical features, except for their software. Yet, for these devices the 1dB de-sense results ranged from -15.4 to -30.1 dB[19] and no two results were identical. The same is true of the quiescent C/N_0 value, which ranged from 25-45 dB.Hz. The NPEF Report [1] makes no mention of these inconsistencies in substantially identical devices.

D. Key data was not reported

While the report states that "[e]ach receiver's C/N_0 was collected",[20] if this is true then NPEF only reported a subset of the information that it received from the participants. The report contains no results for Test Events 2 & 11, which may have shown compatibility. Without the full data set it is impossible to cross check the findings against other performance indicators or even check for consistency of the data to the reported results.

Moreover unlike the TWG tests, in the NPEF tests, LightSquared was not provided access to the "raw data" produced by the receivers. These were collected by the manufacturers, processed in ways unknown to LightSquared and perhaps even to NPEF. What was provided to NPEF was then processed further processed and passed to LightSquared as plots of C/N_0 versus adjacent band signal power. In other words, in the present case, the results were presented to LightSquared on an *as is* basis. Thus, LightSquared was unable to perform the same assessment of the data as it did for the TWG tests, which assessment had revealed many anomalies. (Even then, there are several glaring anomalies and inconsistencies in the data, as described in Section C, above.)

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19 For one of the six Category 2 devices there were no 1dB de-sense results. These figures, therefore, only reflect results for the other five devices.

20 NPEF Report [1], at p. 13.

In addition, it is unclear why there are missing results for so many devices in so many tests. Based on a review of Appendix D of the report, results are reported for all tests for only \ eight Personal/General Navigation devices. This low percentage suggests either that the tests were done in a hurry without appropriate quality control or that there were additional problems which were not reported.

The following table shows the test completions for the devices. The test design called for each test to be repeated twice. The schedule had each test performed once, these were labeled test events 0-8, and then performed again, producing test events 9-17. By this design each device would have been tested twice, allowing for confirmation of test results and providing some insight on test-to-test repeatability. Additionally, within each individual test the device saw the same power levels during the ramp up and ramp down cycles. So the original test design would present the same power level to a device twice in each test and tested each device twice for a total of four exposures to each power level. Having this kind of test repeatability is extremely important in gauging the stability and repeatability of test results.

In the table below Suite 1 is the first cycle of tests and Suite 2 is the second cycle of tests.

Table A.I.3

	General Location & Navigation		Other	
	Devices	Percentage	Devices	Percentage
Test Suites Completed				
Suite 1 only	32	31.4%	12	28.6%
Suite 2 only	27	26.5%	5	11.9%
Both Suites	8	7.8%	1	2.4%
Suite 1 but not 2	2	2.0%	3	7.1%
Suite 2 but not 1	5	4.9%	2	4.8%
Neither	28	27.5%	19	45.2%
Total	102	100.0%	42	100.0%

It is alarming that only 7.8% of the devices were able to complete both test suites and this fact alone raises very serious questions. The basic design of the test was undermined by this low completion percentage. Additional questions arise when contemplating why so few devices were sufficiently stable so as to be able to successfully complete both test suites.

IEEE 1900.2 [13] also provides strong guidance that coexistence analysis should quantify the variability that influences the analysis. The important factors identified to this point, and others to be discussed later, must be taken into account in any reasoned analysis. Subclause 9.7 of IEEE 1900.2 [13] states:

9.7 Analysis uncertainty

All analyses and measurements have an associated uncertainty. This sub-section requires the analyst to explicitly state the uncertainty of their findings.

9.7.1 Uncertainty distribution

When developing an analysis emphasis may be given to minimizing the possibility of a false positive finding, a false negative finding or balancing the two. The analysis should state the emphasis used and the rational for it. There are legitimate reasons why an analysis will choose one emphasis or the other. The effect will be, where there is uncertainty, to deal with it to achieve the desired goal. If one analysis intends to assure with 95% confidence that interference will not be underestimated while a second seeks to assure with the same confidence that inference will not be overestimated then the results may be quite different. By stating the intent of the analysis the reason for divergent results can be more readily identified.

This directive is also found in ISO 17025 [12], subclause 4.13.2.1, which directs:

The records for each test or calibration shall contain sufficient information to facilitate, if possible, identification of factors affecting the uncertainty and to enable the test or calibration to be repeated under conditions as close as possible to the original.

Test repeatability and measurement uncertainty are not reported as is required by ISO 17025 [12]. NPEF's does not report measurement uncertainty nor is test repeatability evaluated. As stated above, proper coexistence analysis needs to include a probability distribution due to the relevant variables involved. Equally the testing should have evaluated and quantified its measurement uncertainty. ISO 4.13.2.1 applies here as well and further direction on calculating and reporting uncertainty with test data is given in ISO 17025 [12], subclause 5.4.5.3:

5.4.5.3 The range and accuracy of the values obtainable from validated methods (e.g. the uncertainty of the results, detection limit, selectivity of the method, linearity, limit of repeatability and/or reproducibility, robustness against external influences and/or cross-sensitivity against interference from the matrix of the sample/test object), as assessed for the intended use, shall be relevant….

ISO 17025 [12] subclause 5.4.6 provides further guidance:

5.4.6 Estimation of uncertainty of measurement

…..

5.4.6.2 Testing laboratories shall have and shall apply procedures for estimating uncertainty of measurement. In certain cases the nature of the test method may preclude rigorous, metrologically and statistically valid, calculation of uncertainty of measurement. In these cases the laboratory shall at least attempt to identify all the components of uncertainty and make a reasonable estimation, and shall ensure that the form of reporting of the result does not give a wrong impression of the uncertainty.

The testing was conducted with a 30 minute baseline, followed by a 15 second dwell time at each power level, increasing to 30 seconds at the higher power levels and a 3 minute dwell time at the maximum power level. During these intervals each device would have performed many measurements. However, no information is presented on how those many measurements were analyzed and used. Was the worst-case reading reported, an average of the readings or some other method used? Further the variation in readings for each time interval is necessary to know in order to understand the stability of the test. Both the method for selecting a value for use in the analysis and the range of readings at each step should be reported and is clearly called for by standard testing practices as shown by ISO 17025 [12].

E. Environmental noise was not properly taken into account

NPEF assumed in its tests that the background noise floor is exclusively due to the receiver's internal thermal noise. This assumption is flawed because the RNSS band is subject to received co-channel noise from many sources, including harmonics of terrestrial transmitters far outside the GPS band, other navigation satellites and sky noise. Aviation standards account for this by allowing a margin for "environmental noise", as described below.[21]

The RTCA MOPS recommend that broadband noise should be added to the receiver in any test set-up designed to assess interference to aviation receivers.[22] The NPEF tests/analyses did not follow this protocol. It is noteworthy that, in the RTCA/TWG testing of aviation receivers, this environmental noise was properly taken into account.[23] It is not possible to theoretically predict, in a general way, the effect of increased background noise on the 1 dB C/N_0 degradation threshold of randomly selected receivers. The effect will depend on the receiver implementation, i.e. the actual mechanism causing C/N_0 degradation in the particular receiver owing to strong adjacent band signals. For instance, if the effect is to cause receiver gain compression, the de-sense threshold may not be affected; if the effect is to cause a rise in the internal noise floor of the receiver, such as through reciprocal mixing or A/D aliasing, the de-sense threshold could be higher to the extent calculated below.

The rise of the composite noise floor, for a fixed amount of received environmental noise, depends on the noise figure of the receiver. The rise is 3 dB for a receiver with 2 dB noise figure, 2.6 dB for 3 dB noise figure, and 2.2 dB for 4 dB noise figure receiver. The calculation for 3 dB receiver noise figure is shown below.

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21 RTCA/DO-229D, Minimum Operational Performance Standards for Global Positioning System/Wide Area Augmentation System Airborne Equipment, Section C.2.3 (December 13, 2006) ("RTCA/DO-229D [14]"); RTCA/DO-235B, Assessment of Radio Frequency Interference Relevant to the GNSS L1 Frequency Band, Section 15-4, ¶ 6 (March 13, 2008) ("RTCA/DO-235B [15]").

22 RTCA/DO-229D [14], at Section M.5.1.

23 RTCA/DO-327, Assessment of the LightSquared Ancillary Terrestrial Component Radio Frequency Interference Impact on GNSS L1 Band Airborne Receiver Operations, Section D.1.1 (June 3, 2011) ("RTCA/DO-327 [16]").

Table A.I.4

Typical Rx NF	3	dB
Thermal PSD (No')	-171.0	dBm/Hz
Effective Noise Density of for all GNSS sources (Io)	-171.9[24]	dBm/Hz
Corrected No = Io + No'	-168.4	dBm/Hz
Correction in Carrier power for the same degradation	2.6	dB

If, for example, nonlinear effects are causing the internal noise floor of the receiver to rise, then, in order to cause 1 dB degradation in the observable noise floor, the latter has to rise 2.6 dB more in the case where there is external noise relative to the case where there is no external noise. If it is further assumed that the rise in internal noise floor is linearly proportional with respect to the adjacent channel signal power (itself a conservative assumption as shown by many instances in the NPEF test results), then the desense threshold will be 2.6 dB higher.

II. THERE IS NO SCIENTIFIC SUPPORT FOR NTIA'S REFUSAL TO ANALYZE COMPATIBILITY BASED ON LIGHTSQUARED'S POWER ON THE GROUND PROPOSAL

In October 2011, in an effort to move the discussion past what proved to be a contentious topic of the choice of propagation models, LightSquared proposed to limit its power on the ground to -30 dBm initially and -27 dBm after several years.[25] The proposal contains two options. One option involves a reduction in base station power for transmitters closer to the ground and a modified version of the Walfisch Ikegami Line of Sight (WILOS) model (the "Height-Power Option"). The other option involves an intensive program of post-deployment measurement to identify and correct any "hot spots" (the Measurement-Based Option"). With either option, LightSquared stated a willingness to further adjust its network if third-party measurements indicated that hot spots remained. LightSquared informally also expressed a willingness to limit its base station deployment to Left Hand Circularly Polarized (LHCP) antennas, which would have the effect of further reducing its power on the ground from the perspective of a GPS receiver.

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[24] RTCA/DO-327 [16], at Section 3.1.1.

[25] LightSquared, Ex Parte Notification, FCC File No. SAT-MOD-20101118-00239 and IB Docket No. 11-109 (October 6, 2011) ("LightSquared Ex Parte Letter [3]"); *see also* Letter from Jeffrey Carlisle, Executive Vice President Regulatory Affairs and Public Policy, LightSquared, Inc. to Julius Knapp, Chief, Office of Engineering and Technology, FCC, FCC File No. SAT-MOD-20101118-00239 and IB Docket No. 11-109 (December 7, 2011) ("LightSquared Update [20]") (providing further detail to the FCC about LightSquared's power on the ground proposal"); Letter from Jeffrey Carlisle, Executive Vice President Regulatory Affairs and Public Policy, LightSquared, Inc. to Marlene H. Dortch, Secretary, FCC, FCC File No. SAT-MOD-20101118-00239 and IB Docket No. 11-109 (December 12, 2011) ("LightSquared Update [21]") (updating LightSquared's power on the ground proposal by (1) eliminating the final power increase phase (establishing a maximum power of -27 dBm after January 1, 2016) and (2) extending the period during which it will maintain the power at -30 dBm to January 1, 2016).

The NTIA Letter [4][26] ignores LightSquared's highly constructive proposals without explanation. Instead, it insists on analyzing the NPEF tests based on an assumed -15 dBm power on the ground from LightSquared operations, and apparently based on using a propagation model that assumes nearly free-space, which is demonstrably too conservative. As discussed below, NTIA's assumptions vastly overstate the actual power to which a GPS device will typically be exposed. Either of LightSquared's options and its LHCP proposal would have provided a far more reasonable approach to ensuring compatibility for the practically all personal/general navigation devices operating almost anywhere near a LightSquared base station.

A. NTIA's choice of base station power and propagation models was inappropriate

A fundamental error in NTIA's analysis is its failure to consider the power at which LightSquared is proposing to operate its base stations, particularly those at lower heights. The following table provides LightSquared's proposed EIRP reduction schedule.[27]

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[26] Letter from Lawrence E. Strickling, NTIA, to Julius Genachowski, Chairman, FCC (February 14, 2012) ("NTIA Letter [4]").

[27] Following submission of the LightSquared Ex Parte Letter [3], LightSquared further modified its proposal to limit power on the ground. The updated proposal is reflected in Table A.II.1 and were provided to NTIA prior to submission of the NTIA Letter [4].

Table A.II.1 LightSquared's Proposed Base Station EIRPs for Modified WILOS and Threshold of -30 dBm (free space propagation up to 100 m and WILOS thereafter)

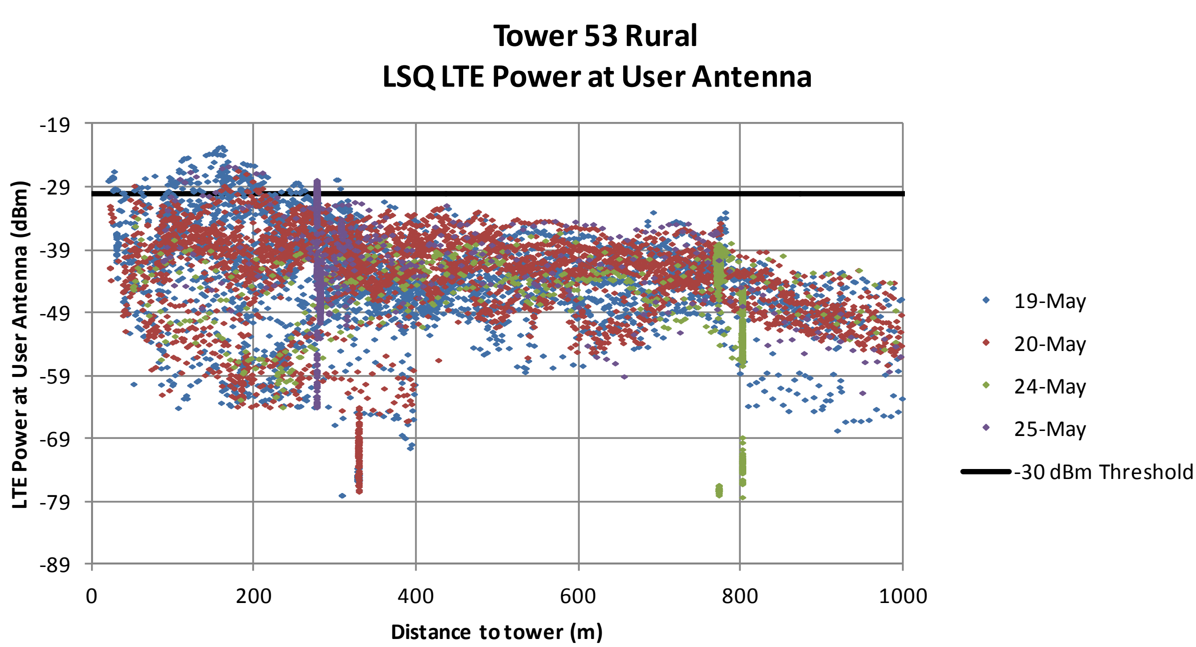
BS Antenna Height (m)	Power Reduction (dB)	Maximum Allowed EIRP (dBm) Argus Antenna
4	26	36
5	23.1	39
6	20.9	41
7	19.2	43
8	17.7	44
9	16.5	46
10	15.4	47
11	14.4	48
12	13.6	48
13	12.8	49
14	11.9	50
15	11	51
16	10.2	52
17	9.5	53
18	8.8	53
19	8.1	54
20	7.5	55
21	6.9	55
22	6.3	56
23	5.8	56
24	5.3	57
25	4.8	57
26	4.3	58
27	3.9	58
28	3.4	59
29	3	59
30	2.6	59
31	2.2	60
32	1.8	60
33	1.5	61
34	1.1	61
35	0.8	61
36	0.5	62
37	0.1	62
>38	0	62

Instead of using these power levels for its analysis, however, NTIA appears to have assumed that all LightSquared base stations would operate at the maximum power of 32 dBW EIRP, regardless of height. It then used this assumption and measurements taken in field tests in the Las Vegas area in May 2011 from three test sites to settle on a propagation model that essentially assumes free-space propagation for more than a mile from each base station.[28] NTIA appears to have rejected the use of WILOS because it would have under-predicted the power on the ground.

NTIA's assumption is fundamentally flawed as the Las Vegas field data can actually be useful in demonstrating the utility of cell site power reductions based on use of the Modified WILOS model. To demonstrate this point, LightSquared has performed an analysis of the Las Vegas field data, adjusted to reflect the power reductions that would be implemented as a result of its proposed Height-Power Option. For the three test sites, LightSquared has reduced the actual EIRP by the values dictated by Table A.II.1 above. Utilizing these reduced values, and adjusting these field measurements on a dB-for-dB basis, it is clear that the actual power on the ground is limited to -30 dBm or less at almost all locations. The dB-for-dB reduction in received power is appropriate as the propagation medium is completely linear.

Figure A.II.1 below shows the Las Vegas data from rural site #53.[29] This site had the highest levels of power on the ground and used an 18 m high antenna.

Figure A.II.1 Las Vegas data for Rural Site #53 collected by Trimble, adjusted for base station EIRP reduction of 9 dB corresponding to antenna height of 18 m.



[28] NPEF Report [1], at 22-25.

[29] Working Group, Final Report, IB Docket No. 11-109, Figure.32: Trimble Reported Field Data for Test Site 53 (June 30, 2011) ("TWG Final Report [17]").

The distribution analysis for this data is shown in Table A.II.2 below.

Table A.II.2 CDF for Trimble Reported Data Set for Site #53
TWG Final Report, Figure 3.2.34

Power (dBm)	Frequency	CDF %
-60	1539	13.25%
-55	650	18.84%
-50	881	26.42%
-45	1657	40.69%
-40	3085	67.24%
-35	2259	86.68%
-30	1235	97.31%
-25	296	99.86%
-20	16	100.00%

Table A.II.2 shows that for an 18 m high antenna, as used in site #53, the LightSquared proposed improvements to NTIA's Height-Power Model would have resulted in a probability of approximately 97% for the power being less than or equal to -30 dBm, or <u>3% probability for the threshold level ever being exceeded</u>.

The same analysis was performed for the suburban site #68, where the antenna height was 17 m, and the urban site #160, where the antenna height was 15.2 m. The results for all three locations are summarized in Table A.II.5.

Figure A.II.2 Las Vegas data for Suburban Site #68 collected by Trimble, adjusted for base station EIRP reduction of 9 dB corresponding to antenna height of 17 m

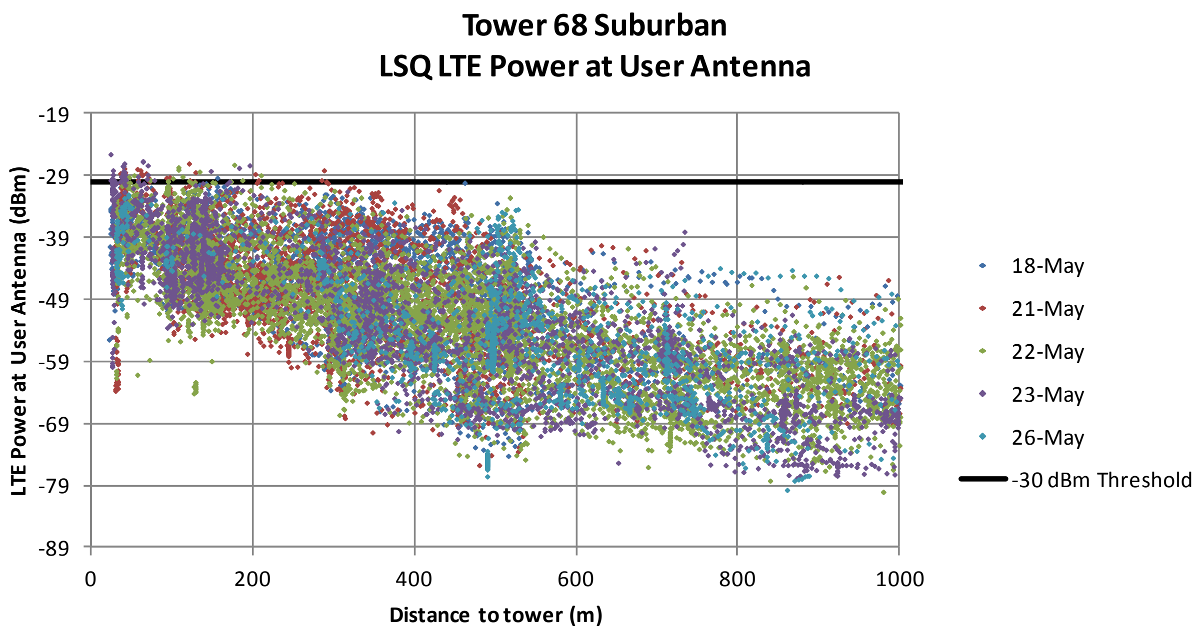


Table A.II.3 CDF for Trimble Reported Data Set for Site #68 TWG Final Report, Figure 3.2.26

Power (dBm)	Frequency	CDF %
-60	3884	18.22%
-55	3202	33.25%
-50	2773	46.26%
-45	3491	62.64%
-40	4329	82.95%
-35	2660	95.43%
-30	877	99.55%
-25	96	100.00%
-20	0	100.00%

Figure A.II.3 Las Vegas data for Urban Site #160 collected by Trimble (TWG Final Report, Figure 42) adjusted for base station EIRP reduction of 11 dB corresponding to antenna height of 15.2 m

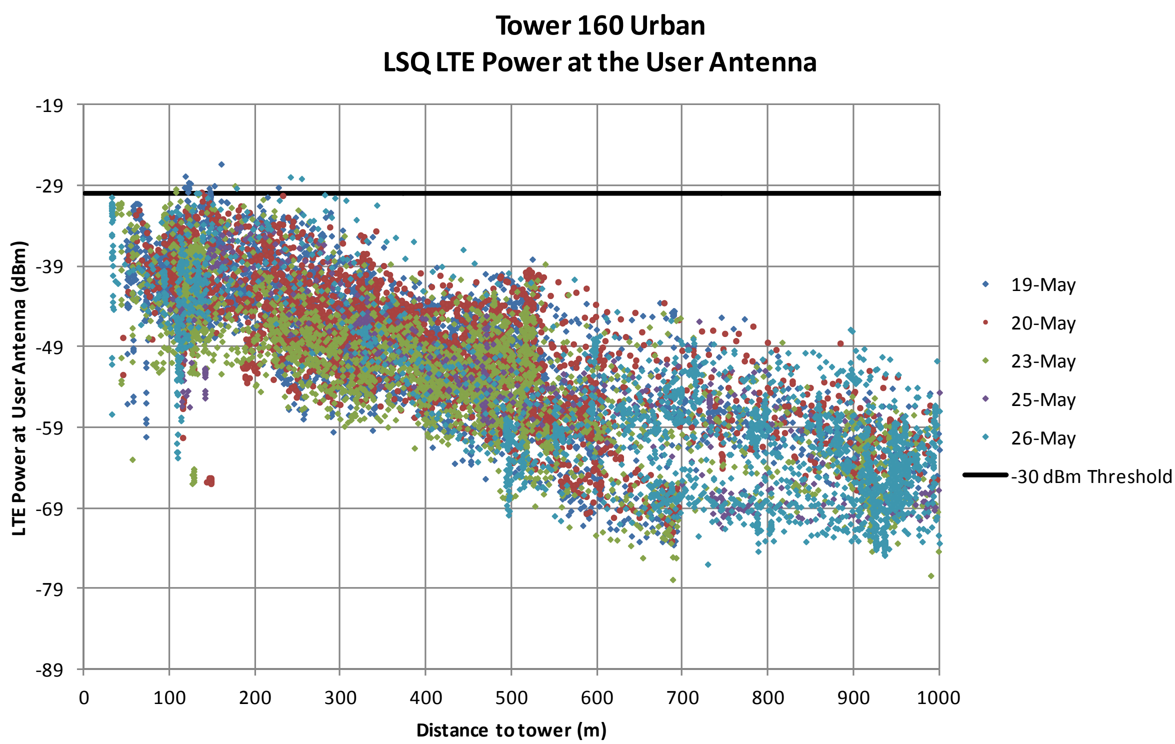


Table A.II.4 CDF for Trimble Reported Data Set for Site #160

Power (dBm)	Frequency	CDF %
-60	3841	32.86%
-55	2313	52.64%
-50	1791	67.96%
-45	1692	82.44%
-40	1010	91.08%
-35	726	97.29%
-30	291	99.78%
-25	26	100.00%
-20	0	100.00%

Table A.II.5 Summary Results Showing Applicability of LightSquared Proposed Modified WILOS Model to Las Vegas Field Data

	Rural Site #53	Suburban Site #68	Urban Site #160
Antenna Height (m)	18	17	15.2
EIRP Backoff as per LightSquared Proposal (dB)	9	9	11
Measured probability of power on the ground exceeding -30 dBm	2.7%	0.4%	0.2%

Table A.II.5 shows that, had the Height-Power approach (free space up to 100 m and WILOS thereafter) proposed by LightSquared been used to adjust the base station powers in Las Vegas, the *actual* probability of exceeding the objective threshold of -30 dBm would have been very small (2.7% to 0.2% in the above examples). Moreover, the morphology around site #53 (2.7% probability) – a site in the Nevada desert at one end of a huge crater and with relatively smooth ground, in the absence of any blockage or ground clutter for over 10 km – is atypical of most morphologies where LightSquared's network will be deployed. Hence the 2.7% value noted above for site #53 may be taken as an upper limit of the probabilities likely to be encountered in typical environments. The value of approximately 0.5% is expected to be more typical across all morphologies.

This also demonstrates how the Irregular Terrain propagation model ("ITM") that NTIA used is completely inappropriate for this task. According to NTIA's own manual, the model is intended for use at distances greater than 1 km.[30] An analysis using the extremely conservative free space propagation model shows that LightSquared's highest power levels on the ground will be achieved at distances ranging from 100-400 meters from the base of the transmit antenna tower (depending on antenna height) – which are clearly not within the area for which ITM is intended. Figures A.II.4 and A.II.5 below demonstrate the maximum expected power on the ground for antennas of 15 meters and 50 meters in height, using LightSquared's base station antenna patterns and the overly conservative free space propagation model.[31]

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[30] NPEF Report [1], at F-3 FN1 (citing National Telecommunications and Information Administration Institute for Telecommunications Sciences, NTIA Report 82-100, A Guide to the Use of the ITS Irregular Terrain Model in the Area Prediction Mode (April 1982)); *see also* Table A.II.1.

[31] A free space propagation model is appropriate for this limited exercise of predicting the *points* of highest power, since it is a relative measurement (e.g.: identification of the physical location of highest power, without regard to the power level that is actually estimated).

Figure A.II.4 - Power on the ground as a function of distance for a 15 m high base station antenna

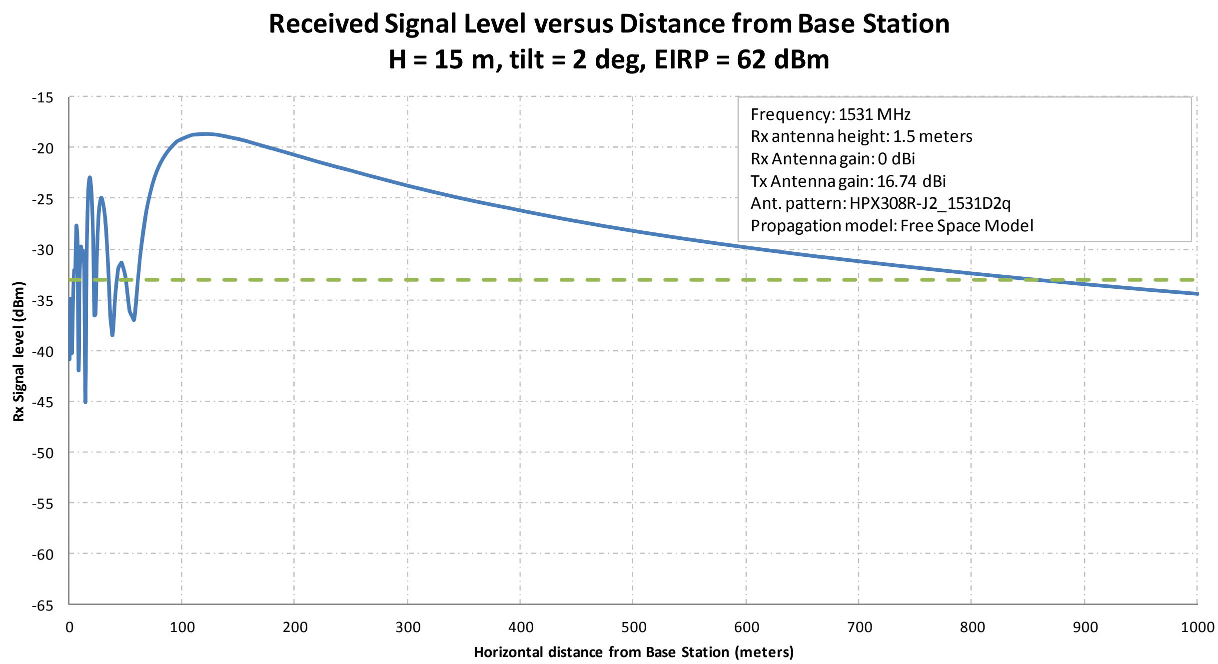
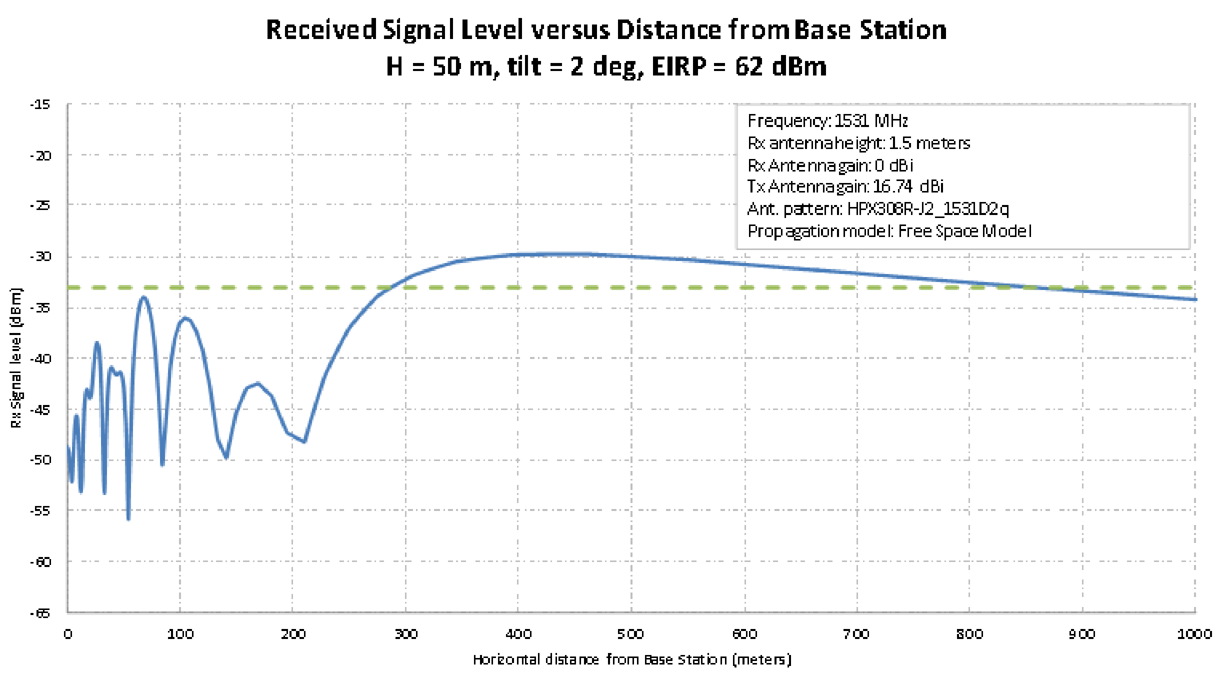
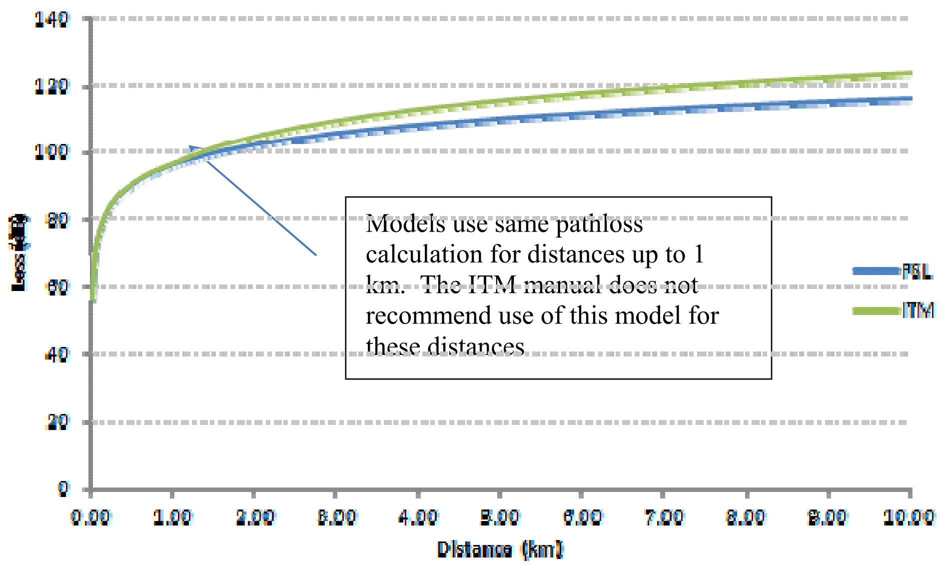


Figure A.II.5 - Power on the ground as a function of distance for a 50 m high base station antenna



In reality, the ITM model uses a free space line of sight calculation for distances of 1 km or less. Because LightSquared's maximum power will be achieved within this 1 km zone, there is no practical difference between a free space model and the ITM for NTIA's intended use.

Figure A.II.6 - Variation of power on the ground with distance for ITM and FSL



Furthermore, the Longley-Rice model, which is the basis of the ITM, has been criticized as being unsuitable for modeling urban clutter.[32] According to Rappaport [5],

> One shortcoming of the Longley-Rice model is that it does not provide a way of determining corrections due to environmental factors in the immediate vicinity of the mobile receiver, or consider correction factors to account for the effects of buildings and foliage. Further, multipath is not considered.

In Parsons [6][33] the author states,

> Since the original publication there have been several revisions and modifications of the Longley-Rice model and some corrections have been made. … One significant development, relevant to mobile radio propagation, has been the introduction of an urban factor (UF) used to make predictions in urban areas….

The ITM model does not use this correction factor and consequently dramatically overestimates the RF power levels. Is this the difference between fast fading and slow fading and its impact on devices?]Using the urban factor correction leads to an increase of the median path loss at 1 km by 34 dB.[34] In summary, the classic ITM model is an older model that has been revised substantially and superseded by newer models, none of which are considered by the NTIA.

It may be further noted that unlike the NTIA, the FAA used a cellular clutter model (modified Hata-Okumura) for path geometries that would have a high likelihood of encountering urban clutter. For an aircraft parked at a runway, the modified Hata-Okumura model would be used if a clear line of sight did not exist with respect to a given base station.[35] In the same scenario, the NTIA would use free space propagation if the distance was less than 1 km, *regardless of blockages*. It is noteworthy that whereas the FAA's model is *site-specific*, i.e. acknowledges the presence of blockages, the NTIA's ITM model does not.

The extent to which NTIA's insistence on the ITM model is unreasonable, relative to the use of actual terrain and obstacle data, is easily illustrated by showing the levels of power on the ground in the Washington, D.C. area using an industry-standard RF planning tool (CelPlan©). This tool was run assuming free space propagation, both with and without terrain and morphology[36] (collectively, "obstacles").

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[32] Rappaport, T. D., Wireless Communications and Practice (2 Ed.), Prentice Hall, 2002. pp. 145-46 ("Rappaport [5]").

[33] Parsons, J. D. The Mobile Radio Propagation Channel (2. Ed.), John Wiley and Sons, Chichester, UK, 2000 p. 60 (Parsons [6]).

[34] According to Parsons, UF (dB) = $16.5 + 15*\log_{10}(f/100) - 0.12\ d$, where f is in MHz and d is in kilometers. For f = 1531 MHz and d = 1 Km, UF = 34.1 dB.

[35] *See* Technical Appx. Exhibit B, *infra*.

[36] The analysis utilizes 1 meter resolution obstruction data for the densest portions of downtown Washington, DC. This is commercial data based on detailed surveys of actual buildings and obstructions in order to provide a highly accurate representation of the impact of actual building clutter on signal propagation. Areas outside of the downtown area utilize 30 meter resolution data.

Figure A.II.7 shows the input parameters. The base stations were assumed to operate at full power (32 dBW) regardless of antenna height, except where they were bound to a lower limit by LightSquared's existing requirement to operate at lower power near airports and navigable waterways.

Figure A.II.8 shows the coverage area. The tool was used in two modes: (i) free space propagation everywhere*, ignoring* obstacles, shown in Figure A.II.9 (the approach used by ITM) and (ii) free space propagation *considering* obstacles, shown in Figure A.II.10.

Figures A.II.9 and A.II.10 show that, if obstacles are ignored, the estimated power level would exceed -30 dBm over large areas (55%), which would require significant, but unnecessary, reductions in base station EIRP to achieve a -30 dBm threshold. To compensate for the impact of this on network coverage, there would have to be a significant increase in the number of base stations and a corresponding increase in network cost. In contrast, the red areas comprise 2-3%[37] of the coverage area when terrain and blockages are considered. This demonstrates the massive inefficiency which is created by NTIA's insistence on use of an overly conservative propagation model, that its own documentation acknowledges is not well suited for this type of task. LightSquared's Measurement-Based approach provides the needed RF environment to assure continued performance of general location/navigation devices, without inserting unnecessary (and expensive) excess margin.

In addition to the use of an incorrect propagation model, NTIA has further demanded that the power on the ground be limited to -33 dBm, without providing reasonable justification for such a requirement. This change compounds the exceedingly large, and unnecessary, economic burden on LightSquared as compliance would necessitate the construction of a large number of additional cell sites in order to provide appropriate levels of terrestrial coverage.

These coverage maps show the combined impact of reducing the pass/fail criterion from -30 dBm to -33 dBm, when using an extremely lossless propagation model such as ITM, as shown in Figure A.II.9, compared to a real world deployment scenario, shown in Figure A.II.10. In the former case, when terrain/obstacles are ignored, the affected area increases from 55% to 88%. In the latter case, when terrain/obstacles are considered, the affected area increases from 2% to 3%.

[37] In the results shown in Figure A.II.10, blockages were modeled as infinite attenuation. Results were also produced using the diffraction option of the tool and a high resolution terrain/obstacle database to make the loss finite and more realistic. However, the impact on the coverage map was small; the affected area for -30 dBm threshold went up by 1%. This difference is irrelevant to the point being made here, which is the huge difference with respect to the coverage map shown in Figure A.II.9, where terrain and obstacles are ignored.

Figure A.II.7 - Prediction parameters

Parameters	Inputs
Area	1,300 km^2 area centered on the District of Columbia
Tower database	LightSquared tower data ("Tower Data")
Antenna pattern	Argus (1531MHz) (Electronically Down Tilt to 2 degrees)
Antenna height and azimuth	Tower Data
Antenna azimuth	Tower Data
Mechanical tilt	Fixed in 0º
EIRP	Tower Data
Path Loss Model	Free Space model
GIS data	Scenario 1: No GIS database used Scenario 2: 1-meter building layer, 30-meter clutter and terrain databases
Prediction resolution	3 sec = 90 meters
Receiver height	1.6 meters

Figure A.II.8 - Study area

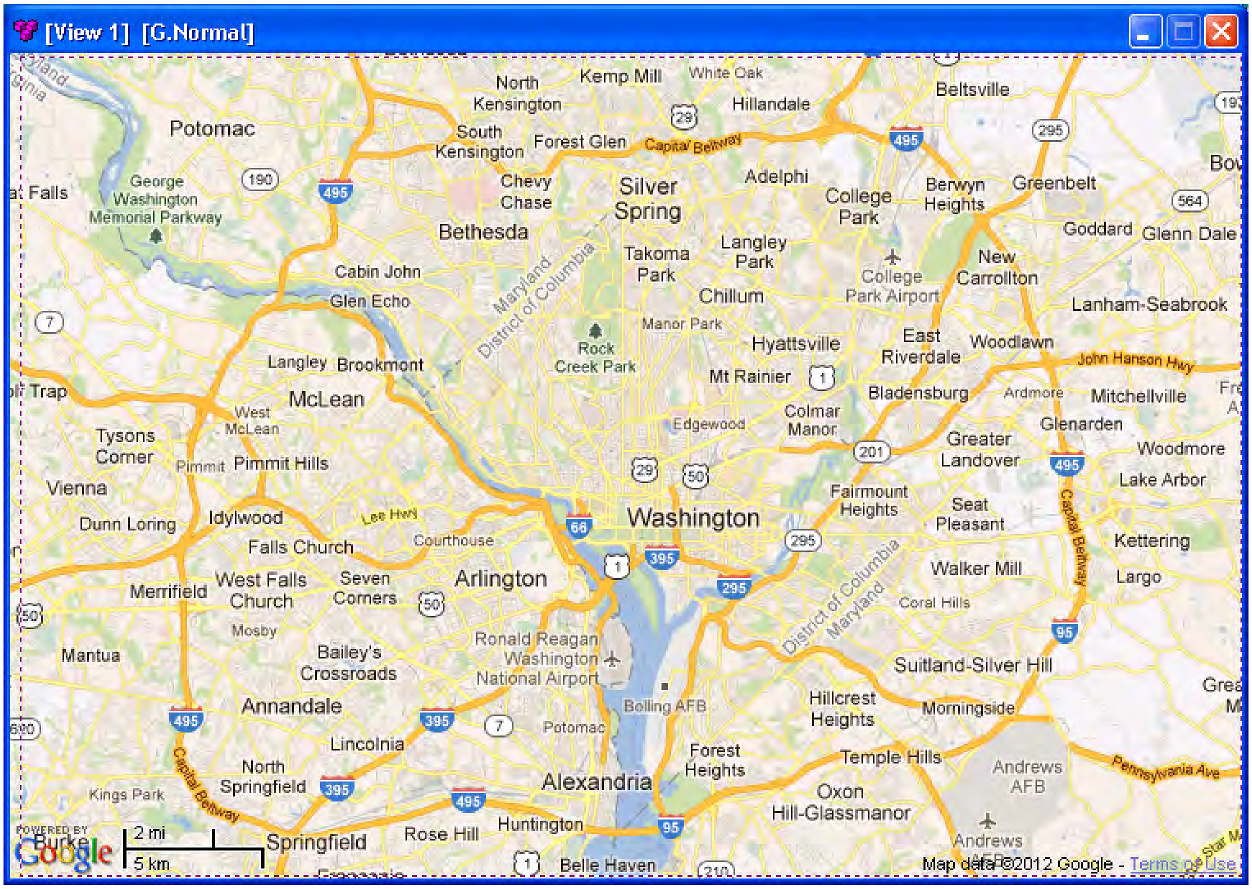


Figure A.II.9 - Aggregated received signal level prediction (using Free Space Line of Site without clutter)

(Sum of the received signals in each pixel)

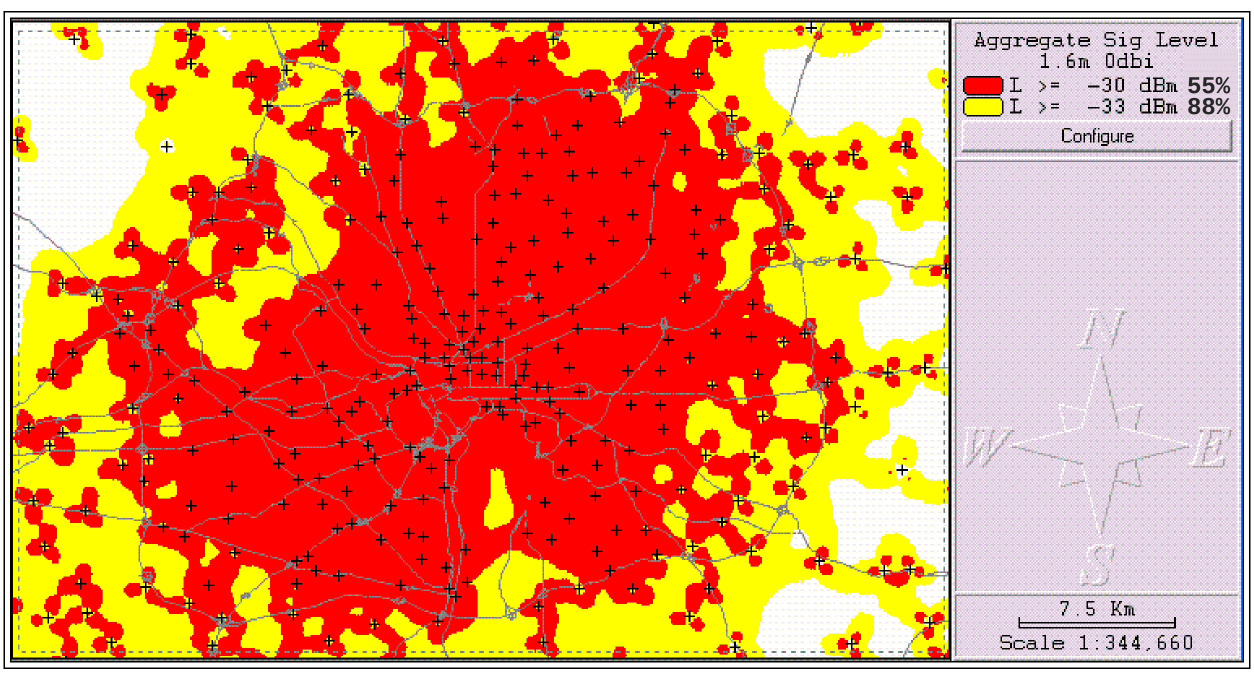
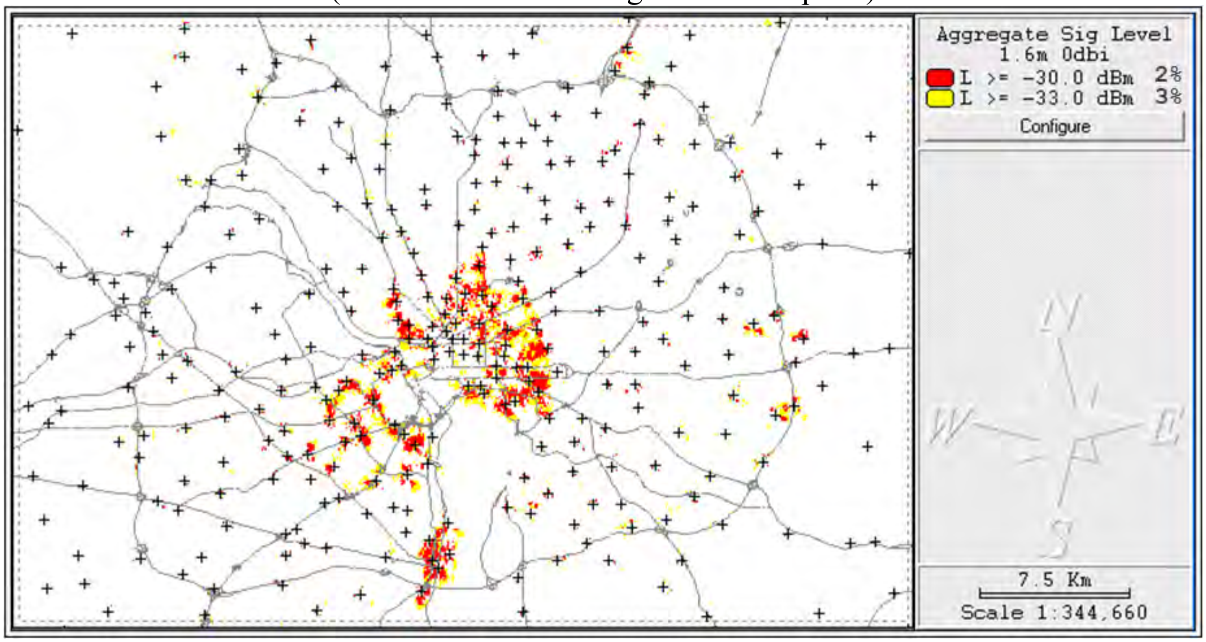


Figure A.II.10 - Aggregated received signal level prediction (using Free Space Line of Site with clutter and terrain)
(Sum of the received signals in each pixel)



Clutter data within the most densely-populated areas is based on 1 meter resolution survey; in the surrounding area 30 meter resolution data is used

In short, the use of ITM would impose an extraordinary burden on the operation of LightSquared's network without any rational technical justification in terms of additional protection to GPS receivers.

In contrast to ITM, WILOS is widely used to model propagation in open urban environments where there is line of sight to the base station. The WILOS model predicts greater loss than free space at distances greater than 20 meters and has been empirically verified to be a better predictor of the median value of RF power in urban environments with clear line of sight to the base station than a rudimentary free space model. Even though WILOS predicts less loss than the free space model, it is still inherently conservative as it ignores blockages. For this very reason, it is not generally used in planning RF coverage for communications networks, but can be a useful tool for where conservatism may be desired. By contrast, cellular RF planning is typically based *not* on line-of-sight models, but on non-line-of-sight models, such as WiNLOS, Hata-Okumura and COST231. In other words, using WILOS everywhere in the coverage footprint of a network would still significantly over-predict the RF power. Nevertheless, LightSquared is willing to accept the WILOS model as the basis for its Height-Power approach.

B. NTIA improperly rejected the Measurement-Based approach

LightSquared's Measurement-Based approach comprised a detailed post-deployment measurement process to identify any hot spots that would be eliminated by reducing base station power as necessary. This approach was intended as an alternative to the theoretical basis that underlies NTIA's use of the ITM (and even LightSquared's proposed use of WILOS in its

Height-Power approach). NTIA, in its letter, does not even mention this proposal, let alone explain its rejection.

NTIA informally indicated that it did not believe that an adequate compliance mechanism could be developed for the Measurement-Based approach. This ignores the fact that nearly anyone that has the ability to operate rather rudimentary test equipment could audit LightSquared's power in the same manner in order to determine if LightSquared was in fact meeting its compliance requirements. This is contrasted to the traditional EIRP-based regulation, where it is impossible to determine compliance without access to carriers' secured communications equipment.

NTIA's insistence on the use of the ITM, with a maximum power threshold of -33 dBm would require LightSquared to construct thousands of additional cell sites in order to compensate for the reduced coverage footprint occurring as a result of reduced transmitter power. As has been demonstrated above, these power level reductions are well above those necessary to protect general location/navigation devices from experiencing receiver overload (which, again, is due to their own design deficiencies). Either of the LightSquared proposals (Height-Power or Measurement-Based) would achieve the stated goal of NTIA to ensure continued operation of GPS devices, but without imposing excessive additional costs to LightSquared over and above the amounts required for LightSquared to comply with the proposed solutions it has submitted. LightSquared has estimated that the cost of complying with the NTIA proposed thresholds would be over $9 billion higher than compliance with LightSquared's proposed solutions.

C. LightSquared's proposed use of LHCP would have further mitigated any potential for overload

Finally, NTIA fails to address LightSquared's offer to use left hand circular polarization in its base station antennas, which would generate approximately 6 dB of additional margin relative to the use of dual linear polarization.[38] The reality is that significant potential exists for creating additional margin across all classes of GPS receivers through the use of some optimized set of base station antenna polarizations. These were presented by LightSquared, but never considered by NTIA.

Examples are provided below of antenna cross-polarization discrimination from two manufacturers of high precision GPS antennas. The measured data about Hemisphere antennas was provided to LightSquared by the manufacturer. The data about the Novatel antenna is publicly available in the manufacturer's data sheets.

[38] Antenna manufacturers estimate that there is over 15 dB of polarization isolation to be gained using LHCP antennas; LightSquared is using the 6 dB value in its analysis in order to account for environmental reflection and differences in antenna elevation angles.

Figure A.II.11

Measured Patterns for Hemisphere's
A52 Antenna at 1531 MHz

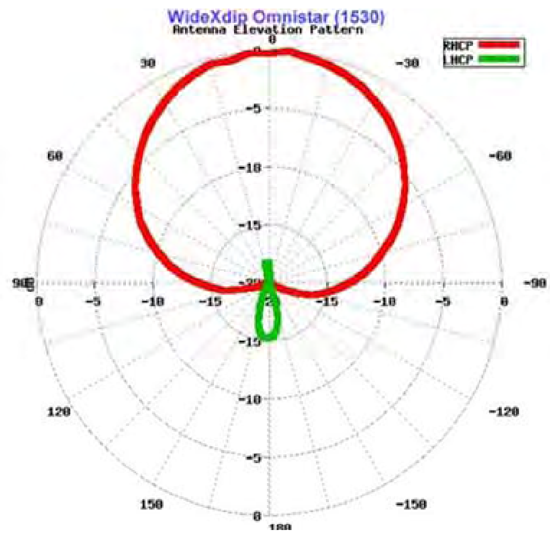


Figure A.II.12

Measured Patterns for Hemisphere's
A52 Antenna at L1 frequency

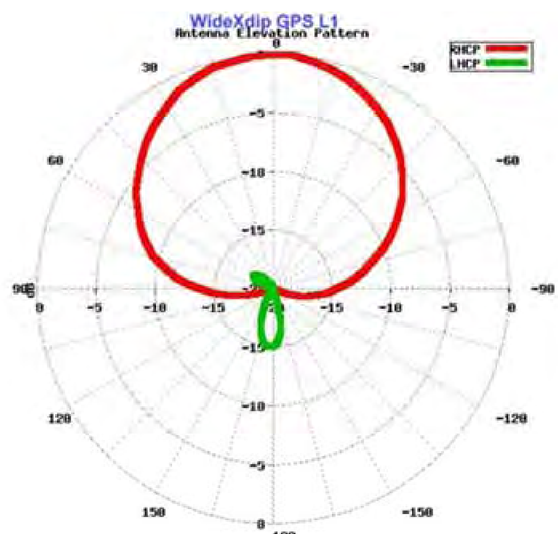
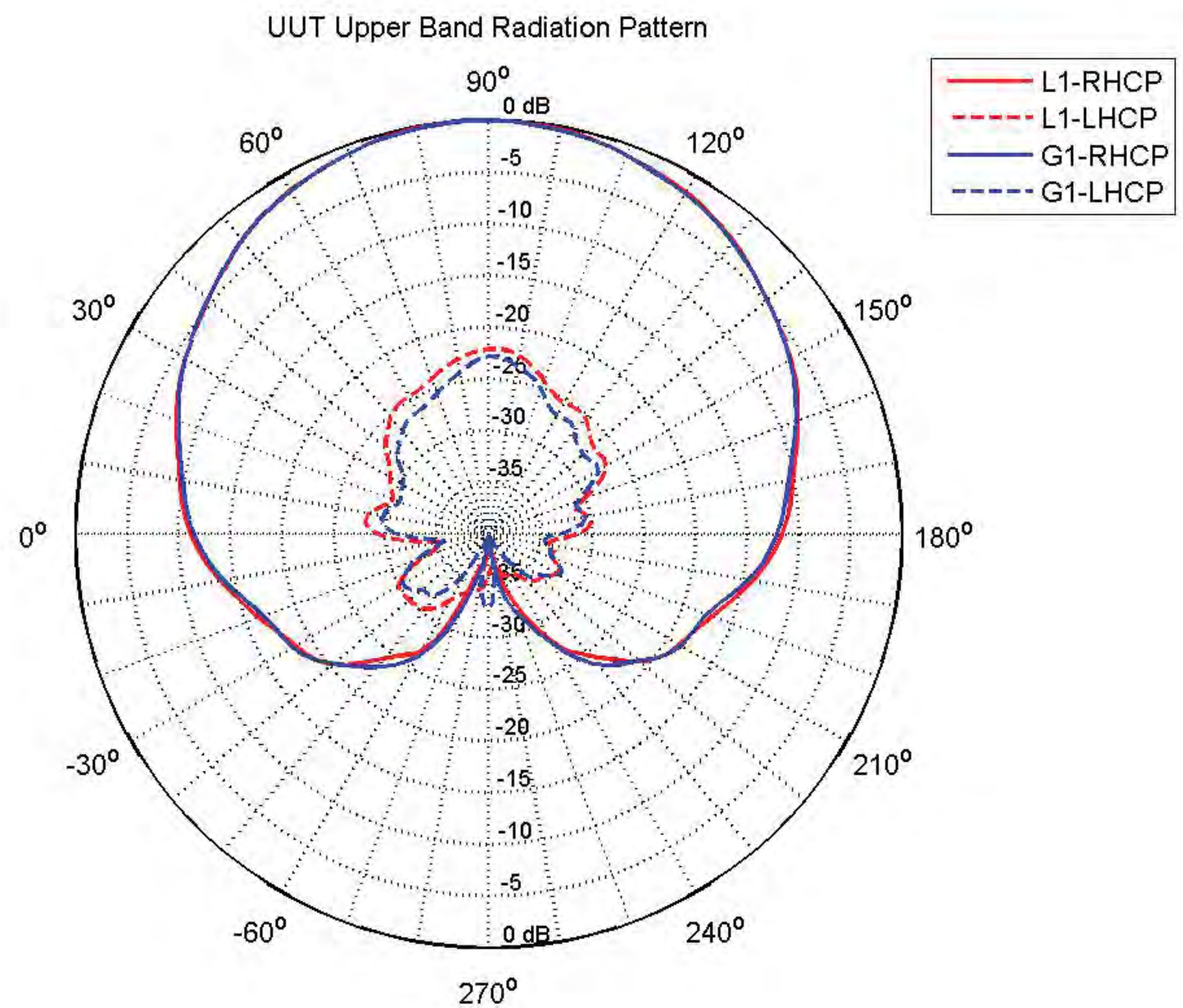


Figure A.II.13 - Polar Patterns for Novatel Antenna (GPS-703-GGG)[39]
"G" refers to Glonass band response



[39] Information available from public data sheets.

III. THERE IS NO SCIENTIFIC BASIS FOR USING A LOSS OF 1 DB IN C/N_0 FOR TESTS TO DETERMINE THAT A PERSONAL/GENERAL NAVIGATION DEVICE WOULD BE INCOMPATIBLE WITH LIGHTSQUARED OPERATIONS

One of the major failures in the NTIA Letter [4] is its use of a standard for "harmful interference" to Personal/General Navigation devices that has no scientific support.[40] NTIA, however, ignores all of this without explanation.[41] In contrast to the NPEF tests, the tests of cellular devices sponsored both by the TWG and by NTIA specifically measured changes in position accuracy through a series of tests. The cellular tests showed all devices to be compatible with LightSquared operations.

As described further below, there is ample empirical and theoretical evidence that a loss of 1 dB in C/N_0 is not an indicator of loss of performance in a GPS device.

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[40] IEEE 1900.2 [13] makes clear that just because potential interference is measurable at a particular level does not mean that it constitutes "harmful interference." More specifically, IEEE 1900.2 [13] defines an "interference event" and "harmful interference" as follows:

4.3 Interference event

An interference event is a measurement event in which a source device or system has a quantifiable performance effect on the recipient device or system or for the user of a recipient device or system. The concept of an interference event is used in the analysis for determining the amount and severity of interference. Interference events are therefore a subset of the measurement events. An interference event is scenario dependent. Depending on the service, performance degradation can be manifested in many ways. An individual interference event may not in itself be deemed harmful. When interference events degrade performance to an unacceptable level from a service perspective, it is termed harmful interference.

4.4 Harmful interference

Harmful interference is the level at which the analysis deems interference events have created unacceptable interference. The level shall be defined in terms of interference events across time and/or users or systems that cause an unacceptable degradation of the recipient system's performance, in the judgment of the analyst. This threshold will be used when determining whether harmful interference has occurred. The analysis of a system may involve more than one threshold. The analysis shall state the reasons for selecting the harmful interference criteria used in the analysis.

Under this IEEE standard, a 1 dB C/N_0 degradation may be a measurable interference event, without constituting "harmful interference" for IEEE purposes. For IEEE purposes (putting aside legal and regulatory purposes), for that to occur, the data would need to show an actual loss of performance that is perceptible to the user and not something that is merely measurable.

[41] NTIA's only attempt to justify its use of 1 dB C/N_0 is its statements that it has used a 1 dB loss in C/N_0 in other situations to manage interference and its understanding that this was consistent with the power levels measured by the TWG. NTIA Letter [4]. The first statement is not scientifically relevant; if it was then doctors would still be bleeding patients to treat disease. The second statement is simply wrong; the issue of whether to use a 1 dB loss of C/N_0 was a very controversial one in the TWG. *See* LightSquared, Reply Comments, FCC File No. SAT-MOD-20101118-00239 and IB Docket No. 11-109 (August 15, 2011) ("LightSquared Reply Comments [7]").

A. The dynamic tests performed by the TWG showed that a 1 dB erosion of C/N_0 had little impact on the postion tracks as determined though statistical analyses

The most compelling data about the irrelevance of a 1 dB loss of C/N_0 came from dynamic tests that were developed by the TWG sub-team evaluating General Location and Navigation devices. These tests recorded live GPS signals in the field in a set of typical environments selected by the sub-team. These environments included dense urban, suburban, deep woods, and forest path locations. The recordings were made by Alcatel Lucent under the supervision of sub-team members and included other normal sources of degradation, such as non-LightSquared additive noise, multipath fading, and Doppler shift.[42] The recordings were rebroadcast in an anechoic chamber to conduct simulations of the impact on actual personal navigation receivers.[43] The LightSquared signal was added as a constant amplitude signal to the GPS signals recorded in the field and radiated toward the GPS receiver from the direction of maximum antenna gain.[44]

These results were then analyzed in conjunction with static tests in which constant power GPS signals from a GPS signal simulator and a constant power LightSquared signal were added together and radiated into the GPS receiver. The results show the LightSquared power levels at which the GPS receivers reported C/N_0 decreases at a range of values relative to the baseline of no LightSquared signal. Table A.III.1, reproduced from the TWG Final Report [17], presents that data for the static tests.

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42 These sources of degradation are due to the existing RF and physical environment in which GPS devices operate. Most GPS devices have features to compensate for a temporary loss of signal so that the device can continue to operate as expected by the end user.

43 As Garmin correctly noted, the laboratory tests were performed using a combination of a lower 5 MHz channel and an upper 5 MHz channel, rather than a single lower 10 MHz channel. Garmin International, Inc., Comments, FCC File No. SAT-MOD-20101118-00239 and IB Docket No. 11-109, pp. 38-39 (August 1, 2011) ("Garmin Comments [8]"). For purposes of selecting an appropriate pass/fail criterion, however, this difference should not be relevant and, in any case, it is likely that the use of only the Lower 10 MHz channel would have shown less impact than that of the two channels.

44 This methodology will yield very conservative results, since it ignores the fact that, as is the case for the GPS signals, the LightSquared base station signal will also suffer blockage and multipath fading, with a mean value that will be several dBs lower than used in the test. Additionally, the LightSquared signal will likely enter the GPS receiver at a lower elevation angle than the GPS signals and hence encounter lower antenna gain.

Table A.III.1

Phase IIb
TEST: Static InterferenceSuceptibility, downlink 1531.0 (10 MHz BW)
Power at Device (dBm) vs C/N degradation

	Device	1 dB	3 dB	6 dB	10 dB	20 dB	LOF
1	P14949	-33.0	-26.0	-21.0	-15.0	-6.0	-3.0
2	G15343	-32.0	-27.7	-24.3	-20.1	-9.4	-2.0
3	G14298	-29.5	-22.5	-17.5	-14.6	-6.6	-6.6
4	G18161	-23.6	-20.6	-18.2	-15.9	-9.3	-5.5
5	G15028	-23.5	-19.7	-14.5	-10.5	lof	-5.2
6	G16382	-22.0	-13.0	-9.0	-8.0	lof	-5.0
7	G12586	-19.7	-15.6	-12.7	-8.8	-3.5	*MPNE*
8	G17641	-13.7	-9.7	-8.7	-4.6	*MPNE*	
9	G12867	-13.3	-9.4	-6.5	-3.0	*MPNE*	
10	G10195	-9.6	-6.4	4.0	*MPNE*		
11	G12559	-9.5	-3.8	*MPNE*			
12	P15427	-8.0	-5.0	-3.0	*MPNE*		
13	G10968	-7.5	*MPNE*				
14	G16062	-7.3	*MPNE*				
15	G15448	-5.2	*MPNE*				
16	G13445	-5.1	*MPNE*				
17	G16534	-4.0	*MPNE*				
18	G17169	-3.5	*MPNE*				
19	G11207	-3.4	*MPNE*				
20	P17655	-2.0	*MPNE*				
21	G10607	*MPNE*					
22	G14188	*MPNE*					
23	G14686	*MPNE*					
24	G16449	*MPNE*					
25	G17763	*MPNE*					
26	G16696	*MPNE*					
27	P13275	*MPNE*					
28	P14730	*MPNE*					
29	P18582	*MPNE*					

MPNE Maximum Power reached with No Effect (> 0 dBm)

LightSquared mapped the results of the static tests to the actual drive test routes, which it presented in a series of figures highlighting the variation in performance for three cases: (i) no LightSquared signal; (ii) a LightSquared signal causing a 3 dB decrease in C/N_0; and (iii) a LightSquared signal causing a 6 dB decrease in C/N_0. Copies of those maps are in LightSquared's Reply Comments [7].[45] The maps show no significant difference among the three cases. In the best case, the receivers performed very well and in the worst case (Dense Urban), performance fluctuated significantly (presumably due to the low GPS signal availability), but was generally no worse in the 6 dB case, and sometimes actually appeared to be better owing presumably to the random nature of the position errors. LightSquared also performed a statistical analysis of the position errors relative to estimated true positions. The analysis was performed for the baseline case of no LightSquared signal, as well as the cases where a LightSquared signal of the power level corresponding to a 6 dB decrease in C/N_0 (in the static tests) is added.[46] The results show no meaningful variation in position accuracy statistics between the baseline and 6 dB cases. In the Dense Urban environment, the position accuracy

[45] LightSquared Reply Comments [7], at Appx. Exh. A.

[46] LightSquared Reply Comments [7], at Appx. Exh. B.

was relatively poor for both cases, with a great deal of variability, and in the Suburban environment, it was routinely excellent for both cases.

B. It is well understood that 1 dB loss of C/N_0 is a very small fraction of the link margin that GPS receivers carry

GPS signal powers received on the ground are not static but time-varying. The reasons a GPS signal power changes incude: variable shadow/blockage conditions, especially for low elevation satellites, movement of the GPS device or people using the device and multipath (always present). Javad GNSS, a GPS manufacturer, has explained why high precision receivers need to carry operating margin to deal with GPS signal variability.[47]

Typically, High Precision receivers report a C/N_0 of around 50 dB.Hz and can maintain tracking down to approximately 20 dB.Hz and lower, depending on particular receiver design. The erosion of 1 dB in this 30 dB dynamic range is not expected to have a significant operational impact. The reason for this large dynamic range is that for precision positioning accuracy, the most important factor is Geometric Dilution of Precision (GDOP). A good GDOP is achieved when the geometry of satellites provide the largest possible tetrahedron. This in turn requires the use of satellites that are in lower elevation angles. Satellites with lower elevation angles have lower C/N_0 but the receiver is required to process signals at this lower C/N_0 with no loss of position accuracy. US Geodetic Survey recommends 15 degree elevation as the cutoff threshold for satellites because (signals from) satellites lower than 15 degree suffer from (excessive) ionospheric and tropospheric effects. At 15 degree elevation, receivers encounter over 35 dB Hz C/N_0. So, receivers conforming to the US Geodetic Survey recommendation need to carry at least 15 dB of margin relative to 50 dB.Hz. In practice, many receivers can track down to 20 dB.Hz, i.e. carry 30 dB headroom. Given this large dynamic range, a 1 dB erosion of C/N0 has no effect on the practical accuracy of results. In other words, a 1 dB erosion of the margin, *a small percentage of the time* (under 1% as per LightSquared's deployment plan) would rarely, if ever, impact the user experience.[48]

The following graph shows an example of the variation of C/N_0 over time, measured with a fixed GPS receiver over a 20 hour 40 minute period. It is clear that, over this period, there was an approximately 20 dB variation in the C/N_0 for the C/A code for the reasons suggested above. There are also short term variations of 3-6 dB riding on the long term varaition mentioned above. Given both the short and long term variations inherent in the received C/N_0, it is inconceiveable that a 1 dB downward movement in the entire C/N_0 curve (the result of a 1 dB degradation of C/N_0) could be perceptible by a user. The C/N_0 variation with mobility is even greater, making a 1 dB C/N_0 degradation even less visible.

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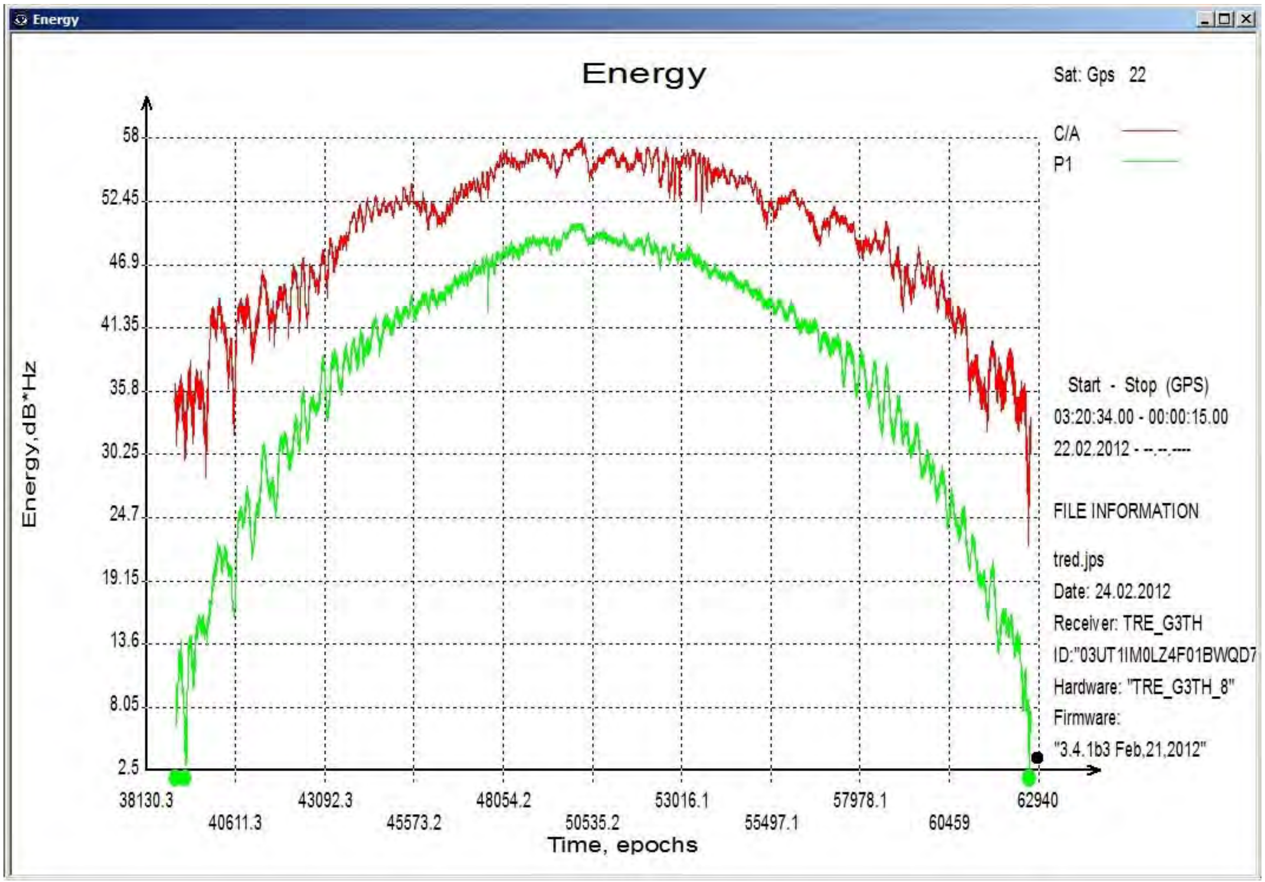
[47] *See* Javad, "GPS C/N0 variations" (March 15, 2012) *available at* http://www.javad.com/jgnss/javad/news/pr20120315.html ("Javad C/N0 Analysis [9]").

[48] Javad C/N0 Analysis [9].

Figure A.III.1 - Typical variation of GPS C/N_0 received on the ground with a fixed antenna



A theoretical examination of GPS position error budgets provides further support that, under normal operating conditions, a 1dB loss should have no more than a very small impact on code tracking and carrier-phase tracking and no noticeable impact on performance from the user's perspective.

1. Code tracking performance in noise environment.

The GPS receiver code tracking loop, or delay lock loop (DLL), is a dominant source of range measurement errors, and its sensitivity to thermal noise is highly dependent on receiver architecture. According to Kaplan,[49] for modern generic GPS receiver architecture - the DLL with early/late discriminator, thermal noise tracking root-mean-squared (RMS) error is:

$$\sigma_{DLL}\,(chips) = \{\, 2d^2 B_L / (C/N_o)\ [2(1-d) + 4d / (T\ C/N_o)]\ \}^{0.5}$$

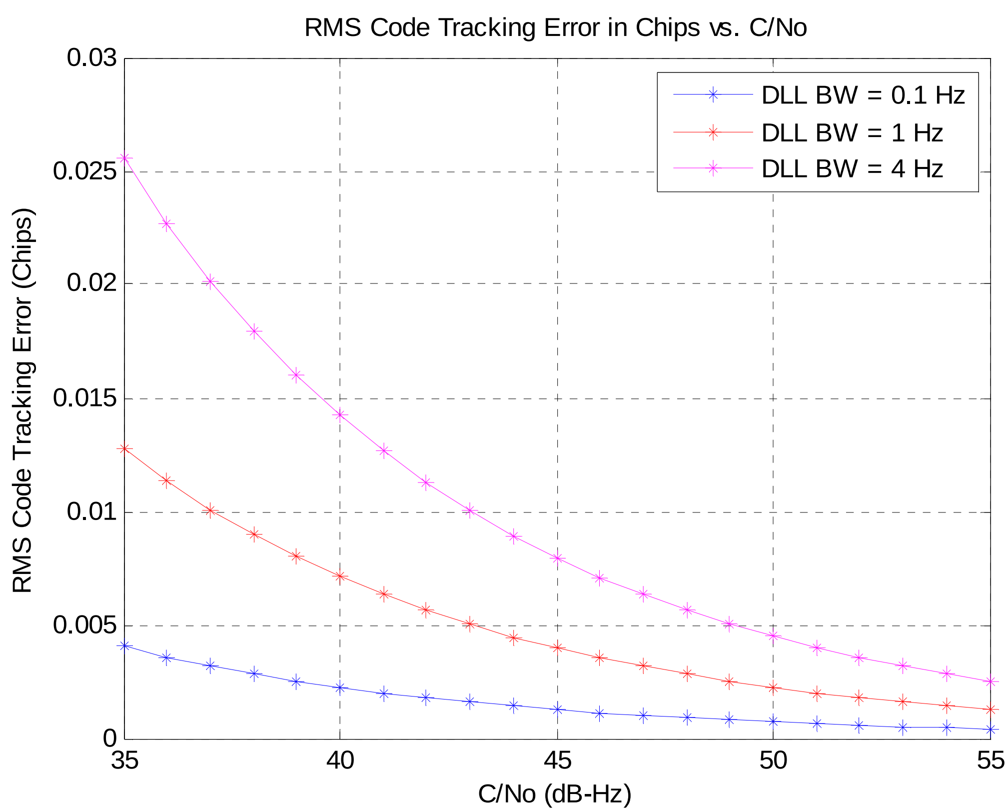
[49] Kaplan, E. D. and Hegarty, C., Understanding GPS Principles and Applications (2 Ed.), Artech House, 2006 ("Kaplan *et al.* [10]").

where d is the early-to-late correlator spacing normalized with respect to one chip, B_L is the code loop bandwidth in Hz, C/N_0 is the carrier-to-noise ratio in linear unit, and T is the pre-detection integration time in seconds.

Figure A.III.2 plots the DLL code tracking error as a function of C/N_0 for $d = ½$, and $T=$ 20 ms with three code loop bandwidths. The tracking error appears to be proportional to the loop bandwidth. By changing the C/N_0 level from 35 dB-Hz to 55 dB-Hz, the RMS error ranges from 0.0125 chip at low C/N_0 to 0.001 chip at high C/N_0 for the 1 Hz loop bandwidth case. The code tracking error in chip can be readily converted to meters by using 293m/chip for C/A-code, and 29 m/chip for P(Y) code.

An example shows that code tracking performance degradation by 1 dB C/N_0 reduction is small. Taking C/N_0 = 46 dB to C/N_0 = 45 dB, the RMS code tracking error is changed from 0.0035 chip to 0.004 chip for the loop bandwidth = 1 Hz, which is a difference of only 0.004-0.0035 = 0.0005 chip which is equivalent to 0.1167m - 0.1040m = 0.0145m for P(Y) code and 0.145 m for C/A code.

Figure A.III.2 – RMS Code Tracking Error versus C/No



2. Carrier-phase tracking performance in noise environment.

For the Carrier-phase tracking loop, or phase lock loop (PLL), the PLL thermal noise is treated as the only source of carrier tracking error. According to Kaplan, the PLL is implemented in the form of a Costa loop and the RMS tracking error can be computed as

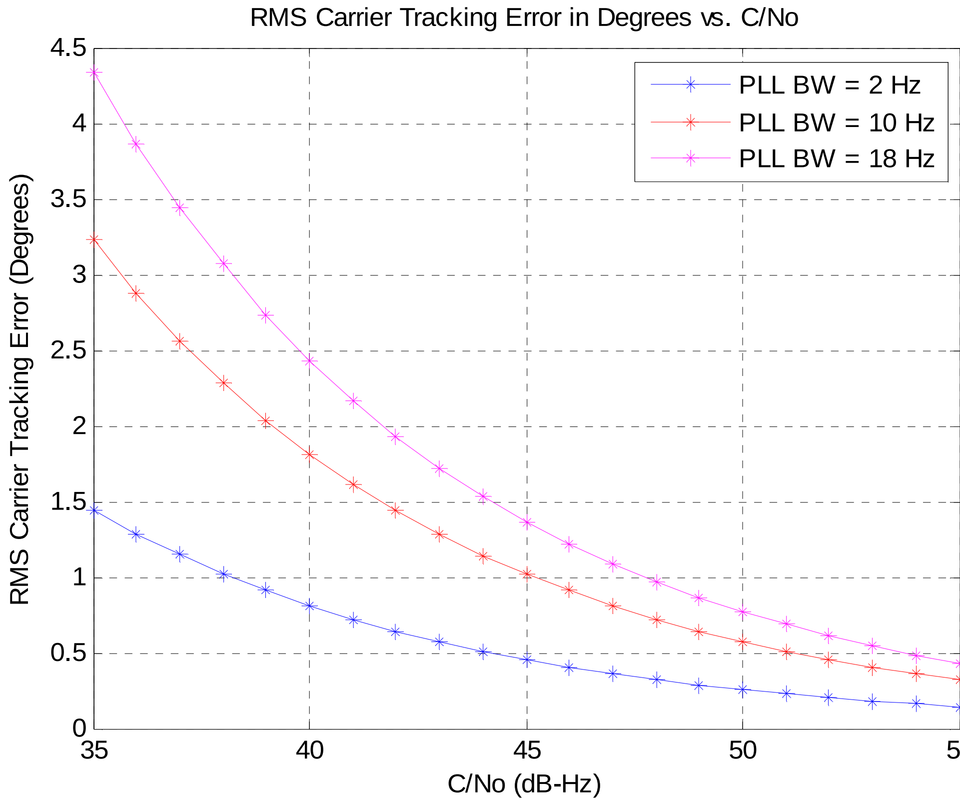
$$\sigma_{DLL}\,(Degrees) = 360 / 2\pi \{ B_L / (C/N_o)\, [1 + 1 / (2T\, C/N_o)]\}^{0.5}$$

Where B_L is the PLL loop bandwidth in Hz, C/N_0 is the carrier-to-noise ratio in linear unit, and T is the pre-detection integration time in seconds.

A plot of the RMS carrier tracking error versus C/N_0 is given in Figure A.III.3 for T = 20ms with B_L = 2Hz, 10Hz, and 18Hz. It can be seen that the carrier tracking error is dependent on C/N_0, the tracking loop bandwidth for a given integration time. For the PLL bandwidth = 2Hz, the RMS carrier tracking error is ranged from 1.45˚ to 0.14˚ when C/N_0 is varied from 35 dB-Hz to 55 dB-Hz. For the L1 carrier (wavelength of 0.19m), the tracking error can be readily converted to the meter scale, which is ranged from 0.76mm to 0.08mm.

For C/N_0 1 dB degradation, for example, from 46 dB-Hz to 45 dB-Hz, the RMS carrier tracking error is changed from 0.41˚ to 0.45˚ for the loop bandwidth = 2 Hz. For the L1 carrier, the difference is only 0.45-0.41 = 0.04˚, which is equivalent to 0.02mm. Thus, the carrier tracking performance degradation by the 1 dB C/N_0 reduction is extremely small.

Figure A.III.3 - RMS Carrier-phase Tracking Error versus C/No



3. Receiver Tracking Error and Overall Pseudorange Error Budgets for Precision and Standard Positioning Services.

The total system UERE (User-equivalent range error) is determined by overall pseudorange error budgets, which include not only receiver tracking error, but also many other error sources as well. The total system UERE budget comprises components from each system segment: the space/control segment, and the user segment. Tables A.III.2 and A.III.3 give the estimates of typical contemporary UERE budgets for Precision Position Service (PPS) and Standard Position Service (SPS) respectively, as provided by Kaplan and Hegarty.[50]

The PPS budget Table A.III.2 is for a dual-frequency P(Y) code receiver, and the SPS budget Table A.III.3 is for a single-frequency C/A code receiver.

[50] Kaplan *et al.* [10], at chapter 7.

Table A.III.2 - GPS PPS Typical UERE Budget

Segment Source	Error Source	1σ Error (m)
Space/control	Broadcast clock	1.1
	Broadcast ephemeris	0.8
User	Residual ionospheric delay	0.1
	Residual tropospheric delay	0.2
	Receiver noise and resolution (**Receiver tracking error**)	0.1
	Multipath	0.2
System UERE	Total (RSS)	1.4

Table A.III.3 - GPSPS Typical UERE Budget

Segment Source	Error Source	1σ Error (m)
Space/control	Broadcast clock	1.1
	Broadcast ephemeris	0.8
	L1 P(Y) – L1 C/A group delay	0.3
User	Ionospheric delay	7.0
	Tropospheric delay	0.2
	Receiver noise and resolution (**Receiver tracking error**)	1.0
	Multipath	0.2
System UERE	Total (RSS)	7.2

The RSS (root-sum-squared) addition of UERE components is computed by assuming each of the errors is independent random variables with the following formulas

$$\sigma_{UERE}\,(m) = (\sigma_1^2 + \sigma_2^2 + \cdots + \sigma_N^2)^{0.5}$$

As discussed above, in studying the receiver tracking error, it is apparent that the code tracking residual error is dominant. The first example showed that at C/N_0 = 46 dB-Hz the receiver tracking error is 0.104m for P(Y) code, which is about the same as the 0.1m booking in Table A.III.2. Also at C/N_0 = 46 dB-Hz the receiver tracking error for C/A code is 1.04m, which is booked in Table A.III.3. At C/N_0 = 45 dB-Hz the receiver tracking error is 0.1167mfor the P(Y) code PPS receiver. By replacing 0.1 m receive tracking error with 0.1167 m, the total system UERE is $\sigma_{UERE}\,(m) = (1.1^2 + 0.8^2 + 0.1^2 + 0.2^2 + 0.1167^2 + 0.2^2)^{0.5}$ = 1.4 m for PPS. Similarly, for the C/A code SPS receiver, at C/N_0 = 45 dB-Hz the tracking error is 1.167m. By replacing 1 m receiver tracking error with 1.167m, the total system UERE is

$$\sigma_{UERE}\,(m) = (1.1^2 + 0.3^2 + 0.8^2 + 7.0^2 + 0.2^2 + 1.167^2 + 0.2^2)^{0.5} = 7.2 \text{ m for SPS.}$$

Therefore, the 1 dB C/No degradation has no practical impact on the GPS accuracy for both PPS and SPS.

With these two system UEREs, we can determine the GPS accuracy for both PPS and SPS. The magnitude of the horizontal error is given by circular error probability (CEP), which is defined as the radius of the circle that when centered at the error-free location includes 50% of the error distribution, by using an average global HDOP of 1 with σ_{UERE} = 1.4m for PPS, and σ_{UERE} = 7.2 m for SPS

$CEP_{50} = 0.75*HDOP*\sigma_{UERE} = 0.75x1x1.4 = 1.1m$ *for PPS*
$CEP_{50} = 0.75*HDOP*\sigma_{UERE} = 0.75x1x7.2 = 5.4m$ *for SPS*

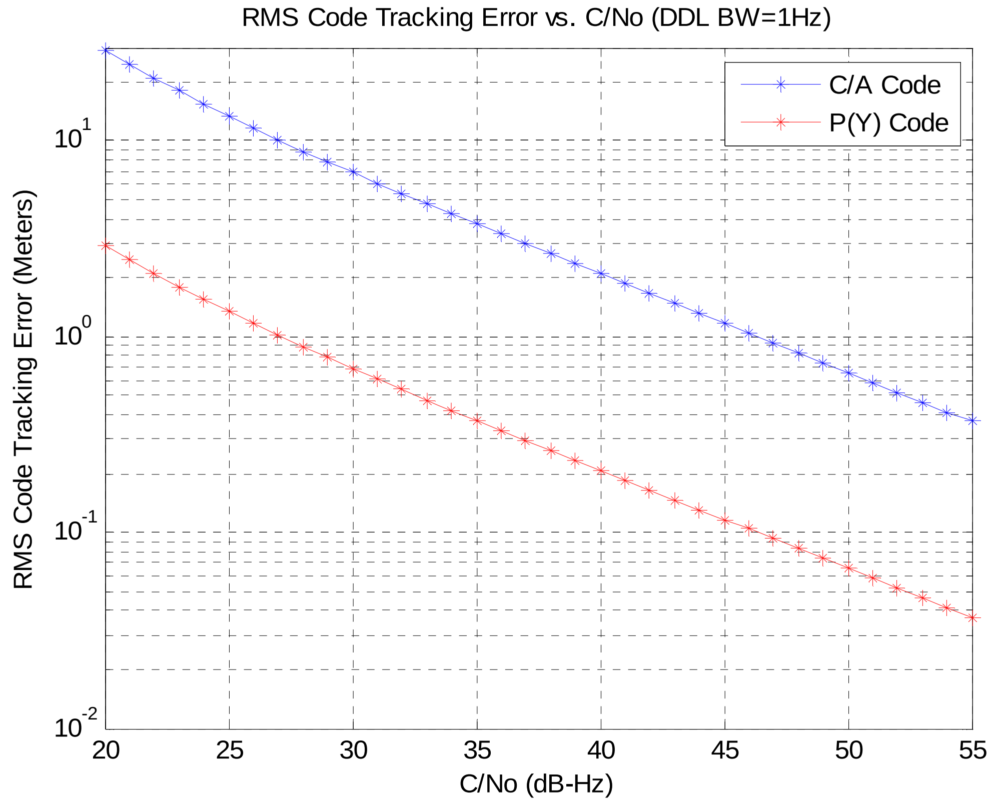
We can also examine how much C/N_0 degradation would be needed in order to have 1 m increase of CEP_{50}. This is $CEP_{50} = 1.1 +1 = 2.1m$ for PPS and $CEP_{50} =5.4+1 = 6.4m$ for SPS, which would lead to $\sigma_{UERE} = 2.1/0.75 = 2.9m$ for PPS, *and* $\sigma_{UERE} = 6.4/0.75 = 8.5m$ for SPS. By assuming that all error sources remain the same except for the receiver tracking error, we can obtain the new receiver tracking errors

$\sigma_{DLL}(m) = [2.9^2 – (1.1^2 + 0.8^2 + 0.1^2 + 0.2^2 + 0.2^2)]^{0.5}$= 2.5 m for PPS, and

$\sigma_{DLL}(m) = [8.5^2 – (1.1^2 + 0.3^2 + 0.8^2 + 7.0^2 + 0.2^2 + 0.2^2)]^{0.5}$ = 4.6 m for SPS.

Figure A.III.4 shows the code tracking error in meters for both P(Y) and CA codes with loop bandwidth of 1 Hz as a function of C/N_0. From this figure, C/N_0 values would be about 21 dB-Hz for 2.5 m error for P(Y) code PPS, and about 33 dB-Hz for 4.6 m error for C/A code SPS. These C/N_0 numbers correspond to 46 -21 = 25 dB C/N_0 degradation, and 46 – 33 = 13 dB C/N_0 degradation respectively.

Figure A.III.4 - RMS Code Tracking Error in meters versus C/No



Again, this confirms that a 1 dB C/N_0 degradation in the GPS receiver would not be expected to have a noticeable impact on the user experience.

C. TWG Cellular KPI Tests used a different metric

In stark contrast to the general location/navigaton industry, the cellular industry has well establshed, detailed performance metrics and test procedures by which it is able to objectively assess the performance of the devices that it sells to its customers. Rather than rely on an overly simplistic, and largely irrelevant metric (such as 1 dB C/N_0), the cellular industry relies on a series of thorough, statistically significant tests that correlate to actual device performance. The TWG cellular testing was based on these recognized industry standards and stayed as close as possible to the following:

- 3GPP 34.171: AGPS Minimum Performance for WCDMA/HSDPA devices (suitable for connectorized testing of 3GPP devices)[51]
- TIA-916: AGPS Minimum Performance for CDMA devices (suitable for connectorized testing of 3GPP2 devices)[52]

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[51] 3rd Generation Partnership Project, Technical Specification 34.171, V9.3.0 (September 2009) ("3GPP 34.171 [11]").

[52] Telecommunications Industry Association, TIA Standard Recommended Minimum Performance Specification for TIA/EIA/IS-801-1 Spread Spectrum Mobile Stations, TIA-916 (April 2002) ("TIA-916 [18]").

- CTIA v3.1: AGPS Radiated test plan for CDMA and WCDMA/HSDPA devices: suitable for radiated testing (in a chamber) of both 3GPP and 3GPP2 devices[53]

These industry standards call for a number of Key Performance Indicators (KPIs) to be measured during testing. The primary KPI is position error, which was chosen to enable passing of the FCC's E911 requirements. For example, the Nominal Accuracy Test in the 3GPP tests[54] requires the test to demonstrate a position error less than 30 m with 95% confidence factor over a large number of repetitions of the test; the Sensitivity Test requires the position error to be less than 100 m, also with 95% confidence.[55] These may be compared with E911 reqirements:

> The FCC's accuracy and reliability requirements for automatic location information (ALI) for wireless carrier enhanced 911 (E911) service require that carriers using handset-based E911 solutions provide location information within 50 meters for 67 percent of calls and within 150 meters for 95 percent of calls.[56]

In contrast, the 1 dB C/N_0 desense threshold is not related to any application driven metric nor are there any standards about how it should be measured.

Unlike the 1 dB threshold criterion, the cellular standards require many receiver performance metrics to also be monitored. As an example the TIA-916 sensitivity testing requirements are shown:

[53] CTIA Test Plan [2], at p. 137.

[54] 3GPP 34.171 [11], at Section 5.3.2.

[55] 3GPP 34.171 [11], at Section 5.2.1.2.

[56] These are the historical requirements for handset based location and there are recently adopted rules, 47 C.F.R. Part 20.18 which will reflect different standards in the coming years

Table A.III.4 – TIA 916 Table 2.1.1.3.3-1 Minimum Standards

Table 2.1.1.3.3-1 Minimum Standards for the GPS Sensitivity Test

Mobile Station Response	Parameter Field	Limit Parameter	Limit Value
Provide MS Information	N/A	T_1	750 ms
Provide Pseudorange Measurement	SV_CODE_PH_WH SV_CODE_PH_FR	N	4
		T_2	16 s
		$CODE_{1R}$	0.11 GPS chips
		$CODE_{2R}$	0.33 GPS chips
		$CODE_{1A}$	0.31 GPS chips
		$CODE_{2A}$	0.63 GPS chips
	PS_DOPPLER	DPR_1	40 Hz
		DPR_2	80 Hz
	SV_CNO	CNO_1	4 dB-Hz
		CNO_2	6 dB-Hz
	PS_RANGE_RMS_ER	R_1	0
		R_2	3
Provide Location Response	LAT LONG	N	1
		T_2	16 s
		$LATLONG_1$	60 m
		$LATLONG_2$	180 m

As can be seen, seventeen performance indicators are monitored for this test. Similar required KPIs are listed for the other TIA tests. These standards also require significant averaging of the readings in order to insure that a stable reading, with an acceptable measurement uncertainty be achieved. The CTIA Test Plan states:

> The pattern data shall be determined by averaging Carrier-to-Noise (C/N_0) measurements at each point on the sphere. The C/N0 measurements will be obtained from the TIA-916 GPS accuracy test. For one measurement report, the reported satellite C/N0 values shall be averaged. If it is necessary to obtain more measurements to reduce uncertainty, repeat the measurement requests at the same position and polarization and independently average the reported satellite C/N0 values for each measurement report. After a sufficient number of measurement

requests have been made, average the average results that were obtained for each measurement request. Sufficient averaging shall be completed to ensure that the uncertainty is less than the value included in the uncertainty budget.[57]

In the cellular tests, each device was exposed to a range of signal levels from the LightSquared signal. The range from nothing detectable to full loss of signal was mapped. It was common to see a 10 to 20 dB range from first detectable influence from the LightSquared signal to total loss of GPS signal. The typical observation was that real impact from the LightSquared signal did not occur until well into this range. At the first detectable influence from the LightSquared signal, the other KPIs were usually unchanged or well within acceptable levels.

An important reason to monitor multiple KPIs is to insure that the test is proceeding accurately. As has been stated, typically there is a progression of influence with KPIs degrading as a function of the LightSquared signal and finally losing all GPS signals. This is true for devices that showed sensitivity, which was much more common with the upper band signal than for the lower band signal. Occasionally anomolous behavior was noted, such as the sudden loss of all KPIs. In these cases invariably it was discovered that some test related malfunction had occurred, most commonly the battery running low.

Monitoring multiple KPIs is essential to gain a true picture of the potential impact of the LightSquared signal. Moreover, it is important to prequalify the device being testing and average out its reading variability in order to get stable, repeatable test results.

The cellular tests also account for external received noise through the requirement that the simulated GPS signal have a C/N_0 of 44 dB.Hz.[58] If there were no need to emulate external noise in the tests, a transmit C/N_0 would not be specified.

D. Other non-cochannel standards allow for a larger degradation without any adverse impact on receiver performance

The 3GPP standard for LTE specifies that, when testing for performance in the presence of an out-of-band blocking signal, the desired signal shall be increased by 6 dB above its sensitivity level. This is equivalent to creating an additional 6 dB margin, which may be used to accommodate the adjacent-band signal.[59]

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[57] CTIA Test Plan [2], at p. 137.

[58] *See* 3rd Generation Partnership Project, Recommended Minimum Performance Specification for Mobile Stations with Position Service, 3GPP2 C.S0036-0 Version 2.0, Section 2.1.1.1.2 (January 29, 2010) (3GPP2 C.S0036-0 [22]").

[59] *See* 3rd Generation Partnership Project, Technical Specification 36.101, V9.10.0 (March 2010) ("3GPP 36.101 [19]").

IV. EVEN LIMITED TO THE MOST OBVIOUS ERRORS IN THE TESTING AND ANALYSIS, THERE IS NO EVIDENCE THAT ANY QUALIFIED DEVICES ACTUALLY ARE INCOMPATIBLE WITH LIGHTSQUARED OPERATIONS

Putting aside the many problems with the NPEF testing that cannot be definitively assessed retroactively, such as the biased selection process, the lack of controls, and the missing information, focusing solely on the obvious errors demonstrates that NTIA cannot reliably conclude that the performance of any of actual personal/general navigation devices tested was perceptibly degraded in a fair test. Table A.IV.1 below lists each of the devices that, based on LightSquared's best reading of the available data, NPEF characterizes as failing. The devices are listed in descending order of the point at which they recorded a 1 dB loss in C/No.

There are several ways to slice the results to see that there is no solid evidence that any of true consumer devices actually "failed." The key deficiency in NTIA's analysis is its use of -15 dBm as the threshold for compatibility. As discussed more fully in Section II above, NTIA has provided no support for rejecting LightSquared's commitment to operate at no more that -30 dBm initially. Accounting for that factor alone means that another 53 devices would have "passed." Accounting for the extra 6 dB from LHCP operation and using a more reasonable 6 dB loss in C/No would cause all but five devices to "pass." Proper accounting for environmental noise (up to 2.6 dB improvement) and antenna orientation (up to 6 dB improvement), might have caused even the few remaining devices to pass. Both the NPEF and TWG results show that there is at least a dB-for-dB relationship between the adjacent band power and C/N_0 degradation, and in many cases an increase of more than 1 dB of adjacent power is required to cause an incremental 1 dB degradation in C/N_0.[60]

Another way to view the results is to disqualify all the devices that supposedly failed that are not truly personal/general navigation devices. The worst-performing device appears to actually be a high-precision device. Several of the other devices are modules or subsystems, whose performance is not necessarily indicative of the performance of the complete, off-the-shelf consumer devices that were to be tested. One was actually a cell phone.

Finally, a moderately close review of the available data shows that many of the devices that were tested produced results that, without further explanation, must be disregarded. As displayed in Table A.IV.1, a large number of the devices that supposedly failed showed an abnormally low quiescent C/N_0, which on its face indicates either that the antenna was improperly oriented or the device was otherwise malfunctioning. Many devices also showed inconsistent results in each of the three repetitions. Again, without some reasonable explanation, these results should be discarded as indicative of something unreliable in the tests or the devices. Finally, six of the devices that "failed" showed a much different result in the TWG tests, another inconsistency that, without explanation, invalidates the results.

[60] *See* Exhibit A, Section I, Figures A.I.3-A.I.7.

Table A.IV.1

Model ID No.	Avg power at which devices experienced 1 dB loss of C/N_0 (per graph)	Defect in selection	Defect in Quiescent C/N_0 (extent below 45 dB, Hz, in dBs)	Inconsistent results among each of three repetitions (in dBs)
350	-53.5	High Precision		4.5
328	-46.1	Discontinued	7	2.2
366	-45.4	Discontinued	2.19	
347	-45.1		8	4
104	-42.1		1.01	
247	-40.9	Incomplete Device, Discontinued		1.9
206	-38.8		2.99	3.1
115	-38			3.7
125	-34.4	Discontinued	3.04	1.7
359	-33.7			1.6
393	-33.6	Discontinued	5.03	3.7
313*	-33.5		11	4.3
249	-32.9	Discontinued	1.43	
248	-31.4	Discontinued		
332	-31			1.2
318	-30.3			
373	-30.1			2.7
235	-29.8	Incomplete Device, Discontinued	1.82	1.7
211*	-29.5		6.92	
320	-29.4	Discontinued	9	
368	-28.8		5.98	5.8
208	-28.2		6.99	
336	-28.1	Discontinued	1.01	
112	-28			
333	-28	Incomplete Device	1	1.7
360	-27.9	Incomplete Device		1.9
388	-27.2		8.12	2.2
134	-26.6		4.4	
218	-26.1	Discontinued		
358	-25.3	Discontinued	2.91	1.1
371	-25.1		4.99	
100	-24.7	Discontinued	4.2	
317	-24.4	Discontinued	1.48	

334	-23.6			1.3
207	-23.4		3.04	2.3
232	-23.3	Incomplete Device	1	1.7
105	-23.2	Incomplete Device	3	1.2
341	-22.7	High Precision, Discontinued		1.9
389	-22.6	Discontinued		
316	-22.5		2.93	1.7
131	-21.4			1.2
201	-21.4		2.61	
301	-21.4		2.85	
342	-21.4	Discontinued	6.07	
302	-21.2		1.1	
123	-21			1.1
397	-20.9	Discontinued	3	6.3
314	-20.8	Discontinued		
325	-20.7		2	1.8
354	-20.5	Discontinued	3.01	
374	-20		5.91	
326	-19.3		3.54	
324	-18.9	Discontinued	4.98	1.1
396	-18.8			
390	-18.6		2.33	
364	-18.3			
307	-18	Incomplete Device	10.03	1.9
110*	-17.8	Discontinued	13.14	1.5
120	-17.5	Discontinued		
379	-16.9			1.2
204*	-16.7	Incomplete Device	13.07	1.1
375	-16.4			
356*	-16.3			1.2
386	-16.3		2.01	
107	-16.1			
124*	-16.1			
338	-16.1		1.02	
203	-15.9		2.67	
383	-15.9	Incomplete Device	8.08	
377	-15.8	Cell Phone	15.94	
327	-15.4	Incomplete Device	7.99	2.4
127	-15.3	Incomplete Device	9.7	
212	-15		1	2.1

* NPEF tests inconsistent with TWG tests of the same device

References

[1] National Space-Based Positioning, Navigation, and Timing Systems Engineering Forum (NPEF), Follow-on Assessment of LightSquared Ancillary Terrestrial Component Effects on GPS Receivers, (January 6, 2012).

[2] CTIA Certification Test Plan for Mobile Station Over the Air Performance, Rev. 3.1, (January 2011).

[3] LightSquared, Ex Parte Notification, FCC File No. SAT-MOD-20101118-00239 and IB Docket No. 11-109 (October 6, 2011).

[4] Letter from Lawrence E. Strickling, NTIA, to Julius Genachowski, Chairman, FCC (February 14, 2012).

[5] Rappaport, T. D., Wireless Communications and Practice (2 Ed.), Prentice Hall, 2002.

[6] Parsons, J. D. The Mobile Radio Propagation Channel (2. Ed.), John Wiley and Sons, Chichester, UK, 2000.

[7] LightSquared, Reply Comments, FCC File No. SAT-MOD-20101118-00239 and IB Docket No. 11-109 (August 15, 2011).

[8] Garmin International, Inc., Comments, FCC File No. SAT-MOD-20101118-00239 and IB Docket No. 11-109 (August 1, 2011).

[9] Javad, "GPS C/N0 variations" (March 15, 2012) *available at* http://www.javad.com/jgnss/javad/news/pr20120315.html.

[10] Kaplan, E. D. and Hegarty, C., Understanding GPS Principles and Applications (2 Ed.), Artech House, 2006.

[11] 3rd Generation Partnership Project, Technical Specification 34.171, V9.3.0 (September 2009).

[12] ISO/IEC 17025:2005, "General requirements for the competence of testing and calibration laboratories."

[13] IEEE 1900.2:2008, "IEEE Recommended Practice for the Analysis of In-Band and Adjacent Band Interference and Coexistence Between Radio Systems."

[14] RTCA/DO-229D, Minimum Operational Performance Standards for Global Positioning System/Wide Area Augmentation System Airborne Equipment (December 13, 2006).

[15] RTCA/DO-235B, Assessment of Radio Frequency Interference Relevant to the GNSS L1 Frequency Band (March 13, 2008).

[16] RTCA/DO-327, Assessment of the LightSquared Ancillary Terrestrial Component Radio Frequency Interference Impact on GNSS L1 Band Airborne Receiver Operations (June 3, 2011).

[17] Working Group, Final Report, IB Docket No. 11-109 (June 30, 2011).

[18] Telecommunications Industry Association, TIA Standard Recommended Minimum Performance Specification for TIA/EIA/IS-801-1 Spread Spectrum Mobile Stations, TIA-916 (April 2002).

[19] 3rd Generation Partnership Project, Technical Specification 36.101, V9.10.0 (March 2010).

[20] Letter from Jeffrey Carlisle, Executive Vice President Regulatory Affairs and Public Policy, LightSquared, Inc. to Julius Knapp, Chief, Office of Engineering and Technology, FCC, FCC File No. SAT-MOD-20101118-00239 and IB Docket No. 11-109 (December 7, 2011).

[21] Letter from Jeffrey Carlisle, Executive Vice President Regulatory Affairs and Public Policy, LightSquared, Inc. to Marlene H. Dortch, Secretary, FCC, FCC File No. SAT-MOD-20101118-00239 and IB Docket No. 11-109 (December 12, 2011)

[22] 3rd Generation Partnership Project, Recommended Minimum Performance Specification for Mobile Stations with Position Service, 3GPP2 C.S0036-0 Version 2.0, Section 2.1.1.1.2 (January 29, 2010).

ATTACHMENT A-1

NPEF'S CONCERNS ABOUT POTENTIAL OVERLOAD FROM LIGHTSQUARED USER DEVICES ARE UNFOUNDED

NTIA also cites the NPEF testing as evidence that some personal/general navigation devices were susceptible to LightSquared handset signal in the 1627.5-1637.5 MHz band and, as a result it concludes that additional analysis is needed to assess potential impact.[1]

NTIA overlooks the extent to which NPEF's testing and analysis contain a number of material flaws. These include many of the flaws that apply to the downlink tests, such as the biased selection of devices and the failure to control the tests and report all the data, as well as some that are unique to the uplink tests, including failing to report an entire data set for one of the uplink tests. Similarly, the analysis contains many of the same kinds of errors, including the use of an unsubstantiated assumption that -10 dBm of LightSquared uplink signals could be present at the GPS receiver.[2]

As described further below, when these flaws are corrected, it is apparent that there is no risk of overload to a GPS device at either the standoff distance of 4.5 meters that was used in developing the agreement with the US GPS Industry Council regarding Out-of-Band Emissions into the GPS band[3] or even at a distance of 1 meter.

A LightSquared device can transmit an EIRP of up to 23 dBm. This is not necessarily the adjacent band power at the antenna connector of the GPS receiver – the parameter that determines compatibility. The difference between 23 dBm and the power at the GPS receiver input depends on the following:

1. Pathloss
   At a standoff distance of 4.5 meters, there is a free space loss of 49.7 dB. If a more conservative 1 meter standoff distance is used, the loss would be 36.7 dB.

2. Number of transmitters
   For the purpose of this analysis, the number of simultaneously-on transmitters within 4.5 meters is assumed to be 2 as a representative number. For 1 meter, a single transmitter is assumed. Note that this is not the number of devices that have open sessions but the

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1 Letter from Lawrence E. Strickling, NTIA, to Julius Genachowski, Chairman, FCC, at 5 note 26 (February 14, 2012) ("NTIA Letter" [4]). *See also* National Space-Based Positioning, Navigation, and Timing Systems Engineering Forum (NPEF), Follow –on Assessment of LightSquared Ancillary Terrestrial Component Effects on GPS Receivers, at 36 (January 26, 2012) ("NPEF Report" [1])

2 NPEF Report [1],at Sections 5.1.1.3 and 5.1.1.4.

3 *See* Dr. A.J. Van Dierendonck, AJ Systems for the US GPS Industry Council, and Dr. Peter D. Karabinis, VP & Chief Technical Officer Mobile Satellite Ventures, LP, "Interference Analysis of Out-of-Band-Emissions (OOBE) Limits to GPS from Ancillary Terrestrial Mobile Satellite Services in the L-Band," at 5 (August 8, 2002), attached as an enclosure to the Letter from Raul R. Rodriquez, Counsel for the U.S. GPS Industry Council, and Peter D. Karabinis, Mobile Satellite Ventures L.P., to James Vorhies, NTIA (August 8, 2002), which is attached hereto.

number of devices that are *simultaneously on the air* at any instant. Each additional transmitter causes the power to increase by 3 dB.

3. Antenna coupling loss
The dB-averaged antenna gain of cellular devices, averaged over all directions, is typically -4dBi. The typical gain of GPS antennas at low elevation angles, with the peak gain point towards the zenith, is -2 dBi. This would yield a typical antenna coupling loss of 6 dB. The TWG cellular subgroup reviewed the antenna patterns of several GPS antennas and decided to book an antenna coupling loss of 5 dB relative to isotropic antennas on both the LightSquared device and the GPS receiver. The same value of 5 dB coupling loss is used here.

4. Uplink Power Control
LTE uses uplink power control. The maximum power is typically emitted by the UE only at the edge of cell. Assuming that the GPS receiver is outdoors, the transmit power will be reduced by the building penetration loss. LightSquared's LTE link budgets use a building penetration loss value of 15 dB for suburban environments. Therefore, value of 15 dB could be booked as the median value of power control when the UE is outdoors. However, the power control also has to contend with slow fading, which could increase the pathloss and increase the device power in some locations. A reduced value of 10 dB is therefore assumed for power backoff.

5. Duty Cycle of each transmitter
In packet data protocol such as LTE, a given user is almost never given continuous use of the uplink channel. Typical duty cycles are of the order of 16%. A duty cycle of 16% causes an 8 dB reduction of power.

The above factors cause the antenna power at the GPS receiver input to be reduced as shown in Table A-1.1 below, where the progressive contribution of each line item is shown. The frequency is 1632.5 MHz, the center frequency of the lower 10 MHz uplink ATC channel.

Table A-1.1 Uplink Power from LightSquared UE

Standoff distance (m)	**1**	**4.5**	**Comment**
Device EIRP (dBm)	23	23	Standardized by 3GPP for LTE
Pathloss (dB)	36.7	49.7	Free space
Rx. Power (dBm)	-13.7	-26.7	
No. of simultaneously on devices	1	2	Assumption
Power gain/loss (dB)	0	3	
Rx. Power (dBm)	-13.7	-23.7	*This is the power that would be received if the uplink channel were a broadcast channel transmitting at maximum power, continuously, with none of the losses shown below.*
Antenna Coupling Loss (dB)	-5	-5	Assumption by TWG Cellular Group
Rx. Power (dBm)	-18.7	-28.7	
Uplink Power Control	10.0	10.0	Based on building penetration loss assumed in LightSquared link budget.
Rx. Power (dBm)	-28.7	-38.7	
Duty cycle (%)	16	16	Assumption: Typical LTE uplink Scheduler characteristics
Power reduction	-8	-8	
Rx. Power (dBm)	-36.7	-46.7	

Based on this analysis, it is reasonable to conclude that the power at the GPS receiver input will be around -37 dBm when LightSquared devices are within one meter of a GPS receiver, and -47 dBm when there are two LightSquared devices within 4.5 meters. None of these levels would cause any of the GPS receivers tested by the NPEF to suffer even 1 dB C/N_0 degradation.

This conclusion is based on Test Events 3, 12 and 4, 13. In these tests, the uplink ATC channels were the only LightSquared signals present. There were other tests in which high power LightSquared signals in both the uplink and downlink bands were present simultaneously. These cases represent unrealistic scenarios, since a strong base station signal implies proximity to the base station, which would cause a much greater UE power reduction (through uplink power control) than assumed above.

August 8, 2002

Mr. James Vorhies
Office of Spectrum Management
National Telecommunications and Information Administration
United States Department of Commerce
14th & Constitution Avenues, NW
Washington, DC 20230

Dear Mr. Vorhies:

As described in the attached documents, the U.S. GPS Council ("Council") and Mobile Satellite Ventures L.P. ("MSV") have agreed on specific out-of-band emissions ("OOBE") limits into the GPS band for the ancillary terrestrial component ("ATC") base stations and terminals that MSV would deploy in connection with its proposed next-generation Mobile Satellite Service system. These OOBE limits have been agreed to by the parties in order to protect devices receiving GPS signals from harmful interference from MSV terminals and ATC base stations.

MSV and the Council jointly submitted to the FCC their agreement. The parties urged the FCC to adopt these OOBE limits in its current rulemaking and licensing proceedings. A copy of their joint filing is attached for your information and review.

In addition to their joint filing, MSV and the Council have also completed an analysis of the potential interference to GPS devices from MSV's ATC base stations and terminals. This analysis, a copy of which is also enclosed, quantifies the interference from MSV's ATC in various GPS scenarios and sets out the technical bases for the OOBE limits the parties have developed to protect GPS receivers. The attached document, dated August 8, 2002, supersedes earlier drafts and more clearly expresses the final views of the parties. The parties disassociate themselves from earlier drafts.

In brief, these limits are -100 dBW/MHz for ATC base stations and initially -90 dBW/MHz for terminals operating in an ATC mode. The limit regarding terminals would be tightened to -95 dBW/MHz within five years from the date MSV service commences. This increase in protection is to account for a greater density of users and the need to protect GPS receivers from the aggregation of interference from multiple sources. MSV's present plans are that all its terminals will themselves include GPS chipsets and process GPS signals.

We urge you to review the technical materials developed by MSV and the Council and to meet with our representatives to discuss these issues. We would welcome an opportunity to present our position to the IRAC and/or individual representatives of agencies with interest in this area. In addition, we also urge you to endorse our proposal for OOBE to protect GPS devices and to communicate your endorsement to the FCC.

Respectfully submitted,

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Enclosures

Interference Analysis of Out-of-Band Emissions (OOBE) Limits to GPS from Ancillary Terrestrial Mobile Satellite Services in the L-Band (IB Docket No. 01-185) August 8, 2002

Dr. A. J. Van Dierendonck
AJ Systems for the US GPS Industry Council

Dr. Peter D. Karabinis
VP & Chief Technical Officer
Mobile Satellite Ventures, LP

1. INTRODUCTION AND EXECUTIVE SUMMARY

Mobile Satellite Ventures, LP (MSV) is proposing to deploy ancillary terrestrial wireless services in the L-band that is currently allocated to Mobile Satellite Services (MSS).[1] At L-band, the frequency range 1525-1559 MHz is assigned to the mobile satellite downlink and the frequency range 1626.5-1660.5 is assigned to the mobile satellite uplink. MSV's use of the L-band brackets the frequency band where GPS is currently operating. MSV proposes an augmented service, via an Ancillary Terrestrial Component (ATC),[2] which includes terrestrial wireless transmissions to overcome satellite signal blockage in densely populated areas. MSV's mobile terminals in ATC mode will receive in the band 1525 to 1559 MHz and transmit in the band 1626.5 to 1660.5 MHz. This means that MSV's ATC base stations (BTSs) will receive in the band from 1626.5 to 1660.5 MHz, and transmit in the band from 1525 to 1559 MHz. Thus, MSV's ATC operations will produce terrestrial transmissions on both sides of the GPS band, potentially generating out-of-band emissions (OOBE) into the GPS band.

MSV and the US GPS Industry Council have conducted technical analyses and have reached agreement on mutually acceptable OOBE limits for MSV's base stations and terminal equipment operating in ATC and satellite mode. The agreed upon broad-band OOBE limits to protect GPS are:

1) **For MSV's ATC base stations:** -100 dBW/MHz over the entire GNSS band (from 1559 MHz to 1610 MHz) and,

2a) **For MSV's terminal equipment operating in ATC mode:** Initially -90 dBW/MHz from 1559 MHz to 1605 MHz, improving to -95 dBW/MHz from 1559 MHz to 1605 MHz for equipment that is placed in service five years following the start of MSV's commercial operations.

2b) **For MSV's terminal equipment operating in satellite mode:** Initially -75 dBW/MHz from 1559 MHz to 1605 MHz, improving to -80 dBW/MHz from 1559 MHz to 1605 MHz for equipment that is placed in service five years following the start of MSV's commercial operations.

The agreed upon limit for narrow-band OOBE of bandwidth less than or equal to 1000 Hz, is 10 dB lower in numerical value than the corresponding broad-band OOBE limit. For example, the narrow-band OOBE limit for MSV's ATC base station is -110 dBW.

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[1] *In the Matter of Flexibility for Delivery of Communications by Mobile Satellite Service Providers in the 2 GHz, the L-Band, and 1.6/2.4 GHz Band,* IB Docket No. 01-185 (Aug. 17, 2001).

[2] *MSV's Next Generation Satellite System Coordination and Interference Considerations,* MSV Presentation to the US GPS Industry Council (May 21, 2002).

2. EMISSION LEVEL DISCUSSION

Un-augmented MSS[3] OOBE into the GPS bands defined the first interference limit to be negotiated for specific MSS entrants. This limit was negotiated at a level of -70 dBW/MHz, developed for a specific aviation application scenario only, and based on a single MSS MET located below the fuselage of an aircraft within 100 feet.[4] Today, this original interference limit is far too excessive for the evolved user base of millions of GPS receivers, the majority of which are mobile, and will be in close proximity to an emitter. In the case of un-augmented MSS, the number of mobile emitters is considered relatively small and far enough away from GPS receivers used for aviation safety-critical operations, such as landing an aircraft. This, of course, is not the case for MSS augmented by ancillary terrestrial operations. Both base stations and mobile terminals can be large in number and, often, in close proximity to GPS receivers, some of which would be used for safety-critical operations. Thus, it is very important to control the emission levels from these terminals and base stations in the GPS frequency band.

Another very important issue regarding OOBE levels in the GPS band is that the interference allotment -70 dBW/MHz is already assigned to the original un-augmented MSS. The proposed ATC augmentation to MSS is an additional, and denser, service. Thus, this new augmented MSS cannot have the same interference allotment in the emissions level originally allocated to un-augmented MSS only.

It is clear that the OOBE limits of any new service that uses spectrum in close proximity to GPS must be set significantly lower than the -70 dBW/MHz level. At the same time, it is understood that MSV must have a stable target for the development and operation of its system (including ATC), which requires the OOBE limits to be sufficient to protect GPS over the long term. The limits agreed to by MSV and the US GPS Council meet this requirement.

The original un-augmented MSS METs could only transmit terrestrially over the return L-band frequencies (from 1626.5 to 1660.5 MHz). MSV proposes ATC operations that would transmit terrestrially in both the forward and return L-band. Thus, the ATC operations' OOBE is coming from both of the adjacent (to GPS) bands, and each band's interference allotment should be allocated separately. Since ATC is in addition to un-augmented MSS, the allocated emissions level for each ATC band would have to be lower than the -70 dBW/MHz allocated to the original un-augmented MSS.

3. SCENARIO AND LINK BUDGET DEVELOPMENT

In the MSV proposed system, there are three types of emitters – the BTS base stations, the pico base stations and the mobile earth terminals (METs). The BTSs are expected to be located on top of towers, or buildings, nominally 30 meters above the ground. The pico base stations are essentially repeaters for use in areas of degraded line-of-sight from the BTSs and indoors. Of

[3] The term un-augmented refers to MSS without ATC. The term augmented refers to MSS with ATC.

[4] ITU-R M.1477 at Annex 5. NOTE 1 to ITU-R M.1477: "This Recommendation is not intended to be used to form the basis for future modifications to maximum unwanted emission levels for the band 1559-1610 MHz that are stated in the Annexes to Recommendation ITU-R. M.1343. The maximum unwanted emission levels for the band 1559-1510 MHz stated in Recommendation ITU-R. M.1343 have been developed pursuant to a specific interference scenario, and are not intended to be applied to any service other than MSS MESs operating in the 1-3 GHz range without further study.

August 8, 2002

course, the METs are anywhere a user could be. The level of interference to a GPS user is then based upon the distance between the emitters and the GPS user, their respective antenna patterns and polarizations, GPS receiver sensitivity and the emission levels. Reasonable scenarios are presented. First, let us discuss GPS receiver sensitivity.[5]

GPS Receiver Sensitivity

MSV originally suggested that the legacy -70 dBW/MHz OOBE limit may be good enough to protect GPS from the OOBE of MSV's proposed ATC. However, the original standards, for aviation receivers,[6] were established considering a single, un-augmented MSS MET with an OOBE level of -70 dBW/MHz. Other than the standard safety-of-life margin, there is no margin remaining for any additional interference sources. Legacy GPS receivers are already in existence and will be used on airlines for the next 20 years with no retrofit. In the presence of interference defined by the established receiver susceptibility masks, GPS receivers will not acquire or will lose lock.

In addition, the FCC mobile E911 mandate has driven GPS receiver technology to include enhanced sensitivity. These GPS-enabled E911 cellular telephones are required to track attenuated GPS signals that are at -180 dBW or less, over 40 dB below the thermal noise floor in a 2 MHz band.

GPS Aviation Receiver Sensitivity and Link Budget

For aviation receivers, values accepted by RTCA and ICAO are -140.5 dBW/MHz for tracking, and -146.5 dBW/MHz for initial acquisition.[7] Well-established link budgets, including a safety margin, equate those numbers to a single -70 dBW/MHz emissions source at distances of 100 feet and 200 feet, respectively, depending upon phase of flight. The 100 feet distance relates to a minimum distance above a source at a Category I decision height. Table 1 provides the link budget for this scenario developed by RTCA for a new version of DO-235 (DO-235A).[8] Note that this link budget is for a single MSS emissions source, and thus, would not include ATC emitters. For the original un-augmented MSS METs, for which the budget was established, this was justified because the density of satellite terminals would be low.

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[5] GPS receiver sensitivity is defined in terms of receiver susceptibility with standard (non-adaptive) gain antennas and not defined in terms of receiver desensitization. The ability to reduce GPS receiver sensitivity towards broadband interference requires elaborate antenna technology, using antenna arrays, making the approach not feasible for the installed base, especially for the mobile user. In addition, attempting to reduce GPS receiver sensitivity toward broadband interference may result in reduced sensitivity of the GPS receiver to the GPS satellite signals.

[6] ITU-R M.1477 at Annex 1. Standards for GPS receivers, developed for aviation, and extended to commercial receivers, including land, marine, and codeless, were established internationally.

[7] *Minimum Operational Performance Standards for Global Positioning System/Wide Area Augmentation System Airborne Equipment*, RTCA DO-229C, Appendix C (November, 2001) and *Minimum Operational Performance Standards for GPS Local Area Augmentation System Airborne Equipment*, RTCA DO-253, Appendix D (January, 2000).

[8] *Assessment of Radio Frequency Interference Relevant to the GNSS*, RTCA DO-235A Draft, Chapter 2 (Current Issue).

August 8, 2002

Table 1 GPS Aviation Category I RFI Scenario Link Budget (Not including ATC Emitters)

	GPS L_1 Frequency	1,575.42 MHz
1	Emissions mask; spurious out-of-band Broadband Noise	-70.0 dBW/MHz
2	GPS antenna gain	-10.0 dBi
3	100 ft separation distance propagation loss	-66.1dB
4	RFI at GPS receiver	-146.1 dBW/MHz
5	Aeronautical Safety Margin	5.6 dB
6	Receiver Susceptibility Mask	-140.5 dBW/MHz

The draft DO-235A also states "An important, and in retrospect, unfortunate aspect of the link budget in Table 1 is that the entire amount of allowable RFI at the receiver is permitted to be consumed by a single MSS MET. As a result, emissions by other RFI sources must be restricted to a greater extent than the original un-augmented MSS METs. The condition that only one MSS MET is always present was a compromise between the MSS and Aeronautical communities. The MSS community wanted to assign probabilities for the presence of one or more METs. The consensus number was that one and only one MSS MET could be present with probability one. Consequently, scenarios involving potential new emitters (RF lighting, public safety devices, UWB devices, etc.) must assume that an MET is present." Consequently, a new aeronautical link budget for new emitters was developed, resulting in a new broadband noise emissions level set at -90 dBW/MHz. This level also accounts for the fact that there could be multiple emitters, such as ATC terminals, in the area.

The link budget of Table 1 can also be applied to ATC base stations and MSV terminals operating in ATC mode with certain adjustments, as discussed below.[9]

__Terrestrial GPS Receiver Sensitivity and Link Budget__

There are essentially three types of terrestrial GPS receiver technologies that have to be considered. The first would be the standard receiver with sensitivity similar to that of the aviation receiver (-140.5 dBW/MHz). The second would be the high precision class of receiver that uses codeless tracking technologies to track the L2 GPS signal, in addition to the L1 GPS signal. Generally, at the L1 frequency, they have a similar sensitivity as the standard receivers. The third type deviates from this, however. That type is the type designed to operate indoors and outdoors under heavy foliage. Receivers embedded in E911 cellular terminals are in this category. This enhanced GPS receiver technology is expected to migrate throughout the installed user base.

Table 2 is the proposed ATC terminal link budget. The scenarios described in Table 2 are applicable to the MSV terminals operating in ATC mode. This link budget starts with a receiver sensitivity to broadband interference (-144.5 dBW/MHz) that is typical for the GPS technology used in E911 cellular terminals, and is 4 dB lower than for the more robust aviation GPS receivers given in Table 1. This is to insure that the interference doesn't dominate the thermal noise floor for which those receivers were designed to operate indoors and under heavy foliage.

[9] MSV terminal equipment, when completing a link through the MSS satellite, will operate initially at a -75 dBW/MHz OOBE limit. Five years following the start of MSV's commercial operations, the OOBE limit for MSV terminal equipment when completing a link through an MSS satellite will improve to -80dBW/MHz.

For the E911 scenario in this environment, it is assumed that a single ATC terminal is 4.5 meters (15 feet) away from the E911 terminal. This link budget results in an OOBE EIRP of -95 dBW/MHz.

Table 2. ATC Terminal Scenario Link Budget

Parameter	Value
GPS Receiver Interference Susceptibility (dBW/MHz) (Broadband Noise)	-144.5
Propagation Loss (dB) (Minimum Distance Separation (m))	49.5 (4.5 m)
GPS Receive Antenna Gain (dBi)	0
Maximum Allowable OOBE EIRP (dBW/MHz)	-95

<u>BTS/ATC Scenarios</u>

With respect to the BTSs and pico stations, as defined in MSV documentation, their location has to be coordinated to prevent interference to nearby GPS timing receivers. It is recognized that timing receivers used for synchronization of networks, such as cellular networks, would usually be located at elevated levels, such as on top of buildings. Thus, they could be located at the same level as the BTS antennas located on the towers, or could be located near pico station antennas, and therefore subject to the high-gain part of the BTS antenna patterns. With respect to the airborne GPS user, BTS towers should not be a problem. Towers will not be allowed near the path of an aircraft, and the BTS antenna pattern, which is tilted toward the ground, will help prevent interference to the GPS receiver on an aircraft.

GPS timing receivers have become the de facto standard for creating precise timing synchronization for virtually all digital cellular systems today. In addition, most of the internet transmissions for terrestrial and satellite reception are also synchronized to GPS time, which is in turn synchronized to the atomic clocks on board the GPS satellites. The resulting timing errors in cellular networks is less than 50 nanoseconds as defined by earth based atomic clocks, to which the GPS satellite clocks are referenced.

GPS timing receivers track at least 5 satellites in order to deliver this level of accuracy. GPS timing receivers are typically located on rooftops of buildings or on the masts of cell sites (tens of thousands such units have been so installed worldwide.) Some receivers are also located indoors in equipment racks that also hold servers and other computer-related products. Also, since many GPS timing receivers are located on masts atop buildings, there is a high likelihood that MSV base station transmitters could be either co-located or located at approximately the same elevation above ground. Thus, the potential of interference to timing GPS from MSV's ATC base stations and MSV's ATC mobile terminals was a concern that has been addressed by the agreed upon emissions limits stated at the outset of this report.

The ATC pico stations represent another potential source of interference. It has been indicated by MSV that pico base stations may be located on ceilings of buildings or on building walls, using omni-directional transmitting antennas. To substantially reduce the potential of interference to GPS from any ATC base station deployment, MSV has agreed to the much-improved OOBE limit of -100 dBW/MHz.

The MSV terminals operating in ATC mode may potentially cause the largest interference problem to GPS users. MSV has agreed that their terminals will initially emit OOBE at or below the -90 dBW/MHz level in the GPS band and has also agreed to implement an improved OOBE limit of -95 dBW/MHz for MSV terminals operating in ATC mode commencing five years after the introduction of their service. The scenarios for the MSV terminals operating in ATC mode are presented in Table 2. These limits will be met by MSV terminals over the frequency range from 1559 to 1605 MHz.

MSV Terminals and Base/Pico Station Scenarios and Link Budgets

As discussed above, since un-augmented, space-based MSS MET and UWB have already received emission level allocations, and the fact that MSV terminals operating in ATC mode will be in the same area, the agreed emission level for base and pico stations in the scenario is -100 dBW/MHz. Thus, their emissions will be somewhat less than the emissions of MSV terminals operating in ATC mode, allowing these terminals to emit at the higher -90 or -95 dBW/MHz level. This is appropriate since these stations can implement larger filters with more out-of-band insertion loss.

This is not the limiting scenario for the MSV terminals operating in ATC mode. Modified scenarios and link budgets equivalent to the ones given in Table 2 are the limiting scenarios and link budgets. The modification starts by assigning the same receiver susceptibility mask two additional emitters – a base/pico station and a terminal. In these close-in scenarios, only one emitter, the MSV terminal operating in ATC mode, should be considered. It is assumed here that the base/pico station will be emitting at 5 to 10 dB lower power.

Link Budget Modifications for Narrowband Emissions

Since the GPS C/A code repeats at a 1 kHz rate, the signal spectrum is a line spectrum with varying line magnitude, and is thus more susceptible to narrowband emissions at certain frequency offsets from 1575.42 MHz (depends upon PRN code). This susceptibility varies by approximately 10 dB versus emission bandwidth for bandwidths under 100 kHz. This varying GPS receiver susceptibility is indicated in the RTCA WAAS and LAAS MOPS, and is summarized below in Figure 1. The wider the emission bandwidth, the more spectral lines are affected, and the effect is averaged over the spectral lines. It should be emphasized, however, that it is the OOBE bandwidth, not the BTS, pico station, or terminal signal bandwidth that is relevant. For example, an emitted local oscillator spur would be classified as a narrowband emission, yet transmitter noise would be classified as a wideband emission. Inter-modulation products, if there are any, would have bandwidths similar to the signal bandwidth. Inter-modulation products are not expected to occur in MSV implementations

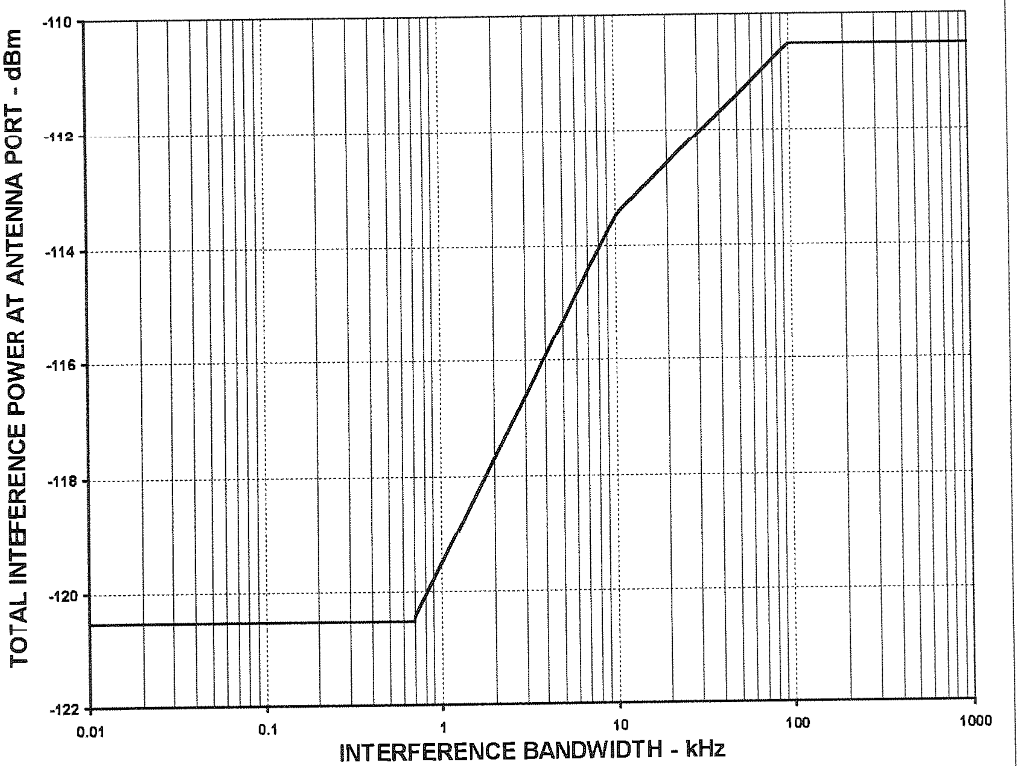

Figure 1. GPS Receiver Susceptibility Versus Interference Bandwidth

Frequency Band Protection

The GPS frequency band is 1575.42 MHz ±12 MHz, and accurate GPS receivers take advantage of as much bandwidth as possible. That is how accurate GPS C/A code receivers mitigate multipath – they track the sharp edges of the code transitions. Essentially, they are tracking the outer lobes of the C/A code spectrum. Thus, the entire GPS band must be protected at the indicated emission levels. Furthermore, the GPS military signals cover the entire 24-MHz band. As the GPS services and its augmentations evolve, more frequency bandwidth will be used. Consequently, these OOBE limits protect the evolving GPS service in the range from 1559 MHz to 1605 MHz.

4. SUMMARY & CONCLUSION

Base station/pico base station transmitters of MSV's ATC network will comply with the -100 dBW/MHz OOBE limit, taking into account their antenna pattern. OOBE from MSV terminals operating in ATC mode will initially be limited to -90 dBW/MHz, and will improve to -95 dBW/MHz, for new ATC terminals, in five years from service commencement. MSV's present plans are to incorporate GPS chips and signal processing in its terminals. The agreement reached by MSV and the US GPS Industry Council regarding OOBE limits for MSV's ATC operations is appropriate for the protection of present and future GPS operations and provides a stable environment for the development and operation of MSV's proposed system.

DECLARATION OF STEVE HOLLEY

I, Steve Holley, make the following declaration.

1. I was employed as a Principal Engineer at LightSquared Subsidiary LLC from March 12, 2007 to March 2, 2012.

2. In my role as Principal Engineer, I participated in the NPEF's "General Location/Navigation" device testing from October 25, 2011 to November 3, 2011, where I observed the test processes, test-set up, and test events.

3. My observations of the testing included the following:

   a. Test participants oriented test device antennas as they chose, apparently to provide maximum exposure to LightSquared's LTE signal, rather than putting them flat on the test table.

   b. Test participants modified test devices between tests, including changing test device antennas. The nature of these modifications did not appear to be recorded.

   c. On the second day of testing, the duration GPS baseline time of several tests was significantly shortened from the established test event durations.

   d. During one test event, the Test Director entered the testing area before the completion of the test. Participants were instructed to remove the last few minutes of collected data.

   e. Each test participant was assigned a grid point location but was free to work within its assigned area. Efforts were made by participants and test administrators to ensure proper spacing of test devices, however, due to the number of devices involved, the spacing between devices varied. These variances in distances between test devices did not appear to be recorded.

   f. Test administrators performed "sniff tests" before the testing program started to determine if the devices were transmitting, however the "sniff test" was not performed before each test cycle.

   g. No testing was performed to determine whether devices were "coupling."

   h. Raw data was not generated in one single format. Because the data of government participants was proprietary, it was not possible to review all data for consistency.

   i. Although test participants were supposed to provide data at the end of each day to the Test Director in standard NEMA format, some manufacturers were permitted to provide their data later, supposedly to download data from their devices or convert the data to NEMA format.

I declare under penalty of perjury that the foregoing is true and correct.

Executed on March 15, 2012.

Steve Holley

EXHIBIT B

ANY CONCLUSION REGARDING THE COMPATIBILITY OF AVIATION GPS RECEIVERS IS PREMATURE

NTIA's handling of the Aviation case is another example of its reaching conclusions without engaging or considering potential solutions offered by LightSquared. The FAA report on which NTIA relies reached a conclusion that mitigation is impractical for low-altitude cases before the FAA had fully defined its criteria, including the establishment of an appropriate propagation model for low altitudes and the definition of compatibility criteria (including exclusion zones) to be used to evaluate low altitude applications,[1] or met with LightSquared to discuss a proposal to accommodate the FAA's concerns.[2] The FAA Report purports to reject the LightSquared low-altitude mitigation proposal because it is impractical, a view that NTIA endorses without explanation, but such a view is clearly premature without the FAA first clearly defining its evaluation criteria and engaging LightSquared on the appropriate propagation models and the specifics of LightSquared's willingness to modify its network to accommodate the FAA's stated concerns. As the FAA has acknowledged, its technical analysis is incomplete, and it has not fully evaluated LightSquared's proposed solution to address all articulated FAA concerns regarding low altitude navigation applications of GPS.[3] Key elements of the FAA's analysis have not been based on substantial evidence or submitted to technical review. Thus, any conclusion that LightSquared's proposed operations would be incompatible with aviation GPS receivers is premature.

The vast majority of joint FAA and LightSquared work was performed and time spent on the higher altitude cases, where the "FAA concluded that the compatibility situation improves as the aircraft altitude increases so that at higher altitudes the interference is expected to be acceptable;"[4] only a very short time in the final few weeks of the process (a process the FAA abruptly terminated) was spent evaluating the low altitude cases, which now form the basis of NTIA's objections.

Throughout the process, the FAA failed to clearly and consistently identify its evaluation criteria for aviation applications of GPS, especially as they relate to low-altitude applications, and failed to provide any evaluation criteria for GPS uses for which mandatory GPS-related standards do not exist, leaving open the question of what other criteria may apply. The FAA initially failed to identify Terrain Awareness and Warning System ("TAWS") as a unique scenario to be analyzed in the RTCA report, and then once it did so, provided ambiguous information as to whether a minimal exclusion zone would be acceptable and failed to define

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1 For purposes of this Exhibit, the terms "criteria" generally refers to the methodologies proposed by the FAA to evaluate LightSquared's proposed operations and mitigations, as well as criteria proposed by the FAA to evaluate whether the proposed operations would impact aviation uses of GPS.

2 FAA Status Report: Assessment Of Compatibility Of Planned Lightsquared Ancillary Terrestrial Component Transmissions in the 1526-1536 MHz Band with Certified Aviation GPS Receivers, at Section 6 (Jan. 26, 2012) ("FAA Report" [1]).

3 FAA Report [1], at Sections 4 and 6.

4 Letter from Lawrence Strickling, Administrator, National Telecommunications and Information Administration, to Julius Genachowski, Chairman, Federal Communications Commission, at 5 (Feb. 14, 2012) ("NTIA Letter" [2]).

evaluation criteria for the "residual operational risks" of GPS at low altitudes included in the FAA Report, and introducing new and ambiguous concerns like impacts of inadvertent handset use on aircraft,[5] making it impossible for LightSquared to even evaluate, let alone respond to, the potential concern. The FAA provided several different propagation models during the process to evaluate LightSquared's system without clearly settling on any given one until the final FAA Report, and even that model is severely flawed, as discussed below. Moreover the FAA focused improperly on outdated proposals that are no longer relevant and failed to consider available mechanisms to ensure that LightSquared's system operates in compliance with the FAA's stated criteria.

In contrast, LightSquared has submitted a declaration from a distinguished expert in the field of wireless propagation, Dr. John David Parsons, and from a distinguished TAWS expert John Howard Glover, both showing that key aspects of the FAA's report's analysis are not supportable.[6] For example:

- The FAA provided arbitrary or no criteria to derive breakpoints, without any physical justification. Given that *a priori* knowledge of the blocked/unblocked status of base station antennas is necessary in the FAA model, the LightSquared model, also utilizing this information, is closer to physical reality and is supported by the MSS propagation literature.

- The FAA failed to take into consideration the operational realities of TAWS equipment in use, which are more robust and use a sloped approach, rather than the stepped approach for minimum required terrain clearances ("RTC") near airports. Nor did the FAA take into account the many redundancies in TAWS equipment, including alerts well above the minimum RTCs, alternate position sources, and alerts aircraft receive in the event of a possible loss of GPS – the likelihood of which was never established.

An objective examination of LightSquared's mitigation proposals – and the underlying technical analysis – supports LightSquared's view that compatibility can be established between LightSquared's operations and the FAA's stated criteria – even assuming the most conservative definitions of those criteria and without requiring changes to existing FAA standards, as currently articulated. LightSquared made every effort to address the FAA's concerns by proposing to limit its "power-in-air" to the coverage defined in the FAA's Report. Outside of these exclusion zones, LightSquared's aggregate ATCt signal would never exceed -34.1 dBm.[7] LightSquared has presented evidence that its proposal is practicable and effective. It has run models and analysis, described in more detail below, based on actual GPS-based approach and departure procedures at Ronald Reagan Washington National Airport ("DCA") and has completed TAWS analysis demonstrating compatibility. LightSquared continues to believe that

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[5] FAA Report [1], at 16 (stating that the TAWS and HTAWS exclusion zones would need to be coordinated with industry and that "the FAA has not made operational and safety assessments for the additional areas of consideration identified in Appendix A Section 6 "Residual Operational Risks" and these risks have not been coordinated with the users who would be impacted.") *See also* FAA Report [1], at 71.

[6] Attached to this Exhibit are the prior declarations and new declarations from Dr. Parsons and Howard Glover reaffirming their views and responding to the FAA Report. See Attachments B-1, B-3, and B-4.

[7] This limit was agreed to jointly between the FAA and LightSquared based on an assessment of existing minimum operating standards, which include an extra safety margin of 6 dB.

it can develop, deploy, and monitor its system so as to address all FAA concerns, including through the use of appropriate independent third parties to monitor compliance.

LightSquared previously provided a detailed assessment of these issues in Appendix C to the FAA Report, which is incorporated herein by reference. Given the extremely short timeframe that LightSquared was afforded to review the draft FAA Report, LightSquared offers additional critiques of the FAA's proposed model below. There are several other issues with the FAA Report. These are not re-discussed here but cataloged in Appendix C of the FAA Report. NTIA adopted the FAA's Report without any discussion of LightSquared's views in Appendix C.

Even if a comprehensive analysis was to show some incompatibility, the FAA has presented no evidence of its conclusion that it is impractical to conduct a more comprehensive testing program that might show that the standard could be modified without requiring any existing receivers to be retrofitted or replaced. In that regard, the FAA ignored that independent laboratory testing of certified aeronautical GPS receivers has demonstrated sufficient additional resilience to drastically transform the technical analysis in favor of compatibility. Given this evidence, the FAA at a minimum should have developed a robust testing program that would have included testing of a representative sampling of receivers currently in use. But even if receiver modifications were required, neither FAA nor NTIA have presented more than generalized statements, without empirical evidence, that the task would be impracticable.[8]

I. THE FAA'S ANALYSIS IS FUNDAMENTALLY FLAWED AND LACKS SCIENTIFIC VALIDITY

As an initial matter, the FAA abandoned the technical process prematurely, at a time when key methodologies, assumptions, and criteria were still being evaluated. LightSquared continues to believe that an objective review of LightSquared's underlying scientific analysis and resolution of the few remaining issues[9] between the FAA and LightSquared would demonstrate compatibility between LightSquared's proposed system and uses of FAA certified GPS receivers.

A. The FAA devoted insufficient time to the key low-altitude cases

The scope of the RTCA Report, commissioned in March 2011 and finalized in June 2011,[10] was to "include receiver vulnerability, as well as [operational] scenario studies including aggregate effects of LightSquared's transmissions on GPS receivers used in aircraft."[11] In conducting its study, the FAA identified five operational scenarios as representative of aviation

8 Both NTIA and FAA state that it would take 10 or more years to develop new standards and retrofit aircraft with new equipment. NTIA Letter [2], at 7; FAA Report [1], at 71. Neither offered evidence that the task would be impracticable in this instance, especially given that the receivers tested were more robust than existing receiver standards, suggesting that only a small percentage of receivers may actually need to be retrofitted.

9 See FAA Report [1], at C-7.

10 RTCA Report: Assessment of the LightSquared Ancillary Terrestrial Component Radio Frequency Interference Impact on GNSS L1 Band Airborne Receiver Operations, DO-327 (June 3, 2011) ("RTCA Report [3]").

11 RTCA Report [3], at 1.1.4 (citing FAA Letter Request dated March 3, 2011).

uses of GPS,[12] but it did not analyze TAWS applications of GPS and it concluded that all identified lower altitude scenarios below 300' (Cat I, II, and III) are compatible with LightSquared's proposed operations.[13] As a result, the RTCA Report focused on analyzing aggregate impact at higher altitudes above 525 meters[14] and did not analyze TAWS.

It was not until October 2011 that the FAA began shifting the attention of the working group to applications and criteria at lower altitudes, for both navigation and terrain awareness, on which NTIA now bases its objections.[15] LightSquared attempted to engage on this topic immediately, seeking clarification of the FAA's interpretation of its criteria, including its views regarding an appropriate propagation model for low altitudes and the acceptability of possible mitigation efforts by LightSquared. The FAA had not provided this information when it terminated the process at the end of the year.

B. The FAA has misstated or omitted key facts

Even assuming the FAA had defined or established a scientifically-based methodology and criteria to evaluate LightSquared's system, it failed to consider key facts. First, it ignored evidence that all aviation devices tested performed better than the standards established by the FAA, as documented in the RTCA Report Appendix D and explained more fully in Section E.2, below.

Second, although with LightSquared's proposed modifications no retrofits or "fixes" would be required for certified GPS receivers, no basis exists for the FAA's position that new receiver standards or retrofits – even if required for some receivers– would not be feasible.[16] The FAA's view that new receiver standards and equipment would take more than a decade to implement lacks empirical support. If, for example, a more robust testing program of representative aviation receivers demonstrated that only the standards – not the underlying equipment – needed updating, the timeframe to update the standard and the associated costs

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[12] The RTCA Report evaluated five operational scenarios selected by the FAA, including Cat I, II, III approaches requiring GPS down to 100'. RTCA Report [3], at 3. 1. The RTCA Report did not contain any specific requirements related to TAWS.

[13] RTCA Report [3], at 3.1.2.

[14] RTCA Report [3], at Table 6-4 (showing that the received RFI power spectral density (PSD) is greatest for the FAF WP Case, when the aircraft is 535.2 m height. The value at this height is -73.55 dBm/MHz.)

[15] The FAA Report also suggests the possibility of additional GPS requirement being defined for Visual Flight Rule and Unmanned Aircraft and other operations. For the purpose of this discussion, in light of the fact that FAA has not previously presented these as requirements nor established evaluation criteria, LightSquared is not attempting here to address its compatibility with these uses. LightSquared is also not addressing the FAA's indication for the first time in Section 6 of its Report (Summary and Conclusions) that additional work is needed to examine the potential impact of LightSquared handsets on certified GPS receivers. The Report makes no effort to justify this suggestion and ignores the conclusions in the May RTCA Report that ATCt base stations were the dominant concern.

[16] *See e.g.* FAA Report [1], at Section 6. *See also* NTIA Letter [2], at 7. *See also* Issues Associated with Protecting and Improving our Nation's Aviation Satellite-Based Global Positioning System Infrastructure: Hearing Before the Subcommittee on Aviation of the House Committee on Transportation and Infrastructure, 112th Congress (Feb. 8, 2012) (testimony of John Porcari, Deputy Secretary of Transportation) ("there's no easy retrofit or filter or any other kind of retrofit that would, from a safety-of-flight perspective, make the proposal, as currently proposed by LightSquared, compatible with aviation.").

could be significantly shortened and accomplished in the near term. Likewise, even if testing showed that some receivers needed to be retrofitted, no support exists that the cost or time associated with such retrofitting could not be accomplished in a timely and cost efficient manner. . Receiver standards – indeed most technical standards –evolve regularly and sometimes under compressed time schedules to address specific issues and new advances in technologies, and there is no evidence to suggest otherwise here. In fact NTIA stated that it would request "through the Department of Transportation that the FAA initiate an effort to examine what changes could be made to the existing standard to eventually make certified GPS aviation receivers compatible with a signal in the lower 10 MHz."[17] For example, TSO-C151b applicable to TAWS is currently being revised,[18] providing an opportunity to address concerns in the near term, including updating TAWS certification standards to eliminate outdated requirements to reflect technological advances in TAWS equipment and aircraft operations.

Third, no support exists for the position that aviation devices need to have a "wide-band receiver with a slow rolloff of the frequency response well beyond the allocated GPS band."[19] LightSquared has demonstrated the feasibility of using filters to allow even high-precision receivers to function within the allocated GPS spectrum, without "listening" beyond it.[20] Indeed, the FAA's testing of a limited number of certified aviation GPS receivers demonstrates conclusively that their performance exceeds the FAA's minimum requirements contained in existing certification standards.

C. The FAA failed to consider TAWS expert's assessment of the flaws in its analysis

In Appendix C to the FAA Report, LightSquared presented the FAA with the assessment of a TAWS expert[21] that temporary loss of GPS information to TAWS equipment in the very low altitude environment would not constitute a significant lowering of the level of flight operational safety, due to both the functionality of modern TAWS equipment, the redundancies built into TAWS, and the inclusion of obstacles in many modern TAWS equipment. LightSquared has provided a declaration from Mr. Glover as Attachment B-4 to further support LightSquared's position. Among the key unrefuted arguments are the following:

- In the process of descending to an altitude low enough for the system to theoretically be exposed to overload-induced loss of GPS data, the airplane must pass through an environment where a TAWS alert will be given before that airplane enters the very low

[17] NTIA Letter [2], at 7.

[18] Draft TSO-C151c – Terrain Awareness and Warning System (Jan. 2012).

[19] Porcari, s*upra* note 16 ("In general terms, the more precise the GPS receiver -- for example, the avionics in an aircraft -- the more precise they are, the more that they are likely to have a wide-band receiver that in fact needs to be able to listen beyond the GPS frequency, acknowledging that and building a policy around that would be, we think, a very good use of staff time and, from a policy perspective, critical to protecting GPS as an asset.")

[20] *See* Exhibit C below.

[21] The expert, Mr. Howard Glover, has worked for more than 35 years on the development, flight testing, and certification of TAWS. His experience includes early Ground Proximity Warning Systems for civil and military aircraft and also modern terrain and obstacle awareness and warning systems and displays. He was secretary of the EUROCAE working group which developed TAWS design standards for US and European certification. He is the holder of more than a dozen patents in the field of airborne alerting systems. He was an FAA Systems and Equipment Designated Engineering Representative for more than 20 years.

altitude zone. In this case it can be assumed that the flight crew will have taken action to avoid the terrain or obstacle threat before the loss of signal has occurred.

- For TAWS equipment that rely on position data from a multi-source navigation computer, the loss of GPS signal does not degrade the position data until Inertial Reference System drift errors become significant – typically only after several minutes. Consequently, Class A TAWS equipment – which are on all commercial aircraft operating under Part 121 operating in an airport terminal airspace environment are relatively immune to a temporary loss of GPS data.

- For TAWS that have internal GPS receivers, they must also have the capability of monitoring the validity and position error of the GPS system, and the TAWS must provide an indication to the pilot if the GPS error is excessive. For these systems the flight crew will be aware that the TAWS system is degraded if a loss of GPS signal occurs.

- TAWS equipment used in commercial aviation have several alerting functions that use radio altimeter signals for determining the height of the airplane above the terrain. These functions are independent of GPS position data.

- Even if a loss of GPS signal occurs while a TAWS alert is in progress, it is unlikely that the pilot would assume that the terrain threat has ceased, and instead the pilot would ensure adequate terrain clearance by immediately climbing to a higher altitude.

D. The FAA failed to consider LightSquared's technical proposals to limit power-in-the-air and address concerns, instead focusing on unnamed practical difficulties in administering LightSquared's proposal

LightSquared made every effort to address the FAA's concerns by proposing to limit its "power-in-air" to the coverage defined in the FAA's Report. Outside of these exclusion zones LightSquared's aggregate ATCt[22] signal would never exceed -34.1 dBm. This proposal involves significantly powering back its base stations by:

- Restricting the power levels of LightSquared base stations in urban areas to ensure that the aggregate emissions at the worst-case altitude over the largest cities do not exceed the overload threshold established in FAA certification standards for GPS aviation receivers and TAWS equipment;

- Limiting the power levels of all LightSquared base stations so as to protect terrain avoidance systems everywhere beyond the exclusion zones in the FAA Report;[23] and

[22] Consistent with FAA and aviation industry practice, LightSquared refers to its terrestrial operations as ATCt when in the context of aviation discussions. This is done to avoid confusion between this term and the established FAA acronym of ATC which refers to "Air Traffic Control."

[23] FAA Report [1], at Section 1.4.

- Agreeing to further limiting the power levels of LightSquared base stations near airports so as to protect navigation during aircraft takeoffs and landings.

In addition to ignoring LightSquared's proposal for addressing all of the FAA's stated TAWS criteria – at significant operational and monetary cost to LightSquared – the FAA also ignored a high-level method proposed by LightSquared to effectively control power in the air, designed to ensure compatibility for GPS receivers in takeoff and landing phases or to engage in more detailed review and analysis.

E. The FAA failed to adequately define or support criteria used to evaluate LightSquared's system

First, as discussed in more detail in Section II below, during the follow-on work to the RTCA Report, the FAA changed several fundamental aspects of the propagation models used for evaluation. Indeed, the FAA continued to change its proposed propagation models – often without justification – throughout the discussions with LightSquared and even after the FAA formally terminated discussions with LightSquared. A more detailed discussion and critique of these models is included in Section II.

Second, as discussed above, the RTCA Report selected and defined operational scenarios that would be representative of aviation uses of certified GPS receivers. Those scenarios included high-altitude scenarios,[24] generic low altitude/terminal area procedures,[25] Category I Precision Approach Procedures[26] used by aircraft on instrument approaches to airport runways, Category II/III Precision Approach Procedures,[27] and Taxiway scenarios.[28] The RTCA Report did not provide evaluation criteria or examine scenarios specific to TAWS, nor did it examine general low altitude navigation applications beyond the Cat I/II/III procedures.[29]

When the FAA first raised low-altitude applications as a potential issue in October 2011, it did not provide specific support for some of its asserted criteria, including the acceptable exclusion zones that could be considered in the TAWS analysis. It also provided new applications of GPS at low altitudes with only limited operational use of certified GPS receivers. Among the undefined and unquantified requirements outlined in the FAA Report are:

While the FAA attempted to define acceptable exclusion zones in Section 1.4 of the FAA Report, that definition varied even during the drafting of the FAA Report and included a caveat that the exclusion zones would need to be coordinated with the industry, suggesting that even the criteria defined in Section 1.4 may be subject to change. For the other low altitude applications

[24] RTCA Report [3], at 3.2.

[25] RTCA Report [3], at 3.3.

[26] RTCA Report [3], at 3.4.

[27] RTCA Report [3], at 3.5.

[28] RTCA Report [3], at 3.6.

[29] RTCA Report [3], at 3.1

of GPS, the FAA did not define criteria that could be used to evaluate LightSquared's system.[30] As discussed herein, although the FAA has not fully defined its criteria or requirements, LightSquared believes that its proposed mitigations will demonstrate compatibility with the criteria articulated in the FAA Report.

F. Various other elements of the FAA's analysis and criteria are flawed

1. GPS Reference Antenna Pattern

For negative elevation angles, the FAA allowed a difference of 6 dB between the horizontal and vertical polarization responses of the "reference GPS antenna," although all examples of GPS antenna provided by the FAA had a much higher difference – close to 11 dB. LightSquared stated its position in the FAA Report on this subject on page C-34.

LightSquared believes, as stated in documents presented to the FAA in meetings during the study that, based on the example antenna pattern used in the RTCA Report, in which the antenna pattern is based on RTCA/DO-235B, Fig. G-13, a minimum discrimination of 11 dB is appropriate in the elevation angle range of 0 to -30 degrees. It is also noteworthy that the RTCA/DO-235B states, "For horizontal polarized signals in the backlobe region, the data suggest a conservative polarization mismatch loss factor is 15 dB."[31]

A higher discrimination of the horizontally polarized signal reduces the net Radio Frequency Interference ("RFI") power as LightSquared's base station signals are dual polarized with approximately equal power in linear-vertical and linear-horizontal polarizations.

Although not discussed with the FAA owing to the premature termination of discussions, subsequent to those discussions ending, LightSquared has indicated to the NTIA that it is willing to use Left Hand Circular Polarization (LHCP) in its base stations as a potential mitigation measure. It should be noted that the antenna discrimination assumed in the analyses in the FAA Report will not be reduced when the base station polarization is changed from dual, linear cross-polarized to LHCP – if anything, there may be a small amount of additional discrimination owing to a residual amount of cross-polar discrimination between LHCP and RHCP.

2. Measured Performance of Aviation GPS Receivers

The FAA's analysis was based exclusively on the RTCA Minimum Operational Standards ("MOPS") as specified in RTCA/DO-239D, completely ignoring the results of the tests performed on four certified aviation receivers by Zeta Associates, which demonstrated that the resilience of the receivers exceeded these MOPS. Since then, three additional certified aviation receivers have been tested by LightSquared and its partners. The results are shown in Table B.I.1 below.

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[30] FAA Report [1], at 16 ("the FAA has not made operational and safety assessments for the additional areas of consideration identified in Appendix A Section 6 "Residual Operational Risks" and these risks have not been coordinated with the users who would be impacted.")

[31] RTCA/DO 235B, Assessment of Radio Frequency Interference Relevant to the GNSS L1 Frequency Band, at G-14 (March 13, 2008) ("RTCA/DO-235B").

Table B.I.1 Margins of Measured Aviation Receiver relative to the MOPS (dB)

	Lower-10 MHZ ATCt Channel
Zeta Rx-1	27
Zeta Rx-2	26.4
Zeta Rx-3	26.4
Zeta Rx-4	23.7
ALU Rx-1	13.1
ALU Rx-2	18.1
ALU Rx-2	18.1

3. Implication of Channel Fading for Compatibility

The presence of channel fading will cause the RFI Power from each base station to change over time. Section II.C.3 below shows that fast fading comparable to cellular/MSS channels is not feasible in the LightSquared scenario owing to the lack of time-varying local multipath at the GPS receiver. However, slow fading owing to changes in the path geometry (including local multipath reflections around the base station), as the plane traverses its course, *can* exist. It is important to take a high level view of what this means for compatibility.

The FAA has taken a position that every time the RFI power exceeds the threshold level, it comprises a functional failure of the GPS receiver.[32] This is far from the way GPS receivers actually behave. At a fundamental level, in A GPS device's tracking mode, there is a coherent integration time of 20 ms for all navigation functions – 20 ms is the symbol duration of the message channel carried by the GPS L1 C/A code. Beyond this, the integration is continued incoherently over several symbols. Typically, in the tracking mode, the carrier tracking loop bandwidth is less than 10 Hz. Thus, fades of duration less than 100 ms are unlikely to cause perturbation to the GPS receiver. This is yet another reason why fast fading, even if it existed, would be reduced by the effect of averaging within a time period that is substantially longer than the mean fade duration.

The slow fading bandwidth will be morphology-dependent. It is clear from geometrical considerations that, at the lower altitudes, which are what the FAA now identifies as the more critical use cases, the fading bandwidth will be greater than at higher altitudes. Clearly, some reduction of RFI power will occur due to the limited response time of a GPS receiver to a time varying adjacent-band signal..

Furthermore, assuming that each event where the RFI power exceeds the threshold value is statistically independent, the FAA proposes that multiplicative probability rules be applied to

[32] FAA Report [1], at Section 3.2.3.

derive the probability that the RFI power remains continuously below the threshold for a period of 1 hour.[33] This leads to potentially specifying the RFI power requirement at probabilities of 1E-10. The FAA did not insist on a pass/fail metric based on this criterion as it lacked the computing resources to simulate this but has opined that the "rare probability requirement" is a lower bound to the estimate of the received RFI power.[34]

LightSquared believes that this logic is fundamentally flawed for the following reasons:

First, it is questionable whether the lognormal probability distribution assumed for slow fading is an accurate representation of physical reality at the individual event-level probability of 1E-6. The lognormal distribution is used to model measured data in cellular propagation at much higher probability levels than 1E-6. There is no empirical evidence that the lognormal model will continue to hold at P = 1E-6 -- the lognormal model is a mathematical function that has been fitted to experimental data and not derived from physical considerations. In practice, it has been found that the tails of the probability distributions of observed data are shorter than those predicted by their mathematical models.

Second, to assume that the power at P=1E-10 can be predicted by multiplying individual event probabilities, each at P=1E-6, represents a physically meaningless application of probability theory.

Third, ignoring the above misapplications of statistics, it is noteworthy that the P=1E-6 requirement was derived from the requirement of service continuity over a period of 1 hour. In the low altitude applications, both for takeoff/landing and TAWS, the basic use case has a much shorter duration than 1 hour. Hence, only the mean power requirement is relevant in these cases.

II. THE FAA'S PROPOSED PROPAGATION MODELS USED IN ASSESSING COMPATIBILITY WITH LIGHTSQUARED'S ATC NETWORK ARE FLAWED

This section summarizes the arbitrariness and inconsistencies of the FAA's propagation models. This section is also supported by declarations from wireless industry technical expert, Dr. Parsons, including a critique of the January 13, 2012 draft version of the FAA Report.[35] These declarations are attached as Attachments B-1 and B-3. In addition, Attachment B-2 contains a critique of the FAA's propagation models.

This section supplements the information provided in Appendix C to the FAA Report. LightSquared had a very short period of time – about a week – to provide inputs to the FAA's propagation model contained in the FAA Report. While LightSquared managed to get most of its key inputs incorporated in this short time, the task was made more difficult by the FAA revising its version of the propagation model while LightSquared was preparing its inputs. Additional analysis and comments from LightSquared on the FAA Report are found in Appendix

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33 FAA Report [1], at Section 3.2.3.

34 FAA Report [1], at Section 3.2.3.

35 The substance of the January 13, 2012 draft version is substantively the same as the FAA Report for purposes of Dr. Parson's review.

C thereto. Now that a final FAA propagation model is available in the FAA Report and LightSquared has had more time to analyze it, it is possible for LightSquared to provide a more detailed critique of the FAA propagation models.

A. Procedural Background

The FAA had previously requested the RTCA to perform a study on the same subject, which resulted in the RTCA Report.[36] The final report from this study recommended a "minor" follow-on study to close out some open items, which included (i) a probability analysis of the cumulative distribution function ("CDF") of the RFI power at the GPS receiver; (ii) a finer determination of the aircraft height corresponding to maximum RFI; and (iii) a determination of the acceptable RFI thresholds for both tracking and inflight acquisition.[37]

B. The FAA Report adopted significant changes in its new propagation model and criteria relative to RTCA study

The follow-on work was not performed by the RTCA but by the FAA itself, using a combination of its own staff and some consultants who had participated in the previous RTCA study. During this work, several fundamental aspects of the RTCA Report were changed completely and new criteria were introduced. The changes in the RTCA Report relative to the FAA Report are discussed below. LightSquared agreed with some of the changes but disagrees with many, as described below.

The FAA Report adopts significant changes in key modeling assumptions, parameters, and operational criteria, not considered in the RTCA Report, which were not able to be fully reviewed by LightSquared prior to publication of the FAA's Final Report, including:

- New propagation models and model-parameters.[38]
    - A propagation model was introduced, whose parameters (breakpoint distances) were based on the probability of line of sight to the base stations. In the previous model, the breakpoints were also arbitrary, (unsupported by empirical data) but were based exclusively on path geometry.
    - The extended Suzuki model was introduced over the normal Suzuki model used previously. The extended Suzuki model was developed for MSS links whereas the normal Suzuki model was intended for cellular links.
    - There was recognition that the standard deviation could not be modeled simply as 8.4 dB, based on the assumption of a narrowband base station signal.[39]
    - The standard deviation of received RFI power was made dependent on the lateral distance.[40]

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36 RTCA Report [3].

37 RTCA Report [3], at Executive Summary.

38 FAA Report [1], at Appendix B.

39 RTCA Report [3], at Appendix B, Section B.2.1.2.

40 The lateral distance is measured from the base station to the nadir point below the aircraft.

- There was a significantly different treatment of the low altitude cases (300 ft and lower). There was much greater use of low-loss models, such as free space and 2-ray, than in the RTCA Report, where lossy clutter-models were used. No reason was provided for the change. The low-loss assumptions about low altitude use-cases shifted the critical height (of maximum RFI power) to lower altitudes. This was compounded by the fact that many Sprint base stations[41] were found to exist in areas assumed in the RTCA Report (apparently erroneously) to be free of base stations to conform to Obstacle Clearance Surface ("OCS") criteria.
- The new propagation model was made *site specific* whereas the old model was *zone specific*. Here, "site" refers to the nadir point of the aircraft and "zone" refers to a circular annular region around the nadir point. This change was necessary because it was found that highly built up areas near major airports presented special cases of high RFI that could not be adequately represented by the model of *uniform base station density per zone* assumed in RTCA Report.

- There was recognition that the base station emits linear, horizontally and vertically polarized signals and that these have different responses in the GPS antenna.

- TAWS was introduced very late in the process. This became quickly the critical requirement, dwarfing all others in terms of driving base station EIRP reductions.

In addition, unlike the RTCA Report, the FAA Report contains several propagation models based on differing aircraft height that may be categorized as follows:

- From approximately 300 ft to 1755 ft (535 m), the *aggregate base station RFI model* is used. LightSquared refers to this as the Higher Altitude model (to distinguish it from the High Altitude model and the Low Altitude models described below).

- Above 535 m, where the High Altitude model applies, the pure free space pathloss model is used for all base stations in the radio horizon. This is one of the few areas where the FAA Report and RTCA Report have remained identical and there is no disagreement between the FAA and LightSquared.

- Below 300 ft (~100 m), where there is a direct LOS to the aircraft, the FAA has performed calculations using both pure free space and the 2-ray model. The FAA has not taken a stand on which model should be used in which scenario. In this section, LightSquared refers to this as the Low Altitude model.

1. Higher Altitude Model – FAA Report

This model is described in the FAA Report, Section 3 and Appendix B. The general methodology is as follows.

[41] At the time of the FAA analysis, LightSquared's base station deployment was expected to largely be an overlay of the existing Sprint network.

A Monte Carlo simulation is performed where each base station produces RFI power samples with a given median value (μ) and standard deviation (σ), the probability distribution being given by an extended Suzuki distribution. The values of μ and σ are determined both by the path geometry and the specific distribution of base station locations and heights visible from the GPS receiver. These aspects are described further in Section 3.2 of the FAA Report. The above shows that the propagation model is site specific, unlike the model in the RTCA Report, which was site-neutral.

The net RFI power at the GPS receiver is calculated as the sum of the power contributions from all base stations within the radio horizon. The extended Suzuki distribution mentioned above is the distribution of the product of two independent random variables, the first having a Rician distribution and the second having a lognormal distribution. In the normal Suzuki distribution, the first random variable has a Rayleigh distribution. In its intended usage mode,[42] the first variable represents fast fading and the second variable represents slow fading.

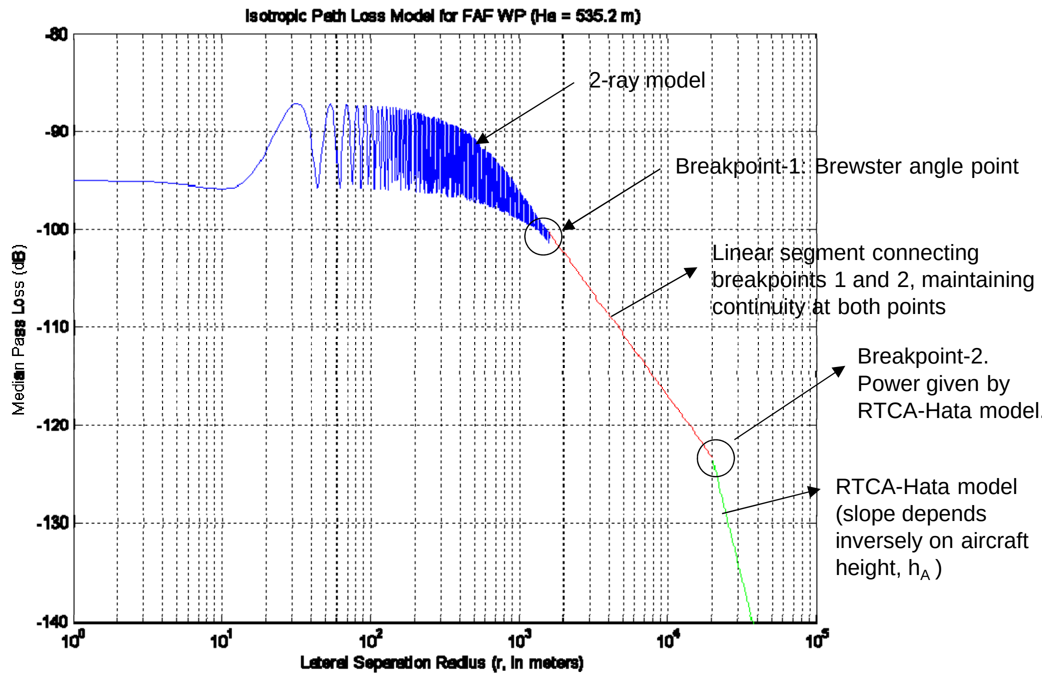
2. Higher Altitude Model - RTCA Report

The methodology of the RTCA Report is reviewed below as background, as it created the framework on which the methodology of the FAA Report is based.

The RTCA's propagation model for the Higher Altitude scenario was based on multiple segments with different μ and σ. Figure B.II.1 illustrates the segments and breakpoints for BTS tower height of 30m, and aircraft height of 535.2m.

[42] It is noteworthy that neither the Suzuki distribution nor its extension stipulates how each variable must vary with time (for an observation point that is time varying, i.e. mobile) or with distance, which is the more fundamental variable).

Figure B.II.1 Breakpoints in FAA's Higher Altitude Propagation Model in RTCA Report



a) Segment-1 (2-Ray Model)

The first segment extends from d=0 to d=r_1, where d is the lateral distance of the base station from the aircraft's nadir point. The breakpoint r_1 is chosen to correspond to the distance at which the Brewster angle occurs, i.e. the distance where the reflection coefficient for vertical polarization becomes zero. No physical reason is advanced by the FAA as to why the 2-ray model should be used up to this point – the sinusoidal variations of the received field strength continue beyond this distance until they decay to a point beyond which the received power falls off with distance with an exponent of 4.[43]

The distance, r_1, is dependent on the path geometry – for lower aircraft heights, r_1 is smaller. For example, for a base station height of 30 m, r_1 assumes the following values for the aircraft heights considered in RTCA Report.

Table B.II.1 First Breakpoint Distances for 30 m base station height

Aircraft Height (m)	First Breakpoint Distance (m)
535.2	1597
53.3	222.9
25.9	190.18
4.0	97

[43] Rappaport, T.D., Wireless Communications Principles and Practice (2 Ed.), Prentice Hall, 2002, at 124 [6].

b) Segment-2 (Linear Connecting Segment)

This is an artificial segment for which the FAA has not provided any physical justification. The only justification seems to be the mathematical one of ensuring continuity across segment boundaries. It joins the pathloss values at the end of segment-1 and start of segment-3 with a straight line (relative to a logarithmic distance axis). The end of segment-1 has a pathloss corresponding distance at which the Brewster angle occurs and the start of segment-3 has a pathloss given by the RTCA Hata model. The slope of segment-2 can be as low as 2.09 and as high as ~ 4 for different scenarios, as shown below.

Table B.II.2 Second Breakpoint Distances for 30 m base station height

Aircraft Height (m)	Second Breakpoint Distance (m)	Segment-2 slope	Elevation Angle (BTS to aircraft) in degrees to 2nd breakpoint
535.2	20000.0	2.089	1.44
53.3	1000.0	2.923	0.13
25.9	190.18	3.564 (Hata model slope)	-1.2
4.0	1000.0	3.983	-1.49

For an aircraft height of 25.9 m, segment-2 vanished as the Hata model loss at 190.18 m was the same as that at the end of segment-1 and a connecting segment was unnecessary.

c) Segment-3 (RTCA adapted Hata-Okumura model)

The FAA used a clutter based propagation model when the elevation angle was sufficiently low. LightSquared agreed with this. However, the distance at which the clutter model should be used was arbitrary – as Table B.II.2 shows, there is no systematic dependence on the magnitude of the elevation angle, which could have been a plausible criterion, based on the assumption that a lower elevation angle increases the probability of blockage, and therefore the applicability of a cellular-like median pathloss law.

While the above description only refers to two breakpoints, there is also a 3rd breakpoint at a distance of 20 km where the extended Hata model increases the median pathloss slope slightly. For the case where the aircraft height is 535.2 m and the 2nd breakpoint is itself at 20 km, the 2nd and 3rd breakpoints merge.

The Hata-Okumura propagation model was modified by the RTCA in a number of ways, some of which were arbitrary.[44] These included:

i. Using the tall antenna mode of the Hata model (which allows antenna heights up to 550 m) and reversing the propagation direction

[44] RTCA Report [3], at Section B.3.1.1.2.

ii. Using the ITU-R extension for ranges greater than 20 km
iii. Using an antenna factor, AF, corresponding to urban scenarios but choosing the suburban option for the main equations (B-15 and B-17)
iv. Using the model beyond the specified frequency range of 150 – 1500 MHz, and refusing to use the COST 231 model which is recommended for the frequency range applicable for LightSquared's frequency ranges (1525 – 1660.5 MHz).

No physical justification was provided for (iii) and (iv), beyond that they yielded larger values of pathloss, which were "deemed unlikely" in the opinion of the RTCA. The record of discussions between LightSquared and the FAA on the subject of propagation models, including an opinion by Dr. Parsons, whose book was referenced by both reports, is provided in Attachment B-2.[45]

It is noteworthy that the suburban correction reduces the pathloss by 11.5 dB relative to a large/medium city, as shown in the following case.

Area correction factor K= 2[log10(fc/28)]^2 +5.4 for Suburban area.
K = 0 for Medium and Large city
For f_c= 1531 MHz, K = 11.4 dB for suburban area.

The FAA's argument was that airports are typically located in suburbia; hence the suburban correction factor is appropriate. However, at the same time, it used the antenna correction factor for urban scenarios. To quote Dr. Parsons:[46]

> If it is sensible to use the "large city" antenna height expression, then to be consistent with this we should not apply the suburban correction factor to the environment. To "mix and match" like this is not good engineering practice and casts doubts on the robustness of the model – it could be construed as a license to choose whatever parameters are necessary to make the model fit a certain data set.

From the above, the general pattern of the arbitrary ways in which the FAA assessed compatibility, even in the RTCA report, includes the following:

- Parameters were chosen in existing propagation models in an arbitrary and sometimes self-contradictory ways. Examples:
    - Use of the Hata-Okumura model outside its specified frequency range when COST231 model was available for the appropriate frequency range.
    - Use of the suburban option in the main equation and the urban option for the antenna factor

- Existing, industry-standard models were modified in arbitrary ways. No empirical data was advanced to support the choices.
    - The 2-ray model was used until the Brewster angle and the RTCA modified Hata-Okumura model was used from another arbitrary distance. The two segments

[45] Fizzle Technologies, "The LightSquared Comments on the use of the Hata Propagation Model," (Sept. 11, 2011) [7].
[46] Parsons, J.D. and Gardiner, J.G., Mobile Communication Systems, Blackie & Sons Ltd., 1989 [11].

were joined together by a straight line, whose slope could approach 2.0 for an aircraft height of 535 m. This implies free space propagation. However, this was used with a standard deviation of 8.4 dB[47] which is without any support for a LOS link.

The net effects of these choices, relative to other equally plausible (or more plausible) choices that could have been made, were sometimes in excess of 10 dB. This is remarkable considering that the RTCA report concluded that, for the lower 10 MHz channel, the link margin shortfall for median pathloss, in the in-flight acquisition mode, was only 3.5 dB and that there was a 2.5 dB positive margin for the Tracking mode. It should be clear from the above that the analytical methods used by the RTCA lacked the certainty to draw such fine-grained conclusions that the FAA is now attempting to draw in the FAA Report. Moreover, the assumptions made appear to have been biased towards maximizing the received RFI power.

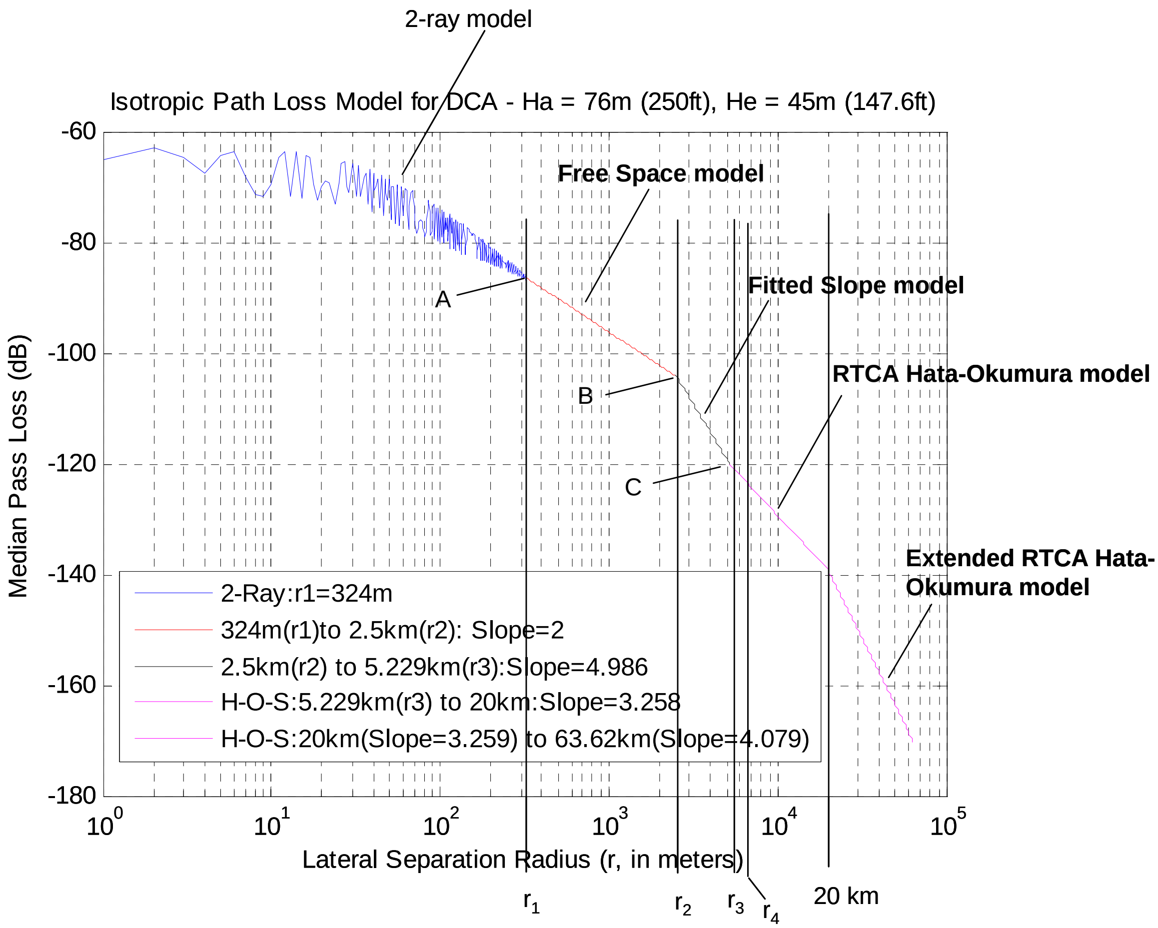
C. The FAA's methodology is flawed

In the FAA Report, as in the RTCA Report, the FAA persisted with a model where the median pathloss varied as a continuous function of log(lateral distance), in piecewise linear segments.[48] However, the breakpoints and the segment characteristics (median value and standard deviation) were different from the RTCA report. Figure B.II.2 shows an example of the median pathloss profile for DCA-1 and DCA-2 scenarios, assuming the aircraft is at a height of 76 m and the base station antenna height is 45 m. As in the RTCA report, the received RFI power analyses were based on Monte Carlo simulations.

[47] In the FAA Report the standard deviation was reduced for smaller lateral distances. However, the pattern of using relatively high standard deviations on links with low excess loss over free space continued.

[48] FAA Report [1], at Appendix B.

Figure B.II.2 Median Pathloss Profile for DCA according to the FAA Propagation Model



A purely mathematical model such as the above may be justified when no information is available about the actual distribution of base station locations and antenna heights, as was the case in the RTCA report. However, when site-specific information is available, as in the FAA report, this information *can* and *should* be utilized, as it leads to a more accurate estimate of the RFI power. The FAA models in its report were made *partially site-specific*, i.e. they used site-specific information about the likelihood of encountering blockage (for a given path geometry[49]) but assumed that all base stations at a given lateral distance, *regardless of their blocked/unblocked status*, contributed the same median RFI power and had the same standard deviation of RFI power. Whether a model such as this will yield an accurate estimate of the actual net RFI power is critically dependent on the functions assumed for median pathloss and standard deviation. This is acknowledged by the FAA in Section 3.3.4 of the FAA Report where

[49] The path geometry is determined by aircraft height, lateral distance to the base station from the nadir point and the base station antenna height.

the sensitivity of the results to Monte Carlo simulation parameters is discussed.[50] Yet, the functions proposed by the FAA were not associated with any empirical support, their only requirement being continuity across breakpoints, e.g. at points A, B, and C in Figure B.II.2.

In contrast, LightSquared proposed a propagation model that is much closer to physical reality, being based on free space propagation and, for blocked links, an additional loss of 10 dB based conservatively on MSS propagation literature and other sources, such as ray tracing and theoretical estimation based on the theory of radar cross sections. In this model, the link to each base station is examined individually and, based on a morphology database, a determination is made if the link is *blocked* or *unblocked*. If the link is blocked, one set of median power and standard deviation values is used; if it is unblocked, another set is used. Both of the above sets are derived from empirical data obtained from the MSS propagation literature. Appendix C of the FAA Report, which contains the LightSquared view, provides more details about this model and its justifications (which included ray tracing and other methods beyond MSS propagation literature). Specifically, the parameter values, supported by empirical data from MSS field trials were[51]:

- Blocked
  - Mean pathloss = free space loss + 10 dB
  - Standard deviation = 3.5 dB

- Un-blocked
  - Mean pathloss = free space loss
  - Standard deviation = 0.5 dB

The FAA's models for median pathloss and standard deviation[52] are described below.

1. Median Pathloss

a) First breakpoint (r_1)

The first segment extends from the nadir point to the point at which the Brewster angle of the 2-ray model occurs (as in the RTCA report). The distance to this point is r_1.

b) Second breakpoint (r_2)

This point is to be determined from the site-specific distribution of the locations and heights of the base station towers around the airborne GPS receiver. The breakpoint, r_2, is selected to be the lateral distance up to which "essentially clear LOS" exists to the base stations.

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[50] ("The CDF tails (e.g. 10^{-6} region) results are quite sensitive to the modeled sigma-dB values. In view of this sensitivity, a modeling change to the continuous distribution was made after it was observed that the large CDF tails were being driven in part by the step-sigma value of 6.4 in the region slightly above 20 km. The associated abrupt step change was judged not to be physically reasonable.")

[51] Loo, C., "A Statistical Model for a Land Mobile Satellite Link," *IEEE Transactions on Vehicular Technology* Vol. 34, No. 3 (August 1985) [8].

[52] FAA Report [1], at Appendix B.

In the Washington DCA-1 and DCA-2 scenarios, this was determined to be 2.5 km. The method is clearly far from rigorous – there is not even a definition of what "essentially clear LOS" means. A factor known as "S" is used in the MSS literature, which could have been used.[53] The S-factor defines the probability of encountering blockage, i.e. S=1 means 100% probability of blockage and S=0 means 100% probability of clear LOS (no blockage). A low threshold value of S could have been set to define an objective basis of selecting the second breakpoint.

Between the first breakpoint, r_1, and the second breakpoint, r_2, the median pathloss is assumed to vary according to an inverse square law (exponent of 2.0), consistent with free space propagation. This is not unreasonable, given that r_2 is selected on the basis of a low S-factor.

c) Third Breakpoint (r_3)

The FAA's determination of the third breakpoint, r_3, is purely an exercise in mathematics without any attempt at an empirical justification. The selection algorithm is as follows:

- r_3 represents a distance where the blockage factor, S, becomes "substantial," although (as above) a quantitative definition of S at r_3 is lacking.

- The median pathloss value for r_3 must satisfy the RTCA Hata-Okumura equation to maintain continuity across breakpoints (the segment beyond r_3 corresponds to the RTCA Hata-Okumura equation). In other words, C (in Figure B.II.2) must land on the RTCA Haka-Okumura line.

- r_3 has a minimum value, r_{3min}, which occurs for an aircraft height (h_A) of 30 m. For the DCA scenarios, r_{3min} is 5 km and r_3 is 5.23 km

- The line joining r_2 and r_3 is a straight line with a slope given by an equation.[54] For the DCA scenarios, the slope is 4.986, not 5.76 as stated in the RTCA Report.[55]

- The above equation makes the slope dependent on the path geometry, with a lower slope for greater aircraft height. Presumably, the heuristic justification of this rule is that S will reduce as h_A is increased. What this means, effectively, is that as h_A increases, r_3 increases. For the DCA scenarios, r_3 = 5.229 km.

d) Fourth Breakpoint (r_4)

The fourth breakpoint is not related to the slope of the median pathloss curve – it is part of the standard deviation model. It is the point at which the standard deviation, given by an assumed polynomial, reaches the value of 6.4 dB. This is assumed to be the standard deviation

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[53] Goldhirsh, J. and Vogel, W.J., "Propagation Handbook for Land-Mobile-Satellite Systems," Report SIR-91u-012, Johns Hopkins University Applied Physics Laboratory, at Chapter 11, 1991 [9].

[54] RTCA Report [3], at Section B.3.3.

[55] RTCA Report [3], at B-5.

in the segment where the RTCA Hata Okumura pathloss model holds. The method of defining standard deviation is discussed below in more detail.

2. Standard deviation of pathloss

It is noteworthy that the FAA used independent compatibility criteria for the median RFI power and the RFI power received with a probability of 1E-6 assuming a lognormal distribution. The standard deviation drives the second compatibility factor (RFI power at P=1E-6), which is the more challenging factor based on the models/ parameters assumed by the FAA. Yet the FAA makes no attempt to offer any empirical basis for the hypothetical *standard deviation versus lateral distance* function. This function is a polynomial fitted to a step function of σ values in different segments as shown in the FAA Report.[56] The choices of the discrete σ values are arbitrary and physically unrepresentative, as discussed below. The only requirement for the σ versus distance function is to reach a value of 6.4 somewhere beyond r_3, where the median pathloss is determined by the RTCA Hata-Okumura model.

The standard deviation functions are shown in the FAA Report, Figure 3-9 for the LAKIE scenario (aircraft height of 535 m) and Figure 3-20 for the DCA scenarios (aircraft height of 100 m). While for LAKIE, the limiting standard deviation of 6.4 is achieved at a distance of 20 km, where significant blockage and scattering may be expected, for the DCA scenario, the limiting standard deviation of 6.4 is achieved at approximately 6 km. This means that LOS links may exist at this distance and they would be assigned a standard deviation of 6.4. Physically, this is extremely unlikely and the FAA has provided no empirical justification for this model. The fallacy of this approach is shown in more detail, with specific examples, in Section III.C.4.

A fundamental area of disagreement between the FAA and the LightSquared propagation models is whether high standard deviation (barring the fast fading component caused by local multipath) and low median pathloss (approaching free space values) can exist simultaneously. The FAA's position that such cases *can* exist is without support in the empirical propagation literature. In contrast, LightSquared's position is supported by several MSS propagation measurements. See Appendix C of the FAA Report for a detailed discussion of the support in the MSS literature for the LightSquared position. A summary position may be stated as follows.

> When there is a direct LOS link, it is well known that the fading is Rician with a large K-factor (carrier to multipath ratio) and a standard deviation around 0.5, as shown by the MSS literature.[57] The smaller K factors are obtained when there is significant blockage/shadowing of the direct ray, leading to a larger standard deviation. Yet, the FAA persisted in using relatively large values of σ with low excess path loss over free space. Specific examples of such cases are shown in Section III.C.4.

On a side note, <u>the notion that the standard deviation should increase monotonically with distance also lacks empirical support</u>. There are many examples in both the LAKIE and DCA

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[56] FAA Report [1], at Equation 7.

[57] *See e.g. L*oo [8], Goldhirsh et al. [9].

scenarios where the blockage (represented by S) actually reduces with distance. There are also examples in the cellular propagation literature where the standard deviation has been found to reduce with distance for certain urban locations, e.g. when an open area is encountered in the propagation path following a built up area.[58]

3. Fast Fading

In both the normal and extended Suzuki distributions, the first random variable is associated with *fast fading* in cellular and MSS scenarios, respectively. Such fading is associated with multipath reflections from surfaces in the immediate vicinity of the receiver (local clutter). Clarke's foundational paper provides a good physical explanation and mathematical model for multipath induced fast fading in cellular environments.[59] In such environments, multipath reflections around the base station do not contribute as much to fast fading.[60] To quote from the above reference:

> The reciprocity theorem applies, of course, in any linear medium, but this should not be taken to imply that the spatial correlation distance at one end of the radio path is the same as it is at the other.

Intuitively, this can be explained by noting that a small movement in the position of a mobile receiver in a substantially multipath-free local environment, such as an open field, does not create a large decorrelation of the received field, even when the base station may be surrounded by clutter (reflecting surfaces). Figures B.II.3 and B.II.4 illustrate why the LightSquared RFI scenario should not include fast fading. The figures show a single transmitter/receiver path as an illustration of the propagation mechanism. In the LightSquared scenario, where a plurality of base stations would exist, the presence of multiple transmitters only affects the net received power, because the signals from different transmitters are uncorrelated.

In the LightSquared scenario, there is almost no time varying local multipath at the GPS receiver which is on an aircraft in level flight.[61] Any time varying multipath, as the aircraft moves through the received field, would be caused by clutter *at the source*, i.e. around the base station. From the path geometry, illustrated in Figures B.II.3 and B.II.4, it should be clear that the fading can only be *slow* (the decorrelation distance is not sub-wavelength, as is typical in fast fading and shown by Clarke). In the act of reversing the propagation direction, in order to use cellular and MSS propagation models, the FAA also assumed that the local multipath conditions at the receiver and transmitter could also be exchanged. This is clearly an error and has led to its assumption that, as in the cellular and MSS channels, the LightSquared RFI channel will also include fast fading. <u>LightSquared believes that there should be no fast fading component in the</u>

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[58] Parsons, J.D, <u>The Mobile Radio Propagation Channel (2 Ed.)</u>, John Wiley and Sons, Chichester, UK, 2000, at 155 [5].

[59] Clarke, R.H, "A Statistical Theory of Mobile-Radio Reception," 47 Bell Systems Technical Journal 6, pp. 957-1000 (1968) [4].

[60] Parsons et al. [11], at 40-41.

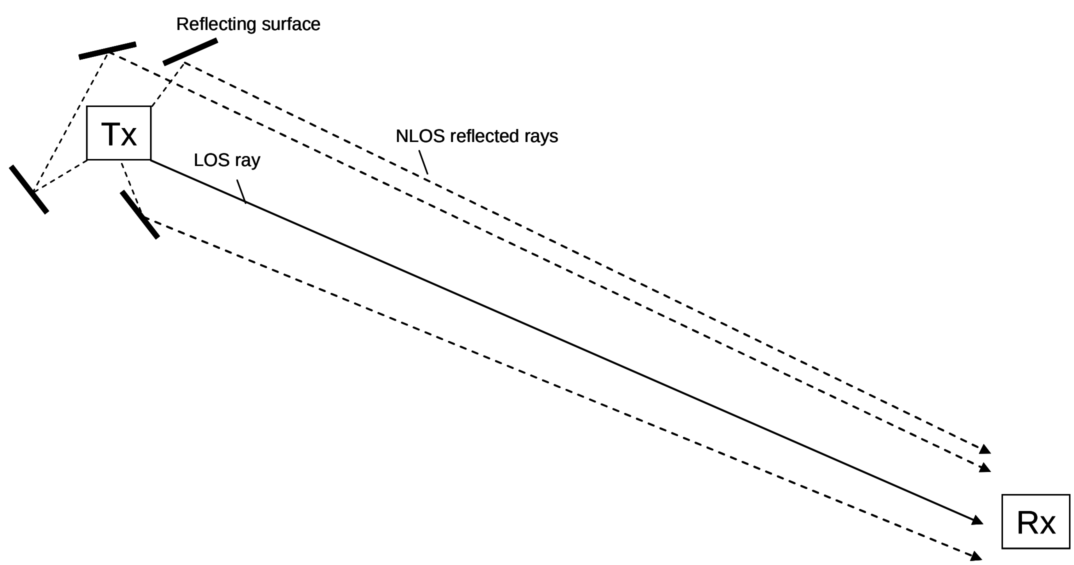
[61] There may be local reflections from the body of the aircraft but they are not time varying when the aircraft is in level flight.

channel model. However, the FAA has chosen to retain the fast fading component in the extended Suzuki propagation model, while providing no supporting rationale.

Fortunately, based on the FAA's particular choice of parameters, the fast fading effects on the median RFI power and the tail of the CDF curve of RFI power, evaluated at P=1E-6, is relatively small. Therefore, the erroneous assumption of a fast fading component in the channel model is non-critical in determining compatibility, further demonstrating the arbitrary nature of the FAA's choice in propagation models.

Figure B.II.3

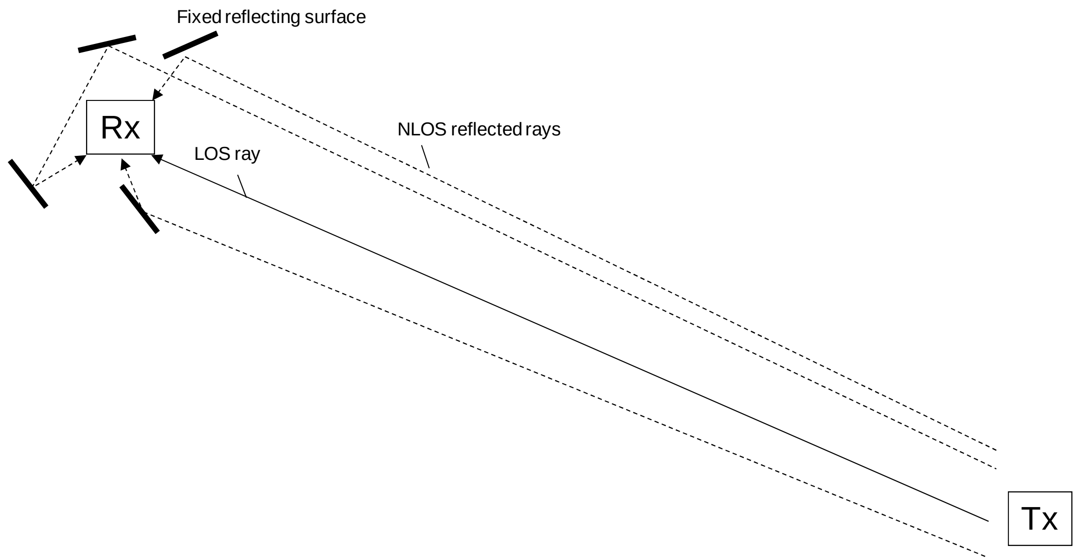
Fading scenario with clutter around Tx. (plan view)



Small movements in the Rx position do not cause much field decorrelation in this scenario. The fading caused by Rx movement is therefore slow. The LightSquared RFI scenario is the same as this with the Rx being the airborne GPS Rx.

Figure B.11.4

Fading scenario with clutter around Rx. (plan view)



Small movements in the Rx position cause significant decorrelation in the field components in this scenario [4]. The fading caused by Rx movement is therefore fast. This represents a cellular/MSS propagation environment, not the LightSquared RFI scenario. In the latter, it is the Tx (base station) that is surrounded by local clutter, not the Rx (GPS device). Nevertheless, the FAA's propagation model erroneously includes a fast fading component.

4. Examples of pathloss and standard deviation values calculated by FAA and LightSquared models

This section provides some examples of median pathloss and standard deviations for particular base station to aircraft links in the DCA scenarios in the third ($r_2 - r_3$) segment. The examples have been selected to highlight the anomalous consequences, from a physical standpoint, of the FAA's propagation model. The mean pathloss and standard deviation values calculated by the FAA and LightSquared models are shown in Table B.II.3 below, together with their blocked/unblocked status based on actual morphology.

Table B.II.3 Values of Median Pathloss and Standard Deviation calculated by FAA and LightSquared Models

No.	Base Station ID	Blocked/Unblocked	Base Station Antenna Height above Sea Level (m)	Distance from nadir point (km)	FAA Values		LightSquared Values	
					Median pathloss (dB)	Pathloss Standard Deviation	Median pathloss (dB)	Pathloss Standard Deviation
1	DC03XC012	Blocked	49.4	3.276	109.16251	2.0057885	116.45141	3.5
2	DC03XC199	Unblocked	139.4	3.457	106.35737	2.2077435	106.91611	0.5
3	WA23XC515	Blocked	51.43	2.571	104.56431	1.3407274	114.34501	3.5
4	WA57XC011	Unblocked	65.89	2.577	104.78052	1.3460329	104.36661	0.5
5	WA73XC422	Blocked	36.81	5.110	119.1558	4.6812924	120.31156	3.5
6	DC03XC179	Unblocked	156.11	5.149	108.30565	4.7518218	110.37652	0.5

The examples in Table B.II.3 have been selected as pairs of cases with similar lateral distance. It will be observed that, at shorter distances such as cases 3 and 4 (around 2.5 km), even when the link is blocked, the median pathloss is very similar to free space (approximately 104 dB). Such cases significantly increase the net RFI power in the FAA model without any physical justification. In the case of relatively large distances, when the link is unblocked, the FAA model assumes a large standard deviation (e.g. 4.75 in case 6) while its median pathloss (108 dB) is 2 dB less than the free-space pathloss (110 dB), also without any physical justification. In contrast, the LightSquared model uses a standard deviation of 0.5 based on the MSS literature for the same case.[62] The above examples show the fallacy of basing the median pathloss and standard deviation on lateral distance and path geometry, which is the model adopted by the FAA, instead of the actual blocked/unblocked status of the base station to aircraft link, as is the method of the LightSquared model.

In summary, if site-specific base station and morphology data *are* available, as is assumed in the FAA propagation model in the FAA Report, it makes little sense to use it *partially* (i.e. to determine the breakpoints) and then force a uniform mathematical model onto *all* base station to aircraft links.

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[62] Loo [8].

D. Summary of deficiencies in the FAA's higher altitude propagation model in FAA Report

The following is a list of deficiencies of the FAA's higher altitude propagation model.

1. Partial use has been made of the site-specific blocked/unblocked status of base station antennas relative to the height of the aircraft. The information is used only to derive the breakpoints of the median pathloss and standard deviation functions relative to distance. These functions appear to be completely arbitrary – no physical justification has been offered. Given that *a priori* knowledge of the blocked/unblocked status of base station antennas is necessary in the FAA model, the LightSquared model, also utilizing this information, is closer to physical reality and is supported by MSS propagation literature.

2. The arbitrariness of the FAA model exists in multiple dimensions, as listed below.

    a. In the FAA model, the median pathloss from a base station depends only on lateral distance from the nadir point of the aircraft and path geometry, not on the blocked/unblocked status of the path. This leads to blocked base stations at small lateral distance having close to free space loss. This causes the median RFI power to be overestimated.
    b. The standard deviation increases with distance, but the function depends on aircraft height. The nature of the above dependence is such that, at low aircraft heights (e.g. 100 ft), an unblocked base station at approximately 6 km could be assigned a standard deviation of 6.4 dB. The MSS literature suggests that the standard deviation for LOS conditions should be 0.5 dB. The high standard deviation severely impacts the criterion based on the tail of the CDF of RFI power. A high standard deviation also increases the mean RFI power.
    c. A fast fading component has been included by borrowing the extended Suzuki model from the MSS propagation literature. Including fast fading in the LightSquared environment is without physical basis as the reversal of the propagation direction between the transmitter and the receiver (assuming that the aircraft is the transmitter and the base station the receiver) does not cause the local multipath environments to also be exchanged. Without significant local multipath at the receiver there cannot be fast fading.[63] The impact of this error appears to be small, but still noticeable in the compatibility assessment.
    d. The Hata-Okumura model has been applied outside its specified frequency range, rejecting the industry standard COST231 model, which would have been appropriate for the frequency range applicable to the LightSquared frequencies. The COST231 model would have yielded significantly greater pathloss.
    e. The parameters of the Hata-Okumura model have been chosen in ways that appear to be arbitrary and self-contradictory, with the net effect of increasing the pathloss by approximately 11 dB in some scenarios. For example, <u>in the DCA and LGA</u>

[63] It is acknowledged that some fast fading (frequency dispersion) exists even for fixed receivers, caused by movements in the environment, such as the rustling of leaves caused by wind and movements of vehicles. However, such fading has an order of magnitude smaller standard deviation than fading caused by the movement of the transmitter or the receiver.

scenarios, where the airports are surrounded by urban environments, the Hata-Okumura Urban model would seem to be the obvious and clearly justifiable choice. Yet the FAA chose the Suburban model instead. Also, the suburban equation is chosen in the main equation while opting for the urban antenna factor (called "large city factor" in the Hata formulation).

f. In an attempt to justify the use of a common mathematical model for all base stations, a monotonically increasing function of lateral distance was used to characterize standard deviation. This runs counter to measured data in the cellular industry where it has been found that the standard deviation depends more on the building density than on distance from the base station – in some cases the standard deviation may actually decrease with distance. This is another proof that the approach of forcing common mathematical functions (*μ versus distance* and *σ versus distance*) on all base stations is fundamentally flawed. Each link needs to be individually characterized regarding μ and σ according to its blocked/unblocked status.

E. Results of FAA and LightSquared propagation models

In this section we examine the results of the FAA and LightSquared Higher Altitude propagation models for the LAKIE (aircraft height of 535 m) and DCA-1 and DCA-2 scenarios (aircraft height of 100 m).

The maximum tolerable RFI objectives stated by the FAA in the FAA Report are as follows.[64]

Tracking:

- Mean interference level must be at or below -34.1 dBm for an aircraft at level attitude. This reflects a 6 dB margin below the receiver susceptibility of -28.1 dBm to account for non-modeled effects and random events.

- Probability of interference level exceeding -30.1 dBm must be $\leq 10^{-6}$ in any hour of flight, considering aircraft banking and pitching. This preserves a 2 dB margin in RF interference for non-modeled effects other than LightSquared.

Acquisition:

- Probability of interference level exceeding -34.1 dBm must be $\leq$ 0. 001 for an aircraft at level attitude.

The FAA and LightSquared agreed that, a 4 dB correction factor was sufficient for accommodating the effects of standard banking (25%) relative to level flight for the GPS antenna reference pattern used in the study.[65] The FAA has assumed the presence of banking in the low altitude DCA scenarios although this is quite unrealistic for an aircraft at a height of about 300 ft and lower. However, to create a comparison of like scenarios in the following analysis, LightSquared has first assumed the presence of banking and then looked at the consequence of

[64] FAA Report [1], at Section 1.3

[65] RTCA Report [3], at Figure 1-1, ATCt Base Station Transmit Antenna Patterns.

removing it. The compatibility with banking may be estimated simply by increasing the received RFI power at P=1E-6 by 4 dB.

Table B.II.4 Results of Higher Altitude FAA and LightSquared Models (Base station EIRP's at 32 dBW)

	Maximum Passing Level	Lakie (Aircraft Height = 535 m)		DCA-1 (Aircraft Height = 95.1 m)		DCA-2 (Aircraft Height = 121.9 m)	
		FAA	LS	FAA	LS	FAA	LS
Tracking: Mean (dBm)	-34.1	-37.5	-38.89	-33.6	-34.28	-34.4	-35.1
Margin (dB)		3.4	4.79	-0.5	0.18	0.3	1.0
Tracking: P=1E-6 (dBm)	-30.1	-31.1	-34.77	-26.9	-28.92	-26.7	-29.65
Margin (dB)		1.0	4.67	-3.2	-1.18	-3.4	-0.45
Acquisition: P=1E-3	-34.1	-37.0	-38.82	-32.3	-33.8	-32.7	-34.75
Margin (dB)		2.9	4.72	-1.8	-0.3	-1.4	0.65

It can be seen from the above that the margins are greater for the LightSquared model. The difference between the models is greater at the higher altitudes. For the lower altitude DCA scenarios, even the LightSquared model yields a small (-1.18 dB) negative margin for the CDF tail for Tracking with banking. If banking is considered unlikely at this height, as discussed above, the margin becomes positive. For Acquisition, there is a very small negative margin (-0.3 dB), which can be easily rectified by reducing EIRP slightly for proximate base stations. When the LightSquared proposal for reducing base station EIRPs to accommodate TAWS is considered,[66] the margins become substantial as shown below (assuming the presence of banking – without banking, the margins for Tracking increase by 4 dB).

It should be pointed out that the DCA-2 scenario (aircraft height of 400 ft MSL) corresponds approximately to the Obstacle Clearance Surface (OCS) at this location, which would represent possibly the worst case. The FAA stated, "the DCA-1 scenario (aircraft height of 312 ft MSL) is used to check for sensitivity of mean aggregate received power to the aircraft antenna height parameter." However, <u>it should be noted that this is a *hypothetical scenario* for DCA as it is below the OCS. Hence, pass/fail determinations should not be based on the DCA-1 scenario</u>.

[66] FAA Report [1], at C-31, Figure C-15.

Table B.II.5 Results of Higher Altitude FAA and LightSquared Models (Base Station EIRP's reduced to accommodate TAWS)

	Maximum Passing Level	DCA-1 (Aircraft Height = 95.1 m)	DCA-2 (Aircraft Height = 121.9 m)
		LS	LS
Tracking: Mean (dBm)	-34.1	-41.73	-42.92
Margin (dB)		7.63	8.82
Tracking: P=1E-6 (dBm)	-30.1	-36.64	-37.92
Margin (dB)		6.54	7.82
Acquisition: P=1E-3	-34.1	-41.30	-42.56
Margin (dB)		7.2	8.46

It is very likely that, with reduced EIRPs, even the FAA propagation model, despite the deficiencies discussed above, will yield positive margins. This verification has not yet been made but has been undertaken by LightSquared and the results are expected shortly. However, the FAA had not discussed LightSquared's proposal for TAWS accommodation, and instead dismissed them as "too difficult to administer." We therefore, now, investigate the veracity of the above claim that LightSquared's proposal for low altitude accommodation is too difficult to administer.

It may appear that given the deficiencies of the FAA's models, the difference with the LightSquared model should have been greater. In fact, they were – when the FAA first presented the results of its new model in the first draft of the FAA Report (December 23 version). The shortfalls for DCA-1 and DCA-2 for the Tracking (P=1E-6) case were 6.9 and 8.0 dB respectively. Between the December 23 version and the final version, the FAA adjusted its models again reducing the shortfalls to their current levels – 3.2 and 3.4 dB respectively. What is clear is a pattern of continuously adjusting the models to attain apparently preconceived notions of what the results ought to be. As the models are not based on any empirical data, there is no barrier to such adjustments.

III. LIGHTSQUARED'S PROPOSED SOLUTIONS ARE DEMONSTRABLE AND EFFECTIVE

As LightSquared indicated in Appendix C to the FAA Report, it believes that its proposal is reasonable, workable, and effective at addressing the FAA's stated criteria. The proposal presents a reasonable way to manage the dynamic aspects of the system, make adjustments to accommodate changes in operation, and can be monitored effectively to ensure compliance.

The FAA has stated that the low altitude mitigation proposals from LightSquared (both TAWS and takeoff/landing cases) are impossible to administer. This position is scrutinized from the viewpoint of the detailed contents of the models.

With respect to the case of aircraft landing and takeoff, Table B.II.5 above shows that when the EIRP reductions forced by the criteria for TAWS accommodation, described in Section III.B, are taken into account, comfortable passing margins exist for both DCA use cases, as per LightSquared's propagation models described above. When the same EIRP reductions are considered with the FAA's propagation models, which LightSquared does not agree with, it is very likely that passing margins would also exist. LightSquared is conducting simulations to ascertain this.

In addition to the discussion in Appendix C of the FAA Report, the following discussion outlines a general technical methodology to ensure compliance of LightSquared base station emissions toward low-altitude applications of GPS, including approach and departure procedures that rely on GPS for aircraft navigation and TAWS applications, with the objectives of being both (1) technically accurate, and (2) operationally manageable. This methodology may be used to evaluate aggregate emissions from existing base stations, to determine specific base stations that need to operate at reduced power/greater down-tilt, or to determine acceptable locations for placing new base stations. Importantly, the methodology can be adapted to address changing factors (e.g. new procedures/applications of GPS or where additional emission reduction may be desirable).

A proof-of-concept trial of the low altitude navigation methodology was successfully performed using Washington National Airport (DCA) and the existing LightSquared proposed tower database.

A. Process for ensuring compliance of aggregate base station emissions toward low-altitude aircraft near airports (Low Altitude Navigation)

During takeoff and landing, aircraft in normal glide paths (including appropriate latitudes for such paths) may be subject to relatively high RFI levels from base stations proximate to runways, especially if they are in LOS of the aircraft. In Appendix C to the FAA Report, LightSquared has proposed that it will reduce the EIRP of all such bases stations. It has provided a mathematical model of how such base stations will be identified and their maximum EIRP levels calculated.[67] As in the case of TAWS, the model is completely deterministic. It is more complex than the TAWS model to the extent that the surfaces of descent/ascent can be complex owing to the existence of obstacles around airports. However, to the extent that the surfaces can be defined, even from a worst case standpoint,[68] the base station EIRP reductions can also be defined.

1. Defining Relevant Surfaces

For a given airport, the process begins by defining all relevant GPS-based Instrument Flight Rules ("IFR")/Visual Flight Rules ("VFR") surfaces that factor into the required OCS, which define the allowed limits of aircraft position within the glidepath. The defined surfaces

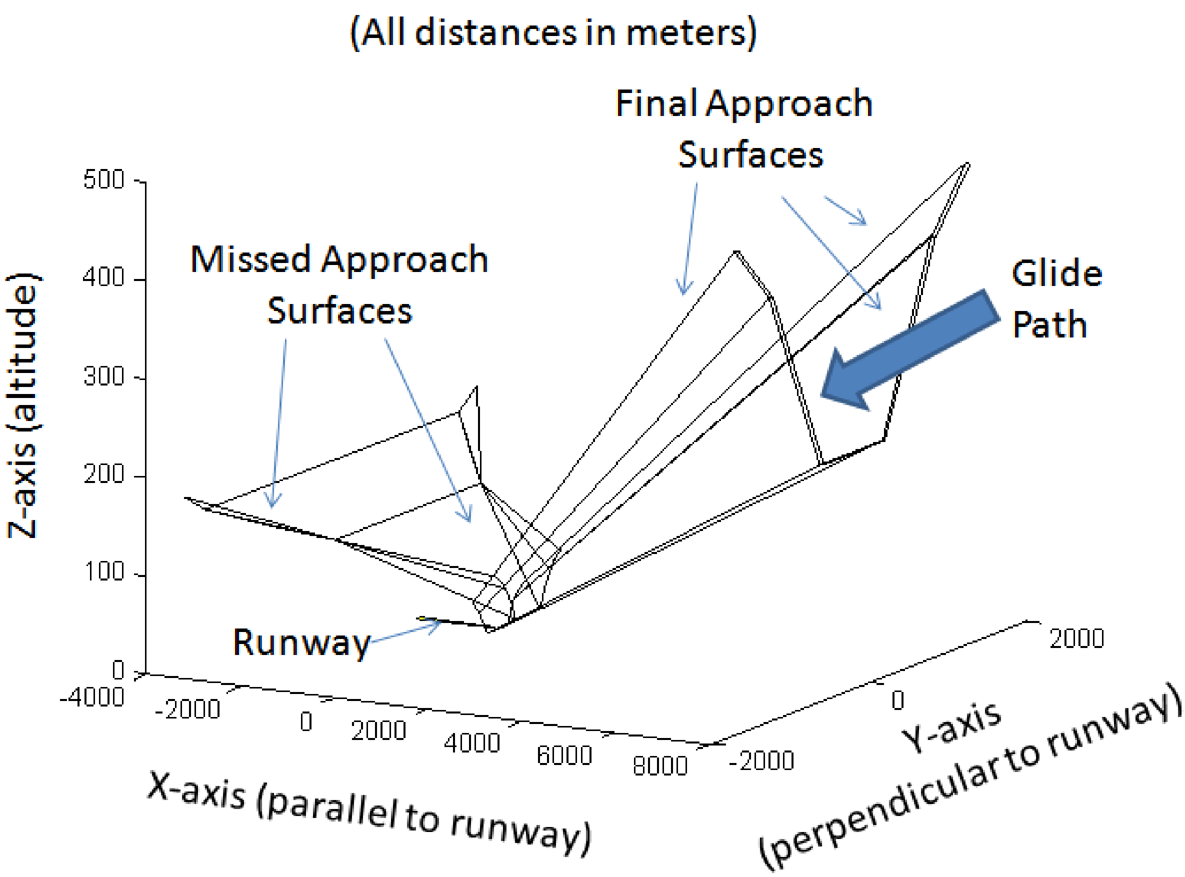
[67] FAA Report [1], at C-11, Proposals for Compatibility for Low Altitude Navigation.

[68] The surface would be simplified to a level that would be acceptable to the FAA as representing a conservative estimate of the glide path in the foreseeable future, even though present obstacles might cause the actual glide path to be further from the proximate base stations.

include: RNAV Final Approach Segments ("FAS"), RNAV Missed Approach Segments, Standard Instrument Departures ("SIDs") using GPS, and Visual Approaches. The surfaces will be determined, at LightSquared's expense, by a professional airspace consulting firm and include case-by-case evaluation and definition of each procedure at a given airport, as well as unique geographic constraints of each airport. The same process can be applied to new and proposed airspace procedures as they are developed.

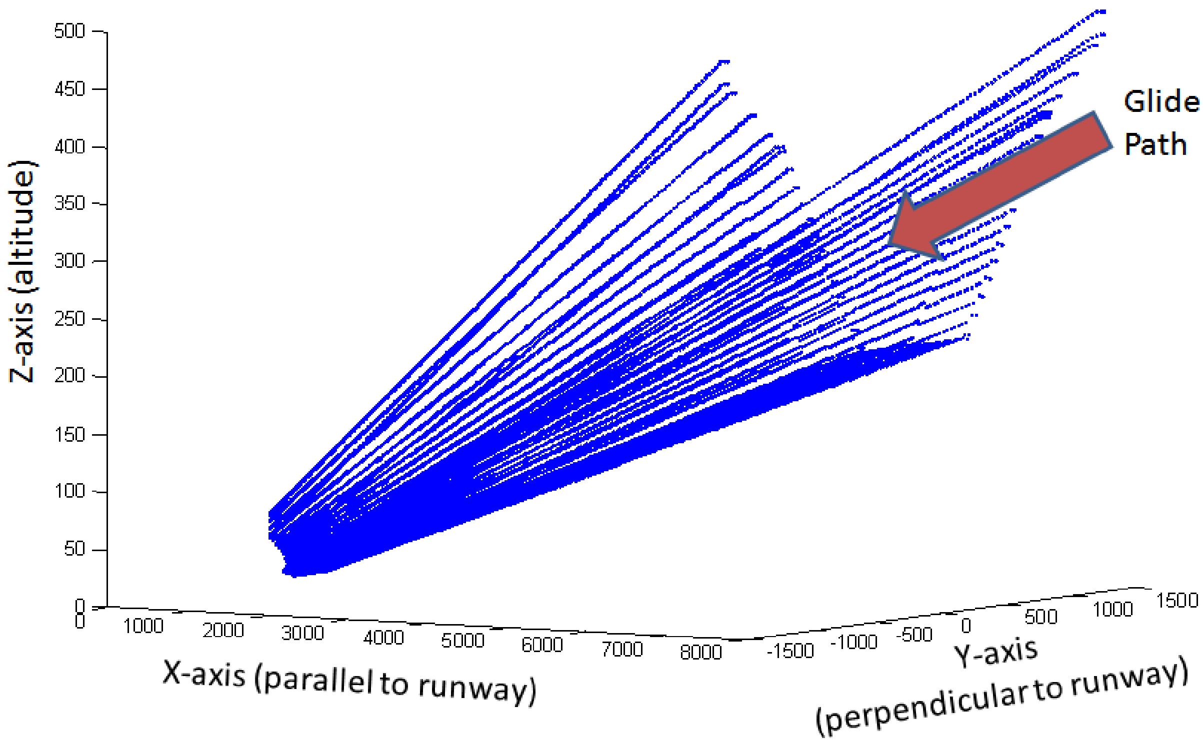
For the DCA study, LightSquared engaged a third-party professional aviation consulting firm to define the relevant surfaces: 43 relevant aeronautical surfaces were defined as 3-dimensional polygons in {lat, lon, and height} coordinates. An example of the surfaces produced for one DCA runway is shown in Figure B.III.1:

Figure B.III.1 - Example of Aeronautical Surfaces for a Given Runway Approach



Next, a software program is used to generate closely spaced sample points in 3D-coordinates covering each aeronautical surface polygon. These sample points represent possible aircraft positions at the limits allowed by the aeronautical surfaces. See Figure B.III.2:

Figure B.III.2: Example of Sample Points Generated for Aeronautical Surfaces



2. Overlaying

The 3-D computer model is next populated with the coordinates of all LightSquared base station antennas within the radio horizon, as supplied from LightSquared's tower database. The base station sector azimuth directions, sector EIRPs, antenna patterns, and antenna down-tilt values are also included in the model. The representative aircraft receive antenna pattern defined by the RTCA study is also incorporated.

At this point, complete geometric information is available to calculate the range, azimuth, and elevation from each base station antenna to each sample point on the aeronautical surfaces. From the azimuth and elevation values, the gains of the base station and aircraft antennas are also determined.

Finally, a common propagation rule set is applied to calculate the received power at each aeronautical surface sample point from each base station sector. The proposed rule set is defined as follows:

1. For base station antenna elevation angles $\geq 6^{o}$ toward the given aeronautical surface sample point, the propagation path is assumed to be line-of-sight, and the 2-Ray propagation model is applied. The electrical characteristics of the ground (conductivity and permittivity) will be assumed constant but the complex reflection coefficient will be calculated individually for each ray, assuming a split of powers between horizontal and vertical polarization.

2. For base station antenna elevation angles < 6^{o} toward the sample point, the probability $P_{blocked}$ that the direct path is blocked (non-LOS) is estimated. The method used to estimate $P_{blocked}$ is described below. Free-space loss (FSL) is used to calculate the unblocked path loss $PL_{unblocked}$, while the FSL value increased by 15 dB represents the blocked path loss $PL_{blocked}$. The final estimated path loss is the weighted average of blocked and unblocked values:

$$PL\ (dB) = -10 \log\left(P_{blocked}10^{-PL_{blocked}/10} + [1 - P_{blocked}]10^{-PL_{unblocked}/10}\right)$$

3. The aggregate received power at each sample point is then calculated as the sum of the individual contributions from each base station sector.

3. Blocked/Unblocked Probability Estimation:

In theory, the blocked/unblocked state of each tower-to-sample-point path can be determined precisely using ray tracing methods. An empirical formula for estimating the blockage probability is proposed, using as inputs: (1) the base station antenna elevation angle toward the sample point, and (2) the height of the base station antenna above ground level. These two parameters were chosen because they are readily available in the model, and because, intuitively, one would expect that these factors would strongly influence whether a given path is blocked or unblocked.

For the DCA trial study, the empirical formula for estimating $P_{blocked}$ was derived by evaluating a limited set of ray-tracing scenarios for the Washington DC area, where the aircraft was placed at a number of different altitudes, and the blocked/unblocked state from each tower was precisely determined toward each aircraft position. The individual blocked/unblocked path states are plotted in Figure B.III.3 against the log of the tower-to-sample-point elevation angle on the x-axis, and the log of the tower height above ground level on the y-axis. Log scales were used to facilitate a least-squares approximation to the data. Also a constant value α (= 0.63^{o}) was added to the elevation angle values on the x-axis to prevent negative arguments of the log function.

If each blocked (red) point in Figure B.III.3 is assigned a value of 1, and each unblocked (blue) point is given a value of 0, then the distribution of blocked and unblocked points can be modeled by a 2-dimensional least squares approximation, whose value is equal to the estimated blockage probability $P_{blocked}$. Figure B.III.4 shows a contour plot of $P_{blocked}$ using a 4-term least-squares approximation of the form:

$$P_{blocked} = A_1 x + A_2 y + A_3 xy + A_4 \qquad (1)$$

where x = log(elev. angle + α), y = log(base station antenna height AGL), and coefficients A_1 – A_4 are determined from the least-squares solution. It was found that the A_1 – A_4 values determined from the Washington DC data also provided a good blockage approximation when applied to points near the LAKIE (LaGuardia) waypoint, provided that base stations in midtown and downtown Manhattan were excluded. This suggests that it should be possible to derive a small set of least squares approximations having the form of Eq. (1); this general methodology can be applied to a large number of airports in regions sharing a common morphology (suburban, urban, etc.).

Figure B.III.3 Blocked/Unblocked Path States as a Function of Elevation Angle & Tower Heights
(from ray tracing analyses of Washington DC area)

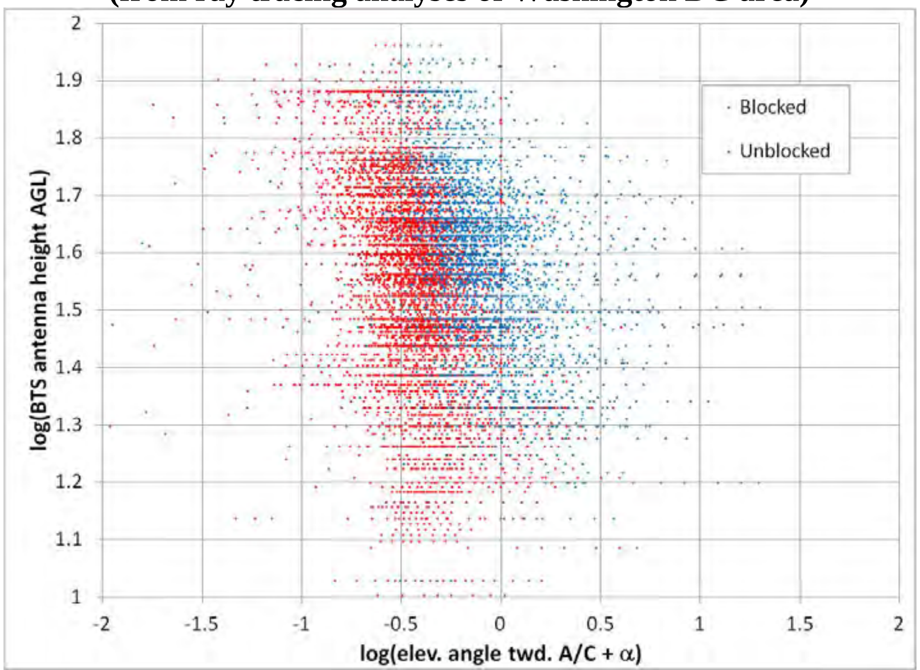
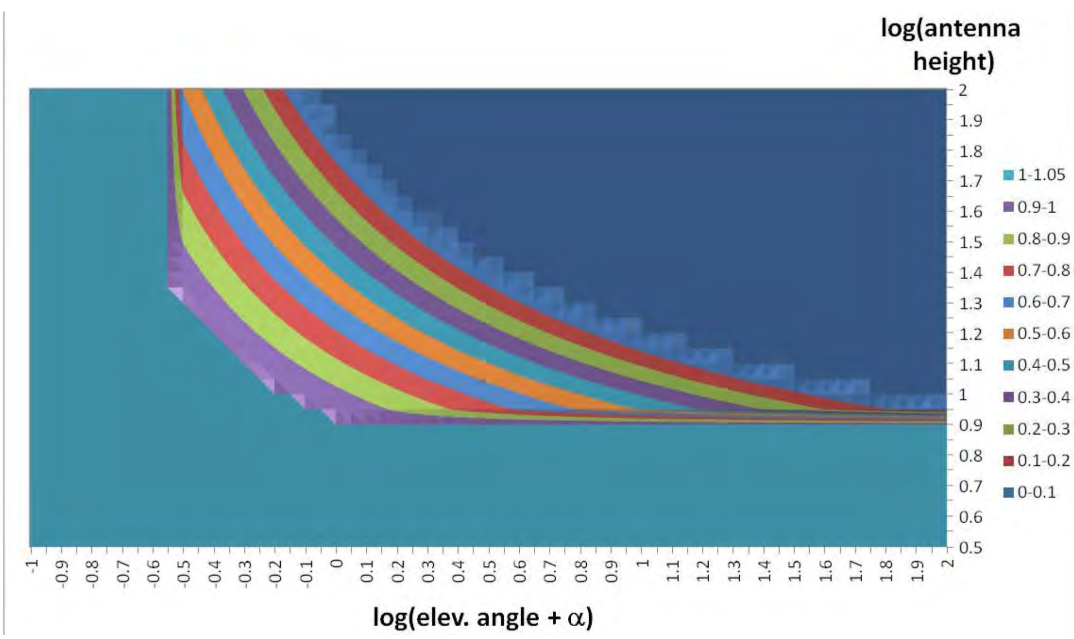


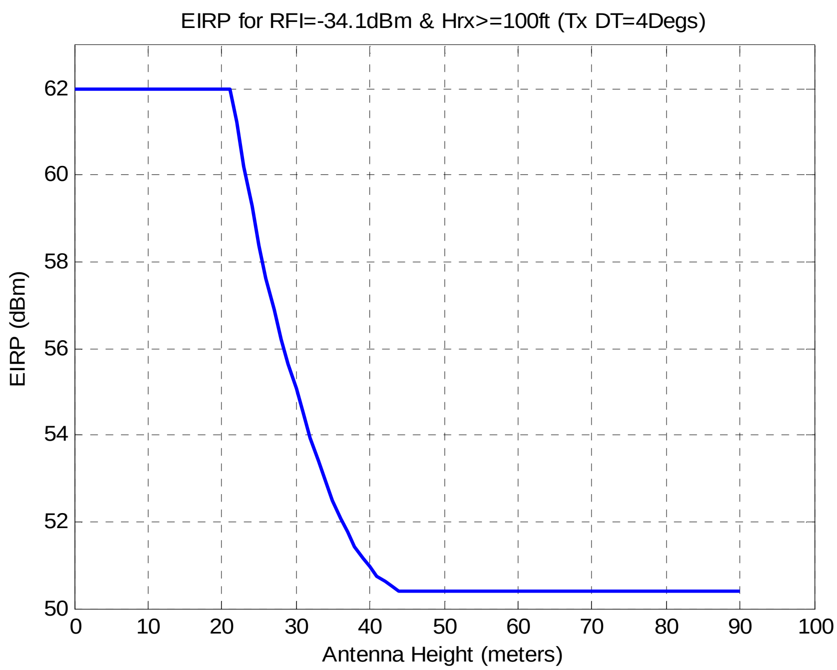
Figure B.III.4 Contour Plot of Least-Squares Approximation for $P_{blocked}$



B. Process for ensuring compliance of aggregate base station emissions for TAWS

In Appendix C of the FAA report,[69] LightSquared's proposals for accommodating the FAA's TAWS evaluation criteria are provided in detail. The FAA's stated TAWS evaluation criteria ultimately came down to ensuring that a *cylinder of exclusion* or "exclusion zone" would exist around each base station antenna whose axis (assumed vertical) would extend from 100 ft above the structure on which the antenna was mounted to 100 ft above ground level; the radius would be 500 ft.[70] LightSquared showed that this cylinder could be created by backing off the base station EIRP according to a schedule of EIRP versus antenna height given in Figure C-4 of the FAA Report and reproduced below as Figure B.III.5.

Figure B.III.5 EIRP Reduction Schedule for TAWS Accommodation: Free Space Propagation



The propagation model used in this schedule was free space. The FAA provided several examples of the use of the 2-ray model at low altitudes, but stopped short of proposing a rule of when (under what types of environmental conditions) to use such a model (beyond stating vaguely that the 2-ray model should be used for "low-level operations, close to the ground".[71] This contradicts the position taken by the FAA in discussions during the joint working sessions, where the FAA agreed that if there was significant scattering, the 2-ray model would be

[69] FAA Report [1], at. C-13, Proposals for Compatibility for Terrain Avoidance Systems.

[70] FAA Report [1], at Section 1.4.

[71] FAA Report [1], at Section 3.1.1.

inapplicable. It also contradicts the FAA's latest Higher Altitude propagation model which uses the 2-ray model in the first segment for aircraft heights up to 535 m.

LightSquared proposed that the use of the 2-ray model be limited to cases of high elevation angle (positive or negative) launch of the transmit signal from the base station antenna. The justifications were: (a) this was articulated in the RTCA Report,[72] and (b) Dr. Parsons has opined in the open literature that such links typically exist for high elevation angles.[73] The FAA never addressed the LightSquared proposal. In the FAA Report, the FAA shows examples of the application of the 2-ray model (for relatively low base station antennas) up to distances exceeding 2 km. It would be quite difficult to find actual scenarios involving low elevation angles that are so devoid of lateral scattering that the 2-ray model would apply.[74] It should be recalled that any lateral scattering greatly reduces the power build up in a 2-ray model for a 10 MHz signal owing to time dispersion. The reason that the power build up occurs *at all* for a 10 MHz signal is that the time dispersion is very small as long as both rays remain in the same propagation plane.

The TAWS power reduction schedule undergoes only a small change when the free space model is replaced by the above mixed (2-ray plus free space) propagation model. The modified schedule is shown below. Note that there is a knee around BTS antenna height of 48 m (154 ft). This is the point that the 2-ray model becomes relevant, where the elevation from the BTS to the aircraft (that is at altitude of 100 ft and lateral distance of 500 ft) becomes more negative than -6 degrees (or |elevation| > 6 degrees).

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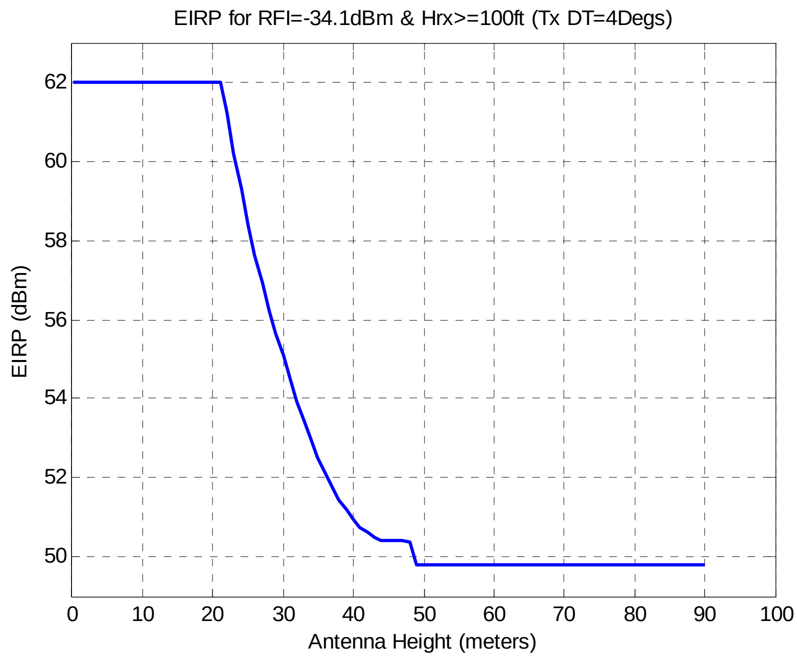
[72] RTCA Report [3], at B.3.1.1.1. ("This (2-ray) model should be reasonably accurate out to a lateral radius where the direct ray launch angel toward the aircraft antenna is above about 6 degrees. For radii much beyond that point, more complex scattering, blockage, and shadowing effects become significant.")

[73] Rappaport [6], at 120 (states the following regarding the applicability of the 2-ray model "This (two-ray) model has been found to be reasonably accurate for predicting large-scale signal strength over distances of several kilometers for mobile radio systems that use tall towers (heights which exceed 50 m)…")

[74] The presence of lateral scattering would make it unlikely that a 6 dB power build up, as is feasible in the 2-ray model, would occur for a 10 MHz bandwidth base station signal. This is because the time dispersion for typical cellular scattering is known to be around 0.2 to 1.0 microseconds, which leads to a coherent bandwidth that is small relative to the base station signal bandwidth. In contrast, the time dispersion is much smaller for ground reflection from a point in the vertical plane containing both the direct and reflected rays. For example, for transmitter and receiver heights of 30 m, separated by 600 m, the time dispersion between the two rays is 0.01 microseconds.

Figure B.III.6 EIRP Reduction Schedule for TAWS Accommodation: 2-ray + Free Space Propagation



We now examine the FAA's position that conformance to such a schedule would be very difficult to administer. This concern is without basis for the following reasons:

- The schedule is completely deterministic and mathematically simple to codify in a spreadsheet. Given a particular base station antenna's height, antenna pattern and downtilt, it is possible to exactly determine the maximum allowed EIRP. There is precedence in previous ATC Orders where an antenna pattern mask was codified into the deployment rules by the FCC. There is similar precedence of specifying a power flux density requirement on the ground, which necessarily includes a dependence on base station antenna height.

- The FAA has cited (and the NTIA reiterated) a need to "constantly monitor" the EIRP levels. The reason for this is unclear, unless the FAA is concerned that LightSquared would surreptitiously change the EIRP levels. LightSquared, in a letter to the FAA, has sought to assuage such concerns by offering to put the oversight of the base station settings under a trusted third party, at LightSquared's sole expense.[75]

- The channel is time invariant, therefore the exclusion cylinder is also time invariant. The power levels on the surface of the cylinder cannot change autonomously.

[75] Letter from Sanjiv Ahuja, Chairman and CEO, LightSquared, to Ray LaHood, Secretary of Transportation (Dec. 18, 2011) [10].

- There is no dependence in the propagation model of a particular environmental morphology. New structures around the base station antenna do not change the propagation model.

In summary, the TAWS power reduction schedule is simple to codify and administer. Beyond vague assertions about complexity, the FAA has never offered any specific reasons as to substantiate its concerns.

References

[1] FAA Status Report: Assessment Of Compatibility Of Planned LightSquared Ancillary Terrestrial Component Transmissions in the 1526-1536 MHz Band with Certified Aviation GPS Receivers (Jan. 26, 2012): http://apps.fcc.gov/ecfs/document/view;jsessionid=yBJtP9QcT47tjYzQh3JyV14WQLxG3DZ24xkQpYJbRrKWRWbPrjbC!-321460796!1471562840?id=7021860338

[2] Letter from Lawrence Strickling, Administrator, National Telecommunications and Information Administration, to Julius Genachowski, Chairman, Federal Communications Commission (Feb. 14, 2012).

[3] RTCA Report: Assessment of the LightSquared Ancillary Terrestrial Component Radio Frequency Interference Impact on GNSS L1 Band Airborne Receiver Operations, DO-327 (June 3, 2011).

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[10] Letter from Sanjiv Ahuja, Chairman and CEO, LightSquared, to Ray LaHood, Secretary of Transportation (Dec. 18, 2011).

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DECLARATION OF JOHN DAVID PARSONS

I, John David Parsons, make the following declaration in connection with my review of the Letter from Lawrence E. Strickling, Assistant Secretary for Communications and Information, U.S. Dep't of Commerce, to Julius Genachowski, Chairman, FCC (dated Feb. 14, 2012) ("NTIA Letter") and the U. S. Department Of Transportation Federal Aviation Administration Status Report: Assessment Of Compatibility Of Planned LightSquared Ancillary Terrestrial Component Transmissions In The 1526-1536 MHz and With Certified Aviation GPS Receivers (Jan 25, 2012) ("FAA Report").

1. I am an Emeritus Professor and Honorary Senior Fellow at the University of Liverpool. I held the David Jardine Chair of Electronic Engineering from 1982 until 1998. During this period I was, at various times, Chairman and Head of the Department of Electrical Engineering and Electronics, Dean of the Faculty of Engineering and Pro-Vice Chancellor (Vice-President) of the University. I received a B.Sc. degree in Electrical Engineering (Magna cum Laude) from the University of Wales in 1959, an M.Sc. in Electronics from the University of London in 1967 and a D.Sc. in Electronic Engineering (Radiocommunications) from the University of London in 1985. I also hold the following certifications; FREng, (Fellow of the Royal Academy of Engineering, London) FIET, (Fellow of the Institution of Engineering and Technology – formerly the Institution of Electrical Engineers, London) and SMIEEE (Senior Member of the Institute of Electronics and Electrical Engineers, New York).

2. In addition to my teaching experience, I have conducted extensive research on various aspects of radio engineering, specializing in radio propagation and radio channel characterization particularly in connection with cellular systems, and have published approximately 150 technical papers in peer-reviewed Journals and at major conferences. I have also authored or co-authored 3 books on the topics of radio propagation and radio engineering. I have acted as a consultant to several companies and have given evidence as an expert witness in Courts of Law. A copy of my CV is attached to this Declaration.

3. I previously reviewed a draft of the FAA Report and provided my opinion on the validity of the FAA's propagation model described therein, a copy of which is attached to Appendix C of the FAA Report. I was recently asked by LightSquared to review a propagation model authored by the FAA and described in Appendix B of the draft FAA Report dated January 13, 2012, for determining the compatibility between LightSquared's terrestrial system and FAA GPS requirements. Based on this review I authored an Opinion titled, "Review of Appendix B in the FAA Status Report dated 13th January, 2012."

4. A copy of my professional assessment is attached hereto.

I declare under penalty of perjury under the laws of the United States of America that the foregoing Declaration is true and correct.

Executed on February 29th, 2012.

[signature]

John David Parsons

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COMMERCIAL IN CONFIDENCE

Review of Appendix B in the FAA Status Report dated 13th January 2012

1 Background

In its Status Report [1] (the report), the FAA presents Section 3 as "Analysis Methods and Results", comprised of the following sub-sections:

- 3.1 Path Loss Models;
- 3.1.1 Deterministic Models;
- 3.1.2 Probabilistic Models;
- 3.1.2.1 Probabilistic Model Background; and
- 3.1.2.2 General "Extended Suzuki" Model Scenario Dependent Parameters.

During a telephonic meeting held on 4th January 2012, LightSquared reviewed the content of a draft version of the report with the FAA and requested the FAA to provide additional information regarding the propagation models it had used in the sections listed above. This information was to include: theoretical and physical descriptions of the models; an explanation of how the parameter values used in the models should be determined; and a justification for the selection of the so-called breakpoints which determine the boundaries between the segments of the multi-segment model. LightSquared also asked the FAA to provide examples illustrating the application of the model and the determination of the breakpoints.

The final version of the report, dated 13th January 2012, contains an appendix (the appendix) which was not included in previous versions of the report and presumably was provided in response to the request described above.

This paper reviews the appendix and presents an opinion of same.

2 Discussion

With regard to the appendix, this paper analyses the models presented and compares them with established methods and practices, assesses the clarity of presentation, and discusses the process proposed by the FAA for selecting breakpoints and optimizing parameters suitable for use in the models presented in the their report.

2.1 Determination of Median Isotropic Path Loss Segment Break Points

In section 3.1.2.2 of the report, the so-called "extended Suzuki" model is introduced. The range from the aircraft nadir to the ATCt cell tower is split into four segments for modelling purposes and the method of determining the break points (r_1, r_2 and r_3) between these segments is explained. For completeness the following is an extract from the report:

> "...the median path loss break points are determined by the following guidelines (see RTCA DO-327, Appendix B [2]):

- At short ranges a two-ray median path loss model is used up to the range r_1 where the vertically polarized component reflection coefficient is at minimum magnitude. This break point varies with aircraft antenna height.
- Beyond the median path loss is extended in a continuous manner proportional to r^{-2} to the range r_2 which is generally around 2 km depending on the local terrain and cell tower heights. As the aircraft antenna height increases, r_1 approaches r_2. Once these break points get within a few hundred meters of each other, r_2 is set equal to r_1 and the second path loss segment is eliminated. This is the case at aircraft heights approaching 535 meters as in the final approach fix Waypoint scenario (see Section 3.2). From r_2 to the point r_3 where line of sight blockage becomes significant as determined for the specific site, median path loss is proportional to $r^{-\Gamma}$. The point r_3 varies proportionally with aircraft antenna height out to a maximum of 20 km at an aircraft antenna height of 535 meters. The parameter Γ is selected to provide continuity in path loss. At aircraft antenna heights slightly beyond 535 meters, the exponent Γ approaches 2 and the entire path loss model becomes deterministic (free space path loss). The

remaining "extended Suzuki" parameters are set to values that reflect this change ($\psi_o(r) = 0$, $\rho^2(r) = 1$, $\sigma(r) = 0$).

- Beyond r_3 the Hata-Okumura suburban median path loss model is used

  Once these break points are known, the remaining "extended Suzuki" parameters $\psi_o(r)$ *and* $\rho^2(r)$, and $\sigma(r)$ can be determined. For the shorter ranges, $0 \leq r < r_2$, the line-of-sight parameter $\rho^2(r)$ will be unity while the Rayleigh parameter $k\psi_o(r)$ will conservatively be 10 dB lower. At r_3 and beyond, there will be increasingly heavy blockage of the line-of-sight component with all of the power resulting from scattering (Rayleigh component). In between these two break points it is reasonable to assume both parameters $k\psi_o(r)$ and $\rho^2(r)$ change linearly with distance."

It is worth pointing out that prior to the issue of the FAA report, both LightSquared and its external consultants were under the impression that a 3-segment model with fixed break points was being used. Now it appears that the proposal is to use a 4-segment model with variable breakpoints.

2.2 Two-Ray Isotropic Path Loss Model (B.1)

This section gives some background information on the calculation of path loss for the situation depicted in Figure B-1 of the appendix. After correctly stating the equations for the reflection coefficient of real ground, the so-called complex field factor is defined and contains the quotient $R_{DIR}(r) / R_{REF}(r)$. Simple derivation shows that this quotient should be squared and therefore, as it stands in the appendix, is incorrect. The equations for the vertically- and horizontally-polarized complex field factors should be:

$$P_v(r) = 1 + \left[\rho_v(r) \cdot \left(\frac{R_{DIR}(r)}{R_{REF}(r)} \right)^2 \cdot \exp(-j\phi(r)) \right] \quad (1)$$

$$P_h(r) = 1 + \left[\rho_h(r) \cdot \left(\frac{R_{DIR}(r)}{R_{REF}(r)} \right)^2 \cdot \exp(-j\phi(r)) \right] \quad (2)$$

If the correction is assumed, then equations (B-1) and (B-2), which are correct, are easily derived.

The equations (B-1) and (B-2) allow determination of the path loss between isotropic antennas located at the points shown in Figure B-1. In practice however, it is essential to know the polar patterns of the transmit and receive antennas to make any meaningful calculations [3]. For given values of h_A, h_E and r, the lengths of the direct and reflected paths can be determined as can the angle θ and hence the reflection coefficient. If the radiation patterns of the antennas are also known, then the antenna gain in the direction of interest can be found and the path loss can be calculated. In practice, the location and height of the transmit antenna is fixed but as the aircraft moves along its flight path, hA and r change and so also do the other variables mentioned above. To get a full picture, incremental calculations therefore have to be made at intervals along the flight path using the appropriate values of the various parameters.

2.3 Hata-Okumura Median Isotropic Path Loss Model (B.2)

This section gives some background to the Hata-Okumura [4, 5, 6, 7] path loss model. The treatment is slightly different from that in Appendix B of ref [2] in that some parameters are defined slightly differently, but the resulting process is essentially the same. The factor α gives the path loss for distances less than 20 km in terms of Hata's formulation for urban areas in quasi-smooth terrain. The expression for the antenna factor $AF(h_A, h_E)$ contains terms $Max(h_A , h_E)$ and $Min(h_A\ h_E)$ which presumably mean respectively, the greater and smaller of h_A or h_E. This is a reasonable interpretation of Hata's formulation (in which the base station antenna is assumed to be the higher of the two antennas) but this is not specifically stated here or indeed, explained or justified. The path loss is expressed by equation (B-3).

It now seems relevant to examine whether this RTCA equation is being used within the range of applicability of the model. The original Hata model was specified as follows:

- f: 150 – 1500 MHz
- h_{Base}: 30 – 300 m
- h_{Mob}: 1 – 10 m
- r: 1 – 20 km

The RCTA model includes the ITU-R extension for lateral separations more than 20 km so distance is not an issue. Neither is the height of the higher antenna (normally the aircraft antenna in this case). However, the FAA has declined to use the COST 231 version of the Hata model which specifically extends its frequency range to 2000 MHz so the model as it stands is being used marginally outside its specified range in this respect. However, perhaps more important is the height of the lower antenna which in the present application is very often significantly higher than the maximum specified value of 10m. This is a matter of some concern as the antenna factor has a significant impact when calculating path loss.

The authors have also pointed out [8], an anomaly in the RTCA formulation of the Hata equations, which is also present in the document under review. Specifically, the essential difference between the original Hata and the current RTCA formulations is the expression used for the mobile (the lower of the two antennas, analogous here to h_E) antenna factor. Hata's formulation is basically for small/medium sized cities while the RTCA expression uses the value of mobile antenna factor applicable for frequencies above 400 MHz in a large city—despite the fact that the RTCA report states that suburban parameters are appropriate for the environment surrounding an airport. It appears that the RTCA report is anomalous in this respect and that there has been an arbitrary choice of parameters based on criteria which are unknown to the current authors. The reason for using the "large city" value remains unexplained.

2.4 Break Point Determination (B.3)

For each of the four segments of its multi-segment model, the FAA document provides a separate sub-section in which the determination of the breakpoint distance is defined. Each sub-section is therefore reviewed here in the order in which they appear. Before reviewing each sub-section in turn, it should be noted that the FAA appendix lacks any form of description or explanation regarding the physical rationale used for the determination of the break points and that only mathematical criteria, seemingly removed from practical considerations, are presented.

2.4.1 Determination of the First Break Point r_1 (B.3.1)

The extract from the report quoted above (Section 2.1), teaches that the first break point is set to occur near the lateral range at which the magnitude of the vertical polarization reflection coefficient ρ_v is a minimum. In other words it is set at a distance corresponding to the Brewster angle, which for the electrical parameters given in the example (σ = 0.15 S/m, ε_r= 7, f = 1531 MHz) is close to 20° as Figure 1 shows. For the heights given in the example, (h_A = 76 m, h_E =

41 m), r_{min}, is stated to be 313.475 m. These figures seem to fit with Figure 2 and show that ψ (the angle of incidence) is about 20° at a lateral distance of approximately 320 m.

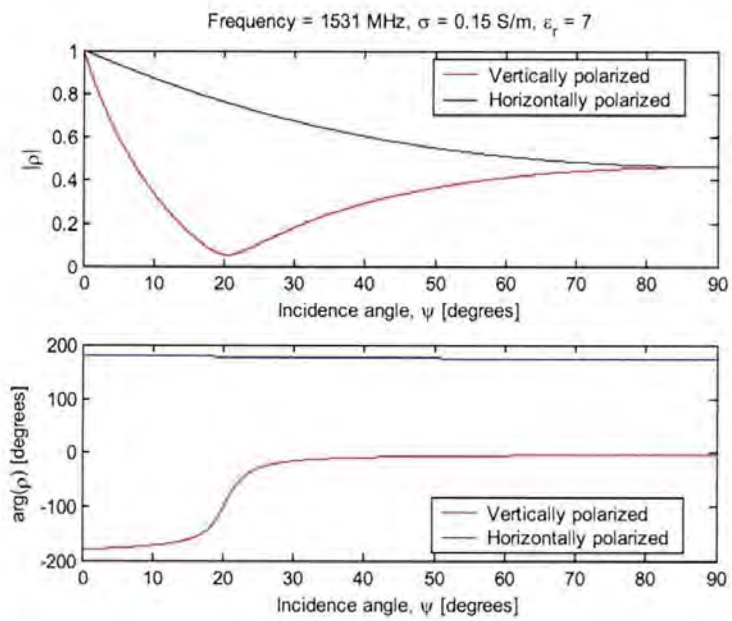

Figure 1: The magnitude and phase of the reflection coefficient at 1531 MHz, for vertically- and horizontally-polarized waves. Electrical parameters for ground used in the FAA appendix have been applied.

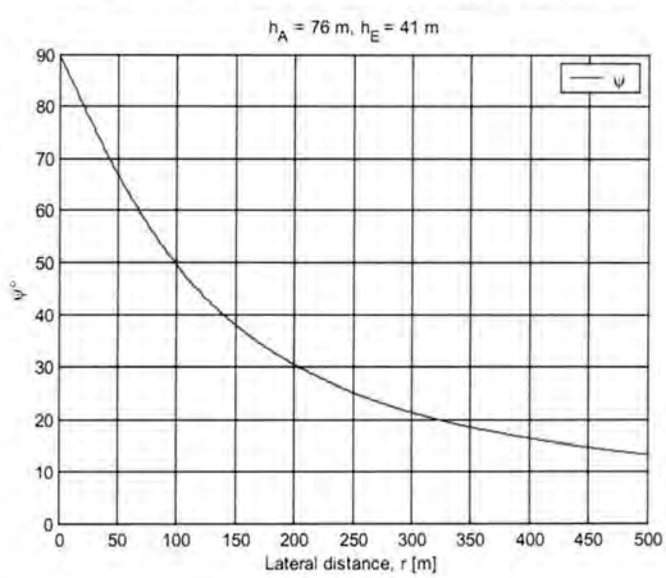

Figure 2: The angle of incidence (ψ) plotted as a function of the lateral distance using antenna height values presented in the FAA appendix.

The appendix then states: "In other words, r_1 is the radial point close to r_{min} at which the 2-Ray horizontal and vertical polarization path losses are equal". It is not immediately obvious that this is the case, but the authors have made the necessary calculations and can verify the accuracy of this statement. If h_A = 76 m and h_E = 41 m, then for a concrete reflecting surface, r_{min} is c.313 m.

We also point out here that the choice of this criterion for establishing the first break point is not explained—it seems arbitrary and has not been justified.

2.4.2 Determination of the Second Break Point r_2 (B.3.2)

This section of the appendix allows for the possibility that this segment may be eliminated. It exists only if a line-of sight (LOS) path is apparent. If r_1 is large, then it may not exist and r_2 is then set equal to r_1. However, if this segment does exist, then free space propagation conditions exist within it and the path loss is independent of polarization. The segment is more likely to exist if r_1 is small and the aircraft is still at a low height for distances greater than r_1. Determination of r_2 has to be done for each site and depends on whether the cell towers up to a range of r_2 have a LOS path to the aircraft or not. The appendix contains no comment on what might constitute a sufficient percentage of cell sites. It is clear that some kind of morphological data base has to be used to determine r_2.

In addition to this section supposedly describing the determination of the second breakpoint, a path loss equation is presented, devoid of both explanation and justification. The equation, reproduced here for convenience, $PL_{segmenr2}(r) = PL_{2RV}(r_1)(r / r_1)^{-2}$, is a function of the lateral distance r and comprises the product of two components—a constant, determined to be the path loss at the r_1/r_2 boundary; and a quotient. The latter component seems to be anomalous for two reasons. Firstly, the quotient is a function of r which we assume to be the same r throughout the appendix and as such should be expressed in conjunction with the previous breakpoint for example as $(r - r_1)$. Secondly, the quotient is raised to the negative power of two which is contrary to the square law proportionality of free-space propagation path loss.

As a final comment on this sub-section, the authors wish to draw attention to the statement "the path loss exponent for the following segment (r_2 to r_3) is computed to be very near 2". This may well be the case, but no evidence has been provided to substantiate or support it. Input documents on free space models and the path loss exponent [10, 11] are available and refer to this type of situation. It is also worth posing the question again, about an appropriate value of standard deviation to associate with a segment in which the exponent is close to two.

2.4.3 Determination of the Third Break Point r_3 (B.3.3)

The procedure for determining r_3 is more complex than for r_1 or r_2. It starts with an evaluation of the distance at which a majority of towers appear to be obscured, assuming their heights to be 30 m (100 ft)—it is stated that this can be done by on-site inspection or by using available software tools and is typically around 5 km. This minimum distance is denoted by r_{3min}.

Having determined r_{3min}, the appendix defines some additional parameters and describes a procedure for calculating r_3 and the path loss for locations in this sector. If the aircraft height is outside the range specified in the equation that defines r_3 then there are no segments and the path loss is the free-space value. At the end of this section it is stated that the associated median path loss for the segment from r_2 to r_3 is given by $PL(r) = \psi_2 (r_2)(r / r_2)^{-\Gamma}$. Again we observe that $-\Gamma$, Γ being as defined in the document, is used rather than $+\Gamma$. This is believed to be incorrect as it implies that the path loss decreases as the distance is increased. The median path loss for ranges greater than r_3 and out to R_o (the radio horizon) is given by the following equation: $PL_{Hata}(r) = Exp[-\alpha](r / 1000)^{-\beta(r)}$. So there is a segment r_2 to r_3 and a final segment from r_3 out to R_o.

This section of the appendix does not discuss the extended Suzuki model [12, 13, 14] *per se* but it would appear that the determination of the third breakpoint is used in connection with this. This has been noted, and in this context we comment that the appendix does not teach how to determine the appropriate parameter values for use in the extended Suzuki model.

Finally in this section we point out that in the latest version of the appendix, the equation defining r_3 contains the factor $Exp(-\alpha)$ whereas in the previous version it was $Exp(\alpha)$. We assume that this is just the correction of a typographical error.

2.4.4 Determination of the Fourth Break Point r_4 (B.3.4)

In this section it is stated that r_4 is not a break point that is concerned with defining path loss segments, but is needed in order to define the standard deviation associated with the log-normal component of the fading signal. The standard deviation is initially defined in terms of a number of step functions; however it seems that there is an omission and that the equation should read $\sigma_{dB}(r) = 6.4$ dB, $r_3 \leq r < r_4$. The text then goes on to explain how this series of step functions is approximated by a fifth-order polynomial and r_4 is defined as the value of r in the range r_{3min} to R_o

at which the value of the polynomial is 6.4 dB. The importance of r4 is not clear and neither is it clear what value of standard deviation should be used for distances greater than r_4.

2.5 Breakpoint determination

We do not see any explanation in the appendix for the choice of break points—physical and engineering criteria are not mentioned and the choice of values seems to have been determined purely by mathematical criteria or to ensure smooth transitions between the various regions of the multi-segment model.

3 Opinion

Overall our opinion is that this appendix is terse and cumbersome. It is very difficult to unravel some of the equations particularly those in section B.3.3 since no indication is given of the logic behind the approach that has been taken. We have come across a considerable number of anomalies, inaccuracies and widespread illogic. Although we have succeeded in resolving many matters, some of them being mentioned in the body of this paper, certain questions remain unanswered. For example it appears that:

1. In section B.1 the equations given for the complex field factors $P_v(r)$ and $P_h(r)$ are incorrect and the correct equations have been quoted as equations (1) and (2) in section 2.2 above. Equations (B-1) and (B-2) in section B.1 of the appendix are correct, but it is not clear whether the FAA calculations of path loss using these equations were made using the correct or incorrect vales of $P_v(r)$ and $P_h(r)$.

2. In section B.3.1, two criteria are quoted for determining r_1: first the distance at which the magnitude of the reflection coefficient for vertical polarization is a minimum and secondly the distance at which the path losses for vertical and horizontal polarization are equal. Neither is it explained nor is it immediately obvious that these amount to the same thing; but calculations by the authors confirm that they do.

3. The in-line equation in section B.3.2 implies that the path loss is inversely proportional to the value of r_2 whereas it is actually directly proportional to $(\text{range})^2$. Further, the square law proportionality only starts at r_1 so the distance involved would appear to be $(r - r_1)$ not r.

4. A problem similar to that described above occurs in section B.3.3 in connection with r/r_2.

5. From section B.3.3 it would appear that there are 4 segments, 0 to r_1, r_1 to r_2, r_2 to r_3 and r_3 to R_o and that different path loss equations apply in these segments. However the values of standard deviation given in section B.3.4 do not correspond with these limits. The distance $(r_2 + r_3)/2$ is introduced without any explanation and as has been pointed out above, there appears to be an omission in the final definition relating to the 6.4 dB value of standard deviation. Further, the importance and relevance of r_4 is not clear, and neither is it clear what value of standard deviation is to be used for distances greater than r_4 although it is tempting to surmise that it is the value given by the polynomial.

The main part of the report gives the impression that the extended Suzuki model is applied in all segments with different parameters appropriate to the conditions existing in that segment. From the appendix it seems that this is not the case—there are four segments that use respectively the 2-ray model, the free space model, the extended Suzuki model and the RTCA version of the Hata-Okumura model. It is not clear whether steps are taken to ensure continuity at the break points, but, in any case, we have previously argued that this is an artificial condition.

Finally we would wish to reinforce our point made earlier, that the appendix is poorly written; contains unwieldy mathematical equations; is devoid of useful description and lacks clarity. It contains several anomalies; is somewhat inconsistent and illogical, and does not serve the purpose expected of a technical appendix, namely to support text that appears in the main document by providing clarification.

4 References

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14. Patzold, M., Killat, U., and Laue, F., "An Extended Suzuki Model for Land Mobile Satellite Channels and its Statistical Properties" *IEEE Trans on Vehicular Technology Vol. 47, No. 2*, pp. 617—630, May 1998.

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Chartered Electrical Engineer
Fellow, Institution of Engineering and Technology (formerly the Institution of Electrical Engineers) (FIET)
Senior Member, Institute of Electrical and Electronic Engineers (SMIEEE)

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Honorary Senior Fellow

CAREER

1982 - 98 Professor of Electrical Engineering, University of Liverpool (Holder of the David Jardine Chair)

1983 - 86 and 1996 - 98
Head, Department of Electrical Engineering and Electronics

1986 - 1989 Dean, Faculty of Engineering
1990 - 1996 Pro Vice Chancellor

1969 - 82 University of Birmingham, Department of Electronic and Electrical Engineering;
1969 Lecturer, 1977 Senior Lecturer
1982 Reader in Radiocommunications

1966 - 68 City of Birmingham Polytechnic (now University of Central England), Principal Lecturer in Electronic Engineering.

1962 - 66	The Polytechnic, Regent Street, London, (now University of Westminster).
1959 - 62	GEC Ltd., Applied Electronics Laboratories, Stanmore, Middlesex, Research and Development Engineer.

OTHER ACTIVITIES

1977	United Nations Expert at the International Telecommunications Training Centre, New Delhi, India.
1978 - 82	Honorary Senior Principal Scientific Officer, Royal Signals and Radar Establishment (RSRE), Malvern.
1982	Visiting Professor in Electronic Engineering, University of Auckland, New Zealand.
1987	Visiting Research Engineer, NTT Radio Communication Network Laboratories, Yokosuka, Japan.
1996	Member, HEFCE National Panel for Electrical Engineering, Research Assessment Exercise

Member of several IEE Committees and Boards.
Chairman IEE Professional Group E8 (Radiocommunication Systems), 1985-88.
IEE Council 1988-89.
Chairman, Mersey and North Wales Centre 1989-90.
Presented IEE Christmas Lecture 1992.
Advisor and Consultant to several industrial companies.

TECHNICAL AND RESEARCH EXPERIENCE

My major technical interest is in the field of telecommunications and my involvement spans a period of over 45 years. Within that general field I have been principally interested in radio communication systems although I have always kept up to date with developments in telephone, television and cable systems. I am familiar with the principles and practical techniques used in analogue and digital radio systems in all frequency bands and have extensive knowledge and experience of first and second generation cellular radiotelephone systems.

As far as research is concerned I have wide interests but have specialised in tackling the problems of mobile, cellular and personal communication systems. A major theme of this research has been the characterisation of the radiocommunication channel; it has encompassed studies of propagation in urban areas and within buildings, man-made electrical noise, digital radio systems and channel simulation. I have also been actively involved in the development of radio system techniques, such as diversity reception, which can be used to mitigate the deleterious effects caused by the radio propagation channel. This research attracted considerable financial support. I always maintained a group of active research workers and during my career more than 30 successful Ph.D. theses were submitted by students who worked under my supervision.
I have given many invited lectures, seminars and overview addresses.

CONSULTANCY

For many years I have been active as a radio and telecommunications consultant to industrial and government organisations. I have also written several reports in connection with cases of litigation and appeared as an expert witness in court cases. In 1988 I gave evidence before a Select Committee in the House of Lords.

Organisations which have sought my advice include:-

Air Call Ltd.
Cellnet
DTI (Radiocommunications Agency)
Ericsson Radio Systems AB
Government of the Isle of Man
Hutchison Microtel
London Fire and Civil Defence Authority
London Underground Ltd.
Mercury Personal Communications
Metropolitan Police
Racal Research Ltd.
Sinclair Communications
Mobile Systems International plc
Wragge and Co (Solicitors) Birmingham
Louis Berkson and Globe (Solicitors) Liverpool

PUBLICATIONS

Books

"The Mobile Radio Propagation Channel", John Wiley, 1992.(second edition , 2000)

"Mobile Communication Systems", (with J. G. Gardiner), Blackie and Sons, 1988.

"Electronic and Switching Circuits", (with S. M. Bozic and R. Cheng), Edward Arnold, 1975.

Contributions to several other books.

Over 100 papers published in international professional engineering journals.

4 "best paper"(premium) awards from the IEE for published papers in 1975, 1982, 1983 and 1992.

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COMMERCIAL IN CONFIDENCE

The LightSquared Comments on the use of the Hata Propagation model

Ajay Parikh (LightSquared) has written a very good commentary on the matters under debate [Appendix A], matters which have only been partially answered by the input from Bob Erlandson (RTCA) [Appendix B]. We will review Appendix A and Appendix B sequentially as follows.

1 Discussion of appendix A

1.1 Introductory paragraph

We agree entirely with the introductory paragraph in which the reasons behind the development of the COST231-Hata model are explained. This is also our understanding of the history of the development of the COST231-Hata model.

1.2 List item number 1

Ajay is correct in his statement that in the two relevant equations, only the first two terms differ. It is quite important to emphasise this, because it means that the dependence on other factors such as antenna heights, and distance remain the same. Moreover apart from the extension of frequency range to 2000MHz, the restrictions on the other parameters remain the same as in the original model. This being the case, we do not see why the correction factors available for the original model should not be applied to the COST 231 model.

Fizzle Technologies Limited

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Ajay has provided numerical values for the path loss attributed to the first two terms in the equation. We agree with his calculations. However we would like to add two further minor points: If the same calculations are made at 1500MHz the following results are obtained; Hata 152.64dB and COST231 153.96dB showing that at the "limit" frequency the two equations give values which are within 1.32dB. Further, at 2000MHz, the figures are; Hata 155.9dB, COST 158.2dB. So as expected the COST model predicts higher losses in the frequency range 1500 - 2000MHz, the difference at 2000MHz being 2.3dB. This analysis demonstrates in numerical terms, the reason that HATA model was extended by COST231.

1.3 List item number 2

Ajay makes a good point here. If it is sensible to use the "large city" antenna height expression, then to be consistent with this we should not apply the suburban correction factor to the environment. To "mix and match" like this is not good engineering practice and casts doubts on the robustness of the model - it could be construed as a licence to choose whatever parameters are necessary to make the model fit a certain data set. In any case, while it could be argued that the environment in the immediate vicinity of the airport is suburban (airports often consist of a number of isolated terminal buildings surrounded by large open areas for runways etc) , it could also be argued that in practice we are concerned with the overall environment over a much larger area.

1.4 List items number 3 and 4

Again inconsistencies are pointed out which have remained unanswered by Bob Erlandson. We have not checked the figures for the aggregated RFI path loss, but as far as we are aware, there is no propagation mechanism in this scenario that could result in a path loss less than would be predicted by the free-space equation. This seems to be a major weakness in the overall prediction model.

1.5 List item number 5

Bob Erlandson has answered this by sending an extract from a paper that is under peer review. On the assumption that the mathematics is correct (and we have not yet studied it in sufficient detail to think otherwise) it does seem that the STD of the individual path losses plays an important part. What we are lacking is any "feel" for why this is the case. We believe the mathematics but, as engineers, we like to have an intuitive feel that makes us comfortable with the analysis. We don't have that yet and a few sentences of explanation would be useful.

2 Discussion of Appendix B

2.1 Introductory paragraph

Bob Erlandson confirms his belief that the original Hata model is the most appropriate in the given situation.

2.2 List item number 1

Continuing from his introductory assertion, he says that his basic reason is because it is "a closer upper bound to actual median path loss measurements in our representative airport environment than COST231". We are uncertain about the meaning of this phrase. Is practical measurement data available, and has LightSquared seen it? Does it confirm his assertion?

Erlandson seems to place great emphasis on the comment in Parsons ("The Mobile Radio Propagation Channel") so perhaps that should be clarified. The comment is meant to imply that from measurements reported in the literature, it seems that areas that the Japanese would classify as suburban may be on the whole, somewhat more built up than areas regarded as suburban in the USA. There is no comment in the book about city centres. Downtown Tokyo is very heavily built up, but so is downtown Los Angeles, New York and many other US cities. We believe that they should all be regarded as essentially similar.

2.3 List item number 2

It all depends on what one is prepared to consider as "good agreement". We think that the agreement between the COST231-Hata model and the Okumura tables is equally good.

3 Summary

In summary we believe that the case that has been advanced for using the original Hata model , particularly with the "suburban" correction factor is far from conclusive and that Bob Erlandson should be asked for further comments particularly on the inconsistency between the correction factors applied for the environment and the antenna height factor. Further he should be asked to comment on the fact that in some circumstances the predicted loss is less than would be predicted by the free-space equation.

Appendix A

In a message dated 8/9/2011 12:33:27 P.M. Central Daylight Time, Ajay.Parikh@lightsquared.com writes:

Bob,

Here are our comments on use of Hata model by RTCA:

The Hata model as adopted by RTCA is restricted to the frequency range of 150-1500 MHz and therefore may not be applicable to the LightSquared operating frequency range of 1525-1559 MHz. Under the European COST 231 program, Hata model was evaluated and found to produce consistently lower path losses in rural, urban, suburban and metro areas. They have developed a more accurate model (Extended Hata) for the frequency range of 1500 – 2000 MHz to correct the situation. It is very similar to the original Hata model, but differ slightly as shown below.

1. The main difference is the first two terms of path loss from the two version:

   For the regular Hata model (fc < 1500 MHz), the first terms is 69.55 + 26.16*log10(fc), which is equal to 152.9 dB if applied for fc = 1531 MHz.

   For the extended Hata model (fc >1500 MHz), the first terms is 46.3 + 33.9*log10(fc), which is equal to 154.3 dB if fc = 1531 MHz.

   Therefore, for fc = 1531 MHz, using regular Hata model would lead to 1.4 dB less loss.

2. RTCA Hata model uses the correction factor for ATC antenna height for a large city, which is logical. However, it uses an additional correction factor K, which should be used only to correct small city formula for suburban and open areas, which is given by 2[log10(fc/28)]^2 +5.4. At fc = 1531 MHz, this correction factor would provide 11.4 dB lower loss for each path. Since we are considering an aircraft near a large city, in our opinion, this suburban area loss correction should not be applied, which would result in aggregate path loss to be 8.9 dB higher at 535.2 meter aircraft height.

3. Because of above two assumptions made in the RTCA report, we believe the aggregated RFI path loss is substantially under-estimated in the report. Also it may explain why the RTCA Hata model has resulted in less path loss (2.6 dB less) than that from the free space model at Ha = 550m, which seems anomalous.

4. Following table compares the mean path losses computed by Hata model as used by RTCA, Extended Hata model , and Free Space propagation losses. As you can see at 2 Km and 10 Km distances the Hata model predicts path loss lower than Free space loss, which is inconsistent with the physics of propagation.

Single path Distance in Km	Path Loss in dB		
	Hata Model as used by RTCA	Extended Hata model (COST 231)	Free space
2	96.1	112	102.2
10	115	130.9	116.2
20	123.2	139.1	122.2

5. It is found that the aggregate mean RFI path loss from probabilistic model is very sensitive to standard deviation (STD) of the individual path losses. Could you please explain the physics behind this phenomenon?

Please indicate at time when we could discuss this on a call.

General Equation

6. PL = A + B log(d) + C

where A,B, and C are factors that depend on frequency and antenna height.

Hata Model

A = 69.55 + 26.16 log(fc) − 13.82 log(hb) − a(hm)
B = 44.9 − 6.55 log(hb)

where fc is given in MHz and d in km.

The function a(hm) and the factor C depend on the environment as shown:

Small and medium-size cities:

a(hm) = (1.1 log(fc) − 0.7)hm − (1.56 log(fc) − 0.8)
C = 0

Metropolitan areas

a(hm) = 3.2(log(11.75hm)^2 − 4.97 for f ≥ 400 MHz (RTCA Model)
C = 0

Suburban environments

C = −2[log(fc/28)]2 − 5.4 (RTCA Model)

Rural area

C = −4.78[log(fc)]2 + 18.33 log(fc) − 40.98

COST 231 (Extended Hata) Model

A = 46.3 + 33.9 log(fc) − 13.82 log(hb) − a(hm)
B = 44.9 − 6.55 log(hb)

where a(hm) is defined as in Hata model.

C is 0 in small and medium-sized cities, and 3 dB in metropolitan areas.

Regards,

Ajay S Parikh
Programs Director,
Distinguished Member of Technical staff

Ajay.Parikh@lightsquared.com

LightSquared

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Reston, VA 20191

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Appendix B

In a message dated 8/12/2011 12:13:49 P.M. Central Daylight Time, ErlandRJ@aol.com writes:

Ajay:
Ken Peterson and I have reviewed your comments below about the use of the Hata model as the basis for the long range propagation model in the RTCA study. For the reasons we discussed with you previously during the RTCA study period, we still believe the Hata model documented in DO-327 is the appropriate one to use rather than the COST231 model.

1) The basic reason is that the Hata-suburban formula is a closer upper bound to actual median path loss measurements in our representative airport environment than COST231. Barton (*The Mobile Radio Propagation Channel*, 2nd Ed., JW Wiley) notes that for loss measurements in typical US suburban areas the values vary between the "suburban" model and the "open" model predictions. COST231 predicts higher losses at the same reference distances

2) The basic Okumura loss measurements cover frequencies up to 1920 MHz. There is good agreement at frequencies between 1525-1575 MHz between the Hata model equation prediction and the sum of component values from the Okumura tables .

Note also that we only use the Hata-suburban model outside of about 20 km for the 535.2 m FAF WP case in DO-327 (see. Fig. B-3)

Attached is an excerpt from our ION Journal paper (in peer review) that we mentioned in the 8 Aug. telecon. It contains the description of the method to compute the CDF for received aggregate RFI power (Sec I, sub-part C.). Also included is an CDF example from the paper at 535.2 m aircraft height for a uniform distribution of RFI emitters having 1.8 m antenna height and 0 dBi hemispheric pattern (100 units per sq. km, ave.). .

Best regards,
Bob Erlandson

DECLARATION OF JOHN DAVID PARSONS

I, John David Parsons, make the following declaration in connection with the FAA's Draft Status Report: Assessment of Compatibility of Planned LightSquared Ancillary Terrestrial Component Transmissions in the 1526-1536 MHz Band with Certified Aviation GPS Receivers dated December 23, 2011 ("FAA Report").

1. I am an Emeritus Professor and Honorary Senior Fellow at the University of Liverpool. I held the David Jardine Chair of Electronic Engineering from 1982 until 1998. During this period I was, at various times, Chairman and Head of the Department of Electrical Engineering and Electronics, Dean of the Faculty of Engineering and Pro-Vice Chancellor (Vice-President) of the University. I received a B.Sc. degree in Electrical Engineering (Magna cum Laude) from the University of Wales in 1959, an M.Sc. in Electronics from the University of London in 1967 and a D.Sc. in Electronic Engineering (Radiocommunications) from the University of London in 1985. I also hold the following certifications; FREng, (Fellow of the Royal Academy of Engineering, London) FIET, (Fellow of the Institution of Engineering and Technology - formerly the Institution of Electrical Engineers, London) and SMIEEE (Senior Member of the Institute of Electronics and Electrical Engineers, New York)

2. In addition to my teaching experience, I have conducted extensive research on various aspects of radio engineering, specializing in radio propagation and radio channel characterization particularly in connection with cellular systems, and have published approximately 150 technical papers in peer-reviewed Journals and at major conferences. I have also authored or co-authored 3 books on the topics of radio propagation and radio engineering. I have acted as a consultant to several companies and have given evidence as an expert witness in Courts of Law. A copy of my CV is attached to this Declaration.

3. I have been asked by LightSquared to review the proposed propagation models for determining the compatibility between LightSquared's terrestrial system and FAA GPS requirements. Most recently, I have been asked to review the FAA Report and

provide my opinion on the validity of the FAA's most recent propagation model described therein.

4. In my professional opinion, LightSquared's proposed approach to modeling propagation is scientifically valid and supported by available scientific literature. The company has drawn on well-established physical and engineering principles and models that have stood the test of time, to characterize the propagation scenario in which its proposed system will operate. At all times it has applied these principles with appropriate scientific rigour.

5. On the other hand, in my professional opinion, the approach to modeling propagation being proposed by the FAA and its consultants is often not supported by similar scientific evidence; it contains significant inconsistencies, and in many ways could be characterized as arbitrary.

I declare that the foregoing Declaration it true and correct.

Executed on January 9, 2012.

John David Parsons

John David Parsons

CURRICULUM VITAE

PROFESSOR DAVID PARSONS

Home address: 70A, Freshfield Road, Formby L37 7BQ .
Telephone: +44 (0) 1704 831343
Email: jdp@liverpool.ac.uk
Date of birth: 8th July 1935

ACADEMIC AND PROFESSIONAL QUALIFICATIONS

1959 B.Sc., Electrical Engineering (Magna cum laude), University of Wales
1967 M.Sc. (Eng.) Electronics, Kings College, London
1985 D.Sc. (Eng.) University of London
Chartered Electrical Engineer
Fellow, Institution of Engineering and Technology (formerly the Institution of Electrical Engineers) (FIET)
Senior Member, Institute of Electrical and Electronic Engineers (SMIEEE)

HONOURS

1988 Fellow, Royal Academy of Engineering (FREng.)

CURRENT STATUS

Retired. Emeritus Professor at the University of Liverpool
Honorary Senior Fellow

CAREER

1982 - 98 Professor of Electrical Engineering, University of Liverpool (Holder of the David Jardine Chair)

1983 - 86 and 1996 - 98
Head, Department of Electrical Engineering and Electronics

1986 - 1989 Dean, Faculty of Engineering
1990 - 1996 Pro Vice Chancellor

1969 - 82 University of Birmingham, Department of Electronic and Electrical Engineering;
1969 Lecturer, 1977 Senior Lecturer
1982 Reader in Radiocommunications

1966 - 68 City of Birmingham Polytechnic (now University of Central England), Principal Lecturer in Electronic Engineering.

1962 - 66	The Polytechnic, Regent Street, London, (now University of Westminster).
1959 - 62	GEC Ltd., Applied Electronics Laboratories, Stanmore, Middlesex, Research and Development Engineer.

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1977	United Nations Expert at the International Telecommunications Training Centre, New Delhi, India.
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I have given many invited lectures, seminars and overview addresses.

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Hutchison Microtel
London Fire and Civil Defence Authority
London Underground Ltd.
Mercury Personal Communications
Metropolitan Police
Racal Research Ltd.
Sinclair Communications
Mobile Systems International plc
Wragge and Co (Solicitors) Birmingham
Louis Berkson and Globe (Solicitors) Liverpool

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"Mobile Communication Systems", (with J. G. Gardiner), Blackie and Sons, 1988.

"Electronic and Switching Circuits", (with S. M. Bozic and R. Cheng), Edward Arnold, 1975.

Contributions to several other books.

Over 100 papers published in international professional engineering journals.

4 "best paper"(premium) awards from the IEE for published papers in 1975, 1982, 1983 and 1992.

DECLARATION OF JOHN HOWARD GLOVER

I, John Howard Glover, make the following declaration in connection with the Letter from Lawrence E. Strickling, Assistant Secretary for Communications and Information, U.S. Dep't of Commerce, to Julius Genachowski, Chairman, FCC (dated Feb. 14, 2012) ("NTIA Letter") and the U. S. Department Of Transportation Federal Aviation Administration Status Report: Assessment Of Compatibility Of Planned LightSquared Ancillary Terrestrial Component Transmissions In The 1526-1536 MHz and With Certified Aviation GPS Receivers (Jan 25, 2012) ("FAA Report").

1. I have worked for more than 35 years on the development, flight testing and certification of terrain awareness and alerting systems ("TAWS"). My experience includes early Ground Proximity Warning systems for civil and military aircraft and also modern Terrain and Obstacle Awareness and Warning systems and displays. I served as secretary of the EUROCAE working group which developed TAWS design standards for US and European certification. I hold more than a dozen patents in the field of airborne alerting systems. I was an FAA Systems and Equipment Designated Engineering Representative for more than 20 years. A copy of my CV is attached to this Declaration..

3. I have been asked by LightSquared to review the FAA's proposed requirements to use to evaluate the impact of LightSquared's system on TAWS. More recently, I have been asked to review the TAWS evaluation criteria in the FAA Report attached to the NTIA Letter.

4. In my professional opinion, the FAA's proposed TAWS evaluation criteria are overly restrictive and do not take into account operational considerations, the many

redundancies in commercial TAWS systems to ensure functionality, or that most commercial TAWS systems are more robust than the Minimum Operational Performance Standards ("MOPS") contained in the FAA Technical Standard Orders ("TSOs") related to TAWS.

5. In my professional opinion, the FAA Report overstates the likelihood that temporary loss of a GPS signal would significantly degrade operational safety of flight. Most significantly, in the process of descending to an altitude low enough for the system to be exposed to interference-induced loss of GPS data, the airplane must pass through an environment where a TAWS alert will be given before that airplane enters the very low altitude zone. In this case it can be assumed that the flight crew will have taken action to avoid the terrain or obstacle threat before the loss of signal has occurred.

6. TAWS systems are divided into three classes – A, B, and C – all of which may use GPS position data to locate the aircraft with respect to the terrain database and also with respect to a runway. Class A Systems are required to be installed on all aircraft operating under Part 121 and commercial aircraft operating under Part 135 with more than 9 seats. Class B Systems are required for all aircraft operating under Part 135 with between 6 and 9 seats or Part 91 aircraft with 6 or more seats. Class C applies to small general aviation aircraft not required to have TAWS systems installed.

7. Class A TAWS are not required to use GPS as a position data source. Some systems obtain position data from a Navigation Computer that blends, Inertial Reference

System data (and for some systems also Radio Navigation data) in order to calculate aircraft position. Other systems do use GPS data in addition to the previously mentioned sources. For any of these systems, the loss of GPS signal does not degrade the position data until Inertial Reference System drift errors become significant – typically only after several minutes. Consequently, Class A TAWS systems operating in an airport terminal airspace environment are relatively immune to loss of GPS data.

8. All FAA certified TSO-C151b Class A and B systems with internal GPS receivers must have the capability of monitoring the validity and position error of the GPS system, and the TAWS must provide an indication to the pilot if the GPS error is excessive. Even if a GPS signal were lost for these systems, the flight crew would be aware of the loss and use back-up systems to ensure continued operational safety.

9. Class A TAWS systems have several alerting functions that use Radio Altimeter signals for determining the height of the airplane above the terrain. These functions are independent of GPS position data. For example, the DO 161A Mode 4 "Too Low" alert mode provides an alert if the airplane descends below 500 feet with the landing gear up, and provides an alert if the airplane descends below 200 feet if the landing gear is down but landing flaps are not set. An advisory call is also required when the airplane descends below 500 feet, irrespective of configuration. This alert would occur even if the TAWS GPS receiver component signal were lost.

10. If a loss of GPS signal occurs while a TAWS alert in progress, it would be improbable that the pilot would assume that the terrain threat has ceased. The correct pilot response to a TAWS alert is to ensure adequate terrain clearance, pilots are trained extensively in TAWS avoidance procedures. The following is an excerpt from Pilot Guide/Flight Manual Supplement for systems provided by a TAWS manufacturer:

> Recommended response to EGPWS alerts are as follows:
> **Caution:**
> 1. Stop any descent and climb as necessary to eliminate the alert. Analyze all available instruments and information to determine best course of action.
> 2. Advise ATC of situation as necessary.
>
> **Warning:**
> 1. Aggressively position throttles for maximum rated thrust. Apply maximum available power as determined by emergency need. The pilot not flying (if applicable) should set power and ensure that TO/GA power and modes are set.
> 2. If engaged, disengage the autopilot and smoothly but aggressively increase pitch toward "stick shaker" or Pitch Limit Indicators (PLI) to obtain maximum climb performance.
> 3. Continue climbing until the warning is eliminated and safe flight is assured.
> 4. Advise ATC of situation.
>
> **NOTE:** Climbing is the only recommended response unless operating in visual conditions and/or pilot determines, based on all available information, that turning in addition to the climbing is the safest course of action. Follow established operating procedures.

11. TSO C-151b requires that Class A and B systems provide Forward Looking Terrain Avoidance (FLTA) and Premature Descent Alert (PDA) functions that provide alerts on a slope rather than a stepped basis as in the TSO to accommodate typical ascent and descent procedures near airports. A typical TAWS system (*e. g.* the Honeywell EGPWS) implements PDA function with a "Terrain Clearance Floor" function (see drawing below). The "floor" slopes upwards from the threshold of the nearest runway, reaching a height of 400 feet at 4 nautical miles from the threshold. It then remains at 400

feet until 12 nautical miles, when it again slopes up to 700 feet at 15 nautical miles. If an airplane descends below this floor an alert is provided, irrespective of landing gear position or flap setting. The floor begins at a distance from the runway threshold that varies with the quality of position data, but is typically ¼ nautical mile. Current systems provide further protection by holding the height of the floor at a minimum of 245 feet unless the airplane track is aligned with the runway within +/- 45 degrees, thus ensuring that an airplane that is not within the approach corridor will receive a terrain alert at a minimum height of 245 feet.

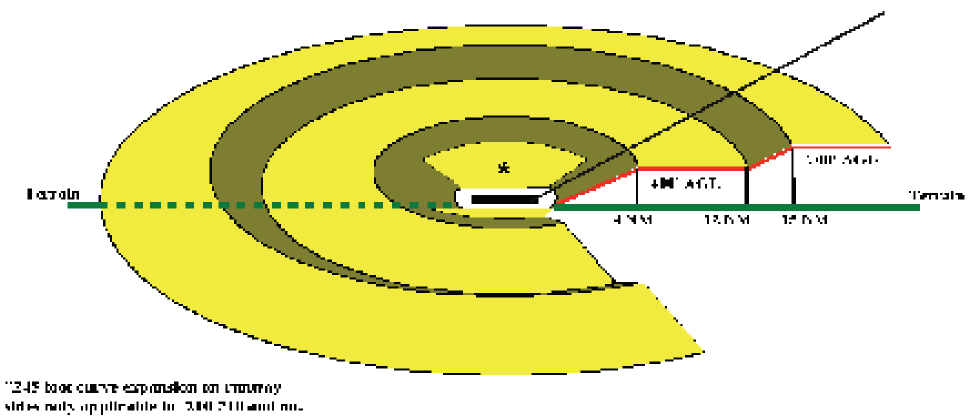

Figure 1.1- Terrain Clearance Floor

Even when the airplane is above the clearance floor, if it is descending at an angle such that its flight path is predicted to intersect the ground before the runway, then the required Forward Looking Terrain Avoidance function will provide an alert. This PDA function ensures that if an airplane is not aligned with the approach corridor to a runway, then a terrain alert will be given if the airplane descends below 245 feet.

If the airplane is within the approach corridor, then a descent below 200 feet will result in an alert unless the airplane is closer than 2¼ nautical miles to the runway threshold, and a descent below 100 feet will result in an alert unless the airplane is closer than 1¼ nautical miles to the runway threshold.

Consequently, if GPS signals are available when the airplane is above 200 feet, and are subsequently lost when the airplane continues to descend, there is a very small volume of unprotected airspace close to the runway. If an airplane is established on an approach path which is sufficiently stable to not generate a terrain alert above 200 feet, then it is considered to be very improbable that anything less than an extreme deviation from the stabilized path below this height would result in a terrain collision. Such an extreme maneuver is likely to result in an accident even if the TAWS function were fully operational.

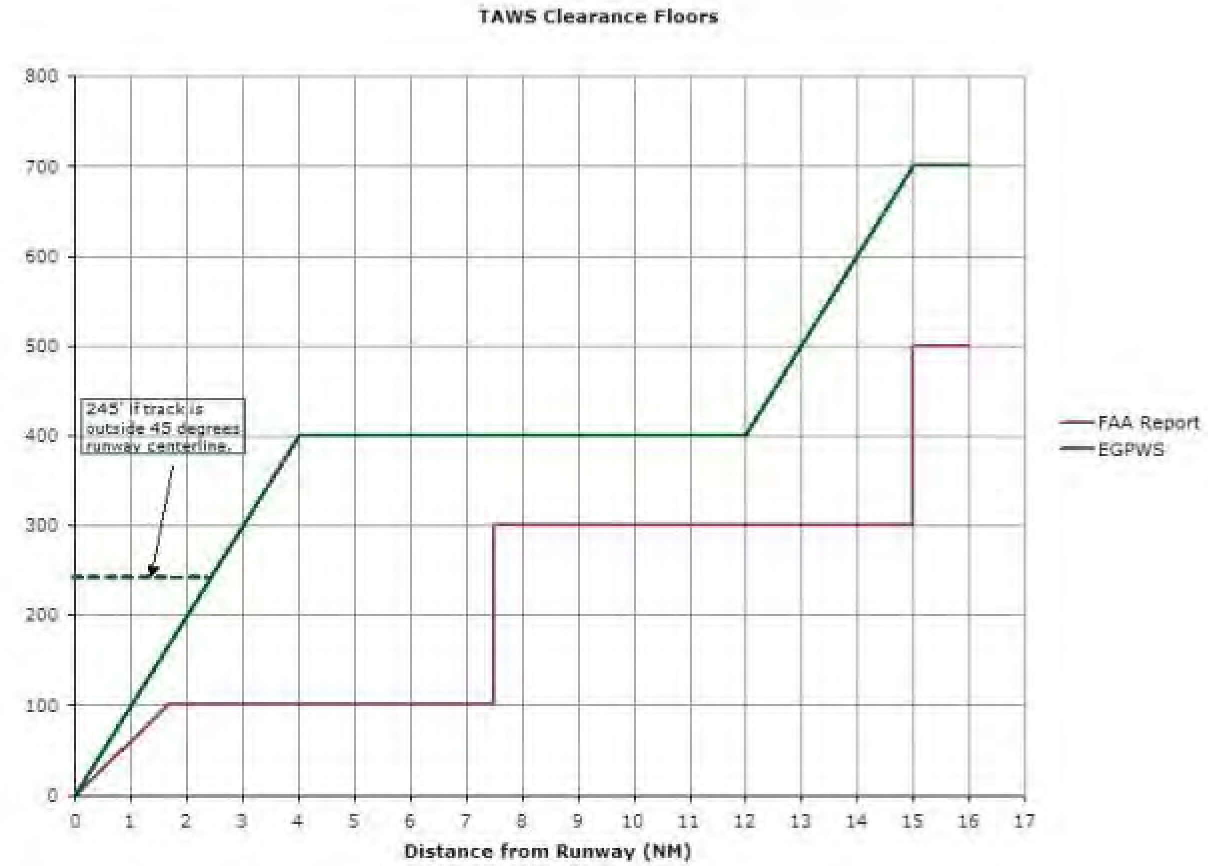

Figure 1.2 - Terrain Clearance Floors: Typical Production Equipment vs. FAA Minimum Requirements.

12. While not mandated, TAWS systems increasingly incorporate obstacle information in their databases. When an obstacle database is available, TAWS alerts are triggered at higher altitudes. Obstacle databases are continually being improved, but typically include obstacles such as buildings, cell/antenna towers, and other manmade structures that exceed 100 feet above ground level close to an airport, and also such structures that exceed 200 feet above ground level further away from an airport. From an operational standpoint, TAWS databases with obstacles allow the TAWS systems to sound alerts above the obstacles, providing more realistic TAWS protection. Since most LightSquared antennas will be mounted on structures that would be included in these obstacle databases, and because such obstacles would cause the TAWS to provide an

alert before the airplane descends to an altitude where interference with the GPS signal is likely, a more realistic TAWS scenario would include these obstacles in the analysis.

13. The FAA's application the requirements of TSO-C151b (Terrain Awareness and Warning System (TAWS)) (the "TAWS TSO") to evaluate the whether LightSquared's proposed system will interfere with TAWS is overly conservative. The TAWS TSO itself provides flexibility not included in the FAA's Report. For example, Appendix 1 Table 3.1.1, which appears to form the basis for the FAA's evaluation criteria in Section 1.4. of the FAA Report, does not mandate a 100' clearance in all Departure and Approach Phases. Specifically:

- The RTC values are for the *projected* terrain clearance (i.e. the clearance which the system predicts the airplane will have if it continues along its current flight path). If the airplane is descending, the terrain clearance directly beneath the airplane will generally be greater, and so the vertical distance between the airplane and any tower beneath the airplane will also be greater than the RTC value.
- Table 3.1.1 Note 2 allows "…a linear reduction of the RTC as the aircraft comes closer to the nearest runway…" instead of the step reduction implied by the Table. Indeed, as noted above, most TAWS equipment today uses such a linear approach.
- Table 3.1.1 Note 3 allows the RTC to be reduced within 1 NM of the runway, and does not mandate the 100' clearance within this radius.

.

14. In conclusion, the FAA report fails to demonstrate that a temporary loss of GPS at low altitudes would result in a significant degradation of safety related to TAWS. Actual TAWS systems are far more robust and contain numerous safeguards to ensure operational safety.

* * * *

I declare under penalty of perjury under the laws of the United States of America that the foregoing Declaration is true and correct.

Executed on March 15, 2012

John Howard Glover

John Howard Glover

John Howard Glover

Total years of experience in aviation industry: *49*
Areas of technical expertise:

- ***Aircraft Operations Analysis***
- ***Alerting Systems Design***
- ***Flight Deck Design***
- ***Systems Certification***

Education:

- ***B.Sc. (Honors): Aeronautical Engineering, Imperial College, London University, UK***
- ***Advanced degree: Associate of City and Guilds Institute (London University): Aeronautical Engineering.***

Experience:

- ***British Aircraft Corp., Bristol, UK (2 years): Research Engineer. Development of missile guidance systems.***
- ***British Royal Aircraft Establishment (2 years), Bedford, UK: Scientific Officer. Development and flight testing of tactical landing system for V/STOL aircraft.***
- ***The Boeing Co., Seattle, WA (9 years): Staff Engineer. Development of flight deck alerting systems, B747 airplane. Development and flight testing of fly-by-wire control system for proposed B707 patrol airplane. Development of advanced propulsion control systems.***
- ***Sundstrand Data Control/Allied Signal/Honeywell, Redmond, WA (36 years): Engineering Fellow. Development, marketing, flight testing and certification of flight safety products.***
- ***Member/officer on several aviation industry technical committees in the USA and Europe:***
    - ***Member of SAE S-7 committee (Transport Airplane Handling Qualities and Flight Deck Design Standards),***
    - ***Secretary of EUROCAE Working Group 44 (Terrain Awareness Warning System design standards),***
    - ***Member of RTCA committee SC-186 (Aircraft Surface Alerting standards).***

Professional Memberships: ***Fellow, Royal Aeronautical Society, UK***

Other Qualifications:

- ***FAA licensed multi-engine and instrument rated commercial pilot (airplane, helicopter and glider).***
- ***Author of several patents in the flight safety and control domains.***
- ***FAA Systems DER for more than 20 years***

EXHIBIT C

GPS RECEIVERS CAN FILTER LIGHTSQUARED'S SIGNALS WITHOUT DEGRADING THEIR PERFORMANCE

The GPS interests have, on several occasions, argued that it is impossible to sufficiently attenuate adjacent band LightSquared signals without sacrificing the present performance of GPS receivers.[1] This claimed is refuted below.

The claim of the GPS interests is based on the following arguments.

1. Bandpass filters necessarily involve insertion loss which can result in a degradation of the receiver's noise figure.

2. Bandpass filters necessarily involve group delay variation with frequency. This degrades position accuracy.

3. Restricting the bandwidth of the received GPS signal can degrade the position accuracy.

4. The filters required will be too large for the current form factors of GPS receivers and/or will cost too much.

I. PRESELECTOR FILTER INSERTION LOSS AND POTENTIAL DEGRADATION IN RECEIVER NOISE FIGURE

An individual filter offering in excess of 45 dB rejection of the lower 10 MHz ATC channel (1526 – 1536 MHz) will typically have an insertion loss of approximately 2 dB at the GPS L1 frequency. An example of such a filter is provided in Attachment C-1. The above 2 dB insertion loss does not have to result in a 2 dB increase in the receiver's noise figure as a low-gain high-linearity LNA can precede the filter to reduce the impact on receiver noise figure. An example of how the insertion loss of the filter can be masked from affecting the noise figure is provided below using commercially available RF components.

This example assumes the following:

- Receiver with a 1.9 dB Noise Figure without any LNA/Filter modifications;
- The cascaded Noise Figure of the receive chain is 2.08 dB;
- Linear noise amplifier (LNA) with 1 dB Input Gain Compression point of -7 dBm;
- LightSquared base station signal level = - 20 dBm.

In these conditions, the small signal gain suppression of the LNA will be negligible (~0.01 dB). Even assuming a higher than typical base station signal level of -20 dBm, the small signal suppression will be ~ 0.1 dB.

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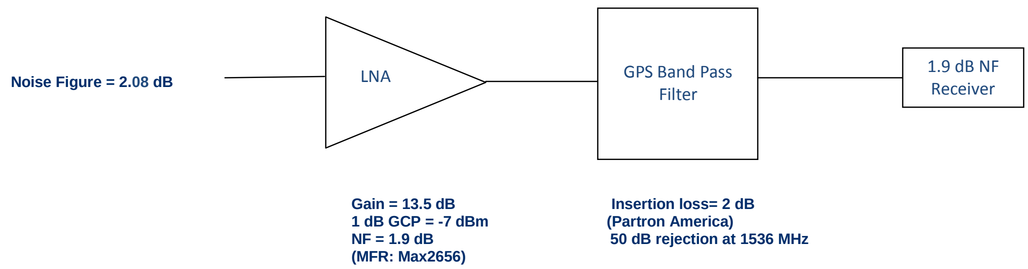
[1] *See e.g.* Garmin International, Inc., Comments, FCC File No. SAT-MOD-201011118-00239 and IB Docket 11-109 (August 1, 2011).

Figure C.I.1



II. GROUP DELAY VARIATION IN THE RNSS PASSBAND

Much has been made of this subject by the GPS interests at various times.[2] The arguments have included the following:

- Group delay variation in the passband causes correlation loss (the cross-correlation function between the received GPS signal and its local replica in the GPS receiver will have a smaller peak).

- Interchannel biases could be introduced in the processing of the GPS signals from different satellites if the frequency spectra of the GPS signals were not identical (owing to the use of different spreading codes). This problem is more pronounced for FDMA constellations such as GLONASS than CDMA constellations such as GPS (and next generation GLONASS).

A. Correlation Loss

This is a purely hypothetical concern. Extensive simulations performed by LightSquared have shown that the loss of correlation is less than 0.27 dB for the P(Y) code and 0.05 dB for the C/A code. The bandpass filter simulated was a 12^{th} order Chebyshev type-I filter with 90 ns of group delay variation between 1559 and 1605 MHz and 55 dB rejection at 1535 MHz.

1. Interchannel Bias

The potential for interchannel bias in CDMA based signals, such as GPS, is a *theoretical* possibility.[3] However, actual measurements with both GPS simulators and live-sky GPS signals

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[2] *See e.g.* Letter from F. Michael Swiek, Executive Director, U.S. GPS Industry Council to Marlene H. Dortch, Secretary, FCC, FCC File No. SAT-MOD-20101118-00239 and IB Docket No. 11-109 (January 12, 2012) (citing Hemisphere's concerns about failure to explore the impact of group delays). *See also* Letter from Catherine Wang, Bingham McCutchen LLP to Marlene H. Dortch, Secretary, FCC, FCC File No. SAT-MOD-20101118-00239 and IB Docket No. 11-109 (October 27, 2011) (noting that Deere & Co., Garmin Intentional, Inc., and Trimble Navigation Ltd. disclosed concerns about group delay in ex parte discussion with the FCC).

showed no systematic performance degradation when an existing high precision receiver was compared with a modified version, which had its frequency selectivity substantially enhanced. The results are provided in Attachment C-2.

2. Filter Size and Cost

The filter size and cost issue is addressed below according to GPS receiver class.

a) Cellular

For processing exclusively GPS L1 signals, cell phones do not need new filtering technologies. The TWG and NTIA tests showed that LightSquared's deployment plans with the lower-10 MHz channel posed no threat to present day cell phones. The potential need for better filtering applies only to circumstances not relevant here: cell phone GPS receivers which wish to process both GPS and GLONASS, and possibly Galileo in the future. These constellations require the passband of the filter to pass the entire 1559-1605 MHz RNSS band whereas legacy, GPS-only receivers typically have a passband smaller than the RNSS band.

Even if those other circumstances were taken into account, Avago Technologies has considered this new requirement and demonstrated that film bulk acoustic resonator (FBAR) technology exists today to manufacture filters, with the same form factor as legacy SAW filters, offering at least 40 dB rejection in the stopbands 1525-1555 MHz and 1626.5-1660.5 MHz, with minimal insertion loss and performance that is stable across a wide range of temperatures.[4] Qualcomm has indicated that it should not add more than about 5 cents to the current manufacturing cost of such a filter to provide this type of increased performance.[5]

b) Personal/General Navigation

The small number of legacy personal/general navigation devices which showed low overload thresholds (below -30 dBm) in both TWG and NPEF tests were essentially poor designs that offered no additional functionality or performance to offset of their more fragile performance. For these receivers, there is no uncertainty about how to improve their performance – simply replicating the design of another receiver that is more robust suffices.

For the future (if more satellite constellations are needed to be accommodated) this receiver class could use the same technology as cell phones; hence the same discussion applies.

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[3] Johnson, G. and Zaugg, T., "Measuring Interchannel Bias in GPS Receivers," Proceedings of the 57th Annual Meeting of The Institute of Navigation, Albuquerque, NM, June 2001, pp. 477-480 ("Johnson, *et al.* [1]").

[4] Working Group, Final Report, App. C.2, at 9 (June 30, 2011) ("TWG Final Report [5]") ("Present Avago FBAR manufacturing technology can support a filter with <1.5 dB insertion loss across narrow GPS + GLONASS (1574-1606 MHZ) that provides 40 dB of rejection in the [adjacent] bands. This performance can be maintained across manufacturing variation and a temperature range of -30 to +85 C.").

[5] TWG Final Report [5], at App. C.5, at 7-8 ("The cost impact could be on the order of 5 cents, depending on volume.").

c) High Precision Positioning

After LightSquared published its results from the ALU tests of improved high precision receivers, the USGIC in its FCC *ex parte*[6] suggested that the improved antennas tested could only be used as external antennas (thereby limiting their applicability), allegedly because they used large filters. This is not necessarily true as demonstrated by Javad GNSS, which achieved improved frequency selectivity through a cascade of LNAs and SAW filters. While the Javad antenna tested in the ALU tests was indeed an external antenna, to allow it to be tested with other manufacturers' receivers, Javad has also created a compact high precision receiver with an internal antenna that is robust against LightSquared's lower 10 channel. Figure C.II.1 shows and picture of the compact Javad GNSS antenna which can withstand LightSquared's lower 10 MHz signal at a level above -10 dBm. The dimensions are approximately 178x109x178 mm.

Figure C.II.1 Example of Compact High Precision Receiver with internal antenna. This receiver can withstand LightSquared's lower-10 MHz signal at a level above -10 dBm.

Javad's design approach of concurrently increasing frequency selectivity and preserving linearity through a cascade of inexpensive, commercially available LNAs and SAW filters demonstrated that reducing susceptibility to overload from adjacent band signals is not necessarily associated with a cost increase for device components. It simply requires a redesign of the RF front end, which may actually reduce costs by introducing the opportunity to use newer less costly components.

d) High Precision Timing

There are a relatively small number of high precision timing receivers which use carrier phase based techniques to derive very accurate timing references (with accuracy of less than 1 ns). These receivers are susceptible to an additional, potential error source not faced by high precision positioning receivers – errors in the receiver's delay calibration.[7] The receiver delay

6 USGIC Ex Parte [3].

7 The net receiver delay cancels out in position estimation.

includes the propagation delay of the GPS signal from the antenna phase center to the point in the receive chain where the time observation is made. It has been suggested by GPS interests that, if the antenna is changed to make it more robust to LightSquared's signals, the delay calibration will be disturbed and therefore the receiver's timing accuracy will be degraded. Furthermore, filtering to increase frequency selectivity may make the delay calibration more vulnerable to temperature changes. These criticisms are addressed below.

The delay calibration is an established procedure that is required to be performed both at the time of initial installation and subsequently if any element of the receiver chain is changed. Moreover, thermal stabilization of the receiver is often performed even in present applications.[8] Schildknecht, *et al.* [6] point out that it is difficult to achieve typical high precision timing objectives without thermal stabilization. Hence, none of the criticisms against the feasibility of making High Precision Timing receivers more robust (through improved frequency selectivity) appear to be valid.

[8] Schildknecht, T. and Dudle, G., "Time and Frequency Transfer High Precision GPS Phase Measurements', GPS World, February 2000, pp, 48 – 52 ("Schildknecht, *et al.* [6]").

References

[1] Johnson, G. and Zaugg, T., "Measuring Interchannel Bias in GPS Receivers," Proceedings of the 57th Annual Meeting of The Institute of Navigation, Albuquerque, NM, June 2001, pp. 477-480.

[2] Wanninger, L., “Carrier-Phase Inter-Frequency Biases of GLONASS receivers,” J. Geod., July 2011, DOI 10.1007/s00190-011-0502-y.

[3] United States GPS Industry Council, *Ex Parte Response Letter*, File No. SAT-MOD-20101118-00239 and IB Docket No. 11-109 (January 12, 2012).

[4] Kaplan, E. D. and Hegarty, C., <u>Understanding GPS Principles and Applications (2 Ed.)</u>, Artech House, 2006.

[5] Working Group, Final Report, App. C.2, at 9 (June 30, 2011).

[6] Schildknecht, T. and Dudle, G., “Time and Frequency Transfer High Precision GPS Phase Measurements’, GPS World, February 2000, pp, 48 – 52.

Attachment C-1

Example of GPS Preselector Filter Specifications

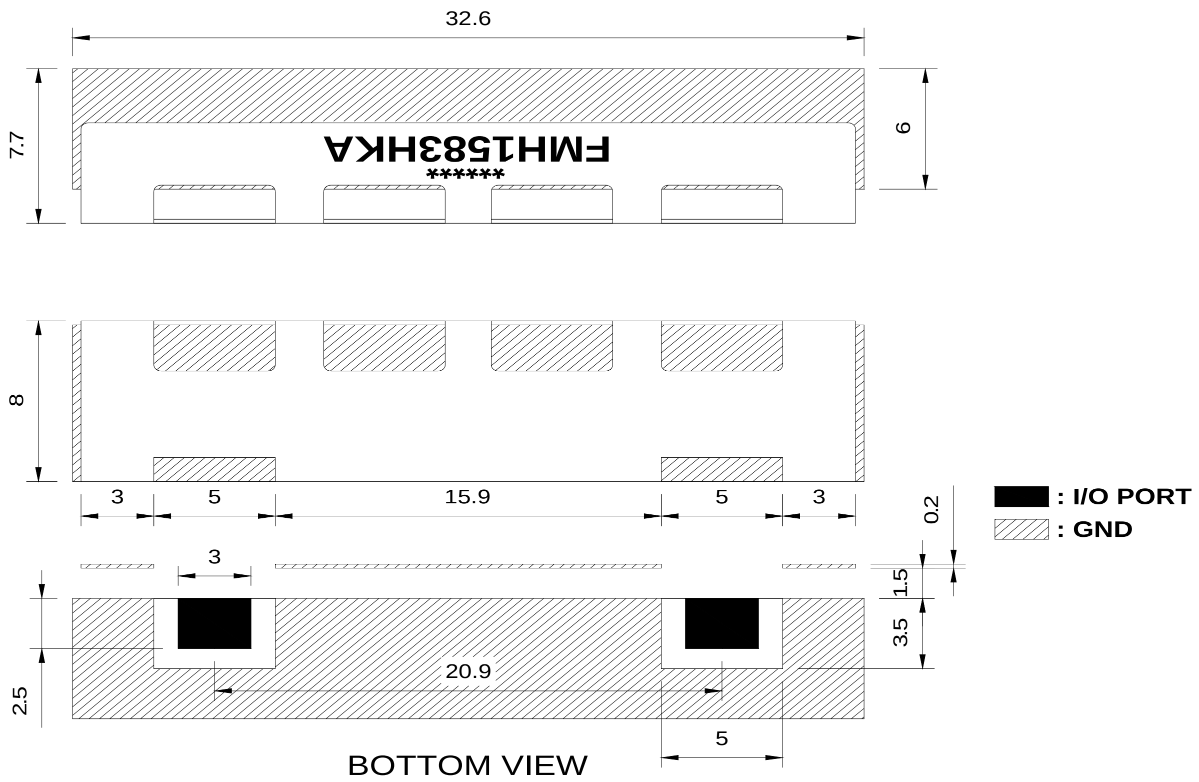
VERSION	:	2.0
WRITTEN BY	:	DUCK-HAN KIM.
CHECKED BY	:	JI-MAN RYU.
ISSUED DATE	:	2011.10.07
PART NUMBER	:	EMH1583HKA

partron
(주)파트론

1. ELECTRICAL SPECIFICATION

ITEMS		SPEC.		
		Typ.	@ 25℃	@ -40 ~ +85℃
Center frequency		1583 MHz		
Bandwidth		1559 ~ 1607 MHz		
Insertion Loss (@1583 MHz)		1.65	1.8 dB Max.	2.0 dB Max.
Insertion Loss (@1559 ~ 1607 MHz)		2.8	3.0 dB Max.	3.2 dB Max.
Ripple 1 (@1559 ~ 1607 MHz)		1.2	1.5 dB Max.	1.6 dB Max.
Ripple 2 (@1565.2 ~ 1585.6 MHz)		0.3	0.4 dB Max.	0.5 dB Max.
G.D.V 1 (@1559 ~ 1607 MHz)		20	25 nS Max.	25 nS Max.
G.D.V 2 (@1565.2 ~ 1585.6 MHz)		8	10 nS Max.	10 nS Max.
Return Loss		17	14.0 dB Min.	14.0 dB Min.
Attenuation	@ 1500 ~ 1536 MHz	50.0	45 dBc Min.	45 dBc Min.
	@ 1627 ~ 1700 MHz	47.0	45 dBc Min.	42 dBc Min.
Input Power		3 W Max.		
Operating Temperature		-40℃~ +85℃		
In/Out Impedance		50 ohm		

2. MECHANICAL SPECIFICATION



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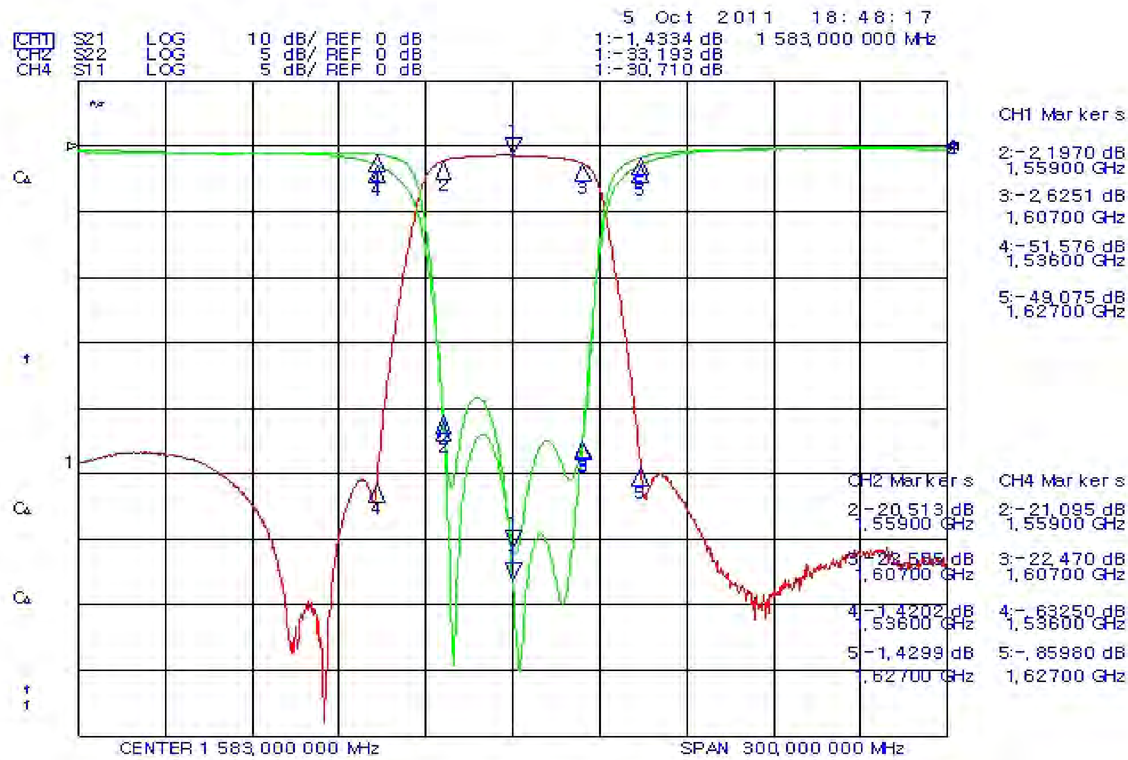

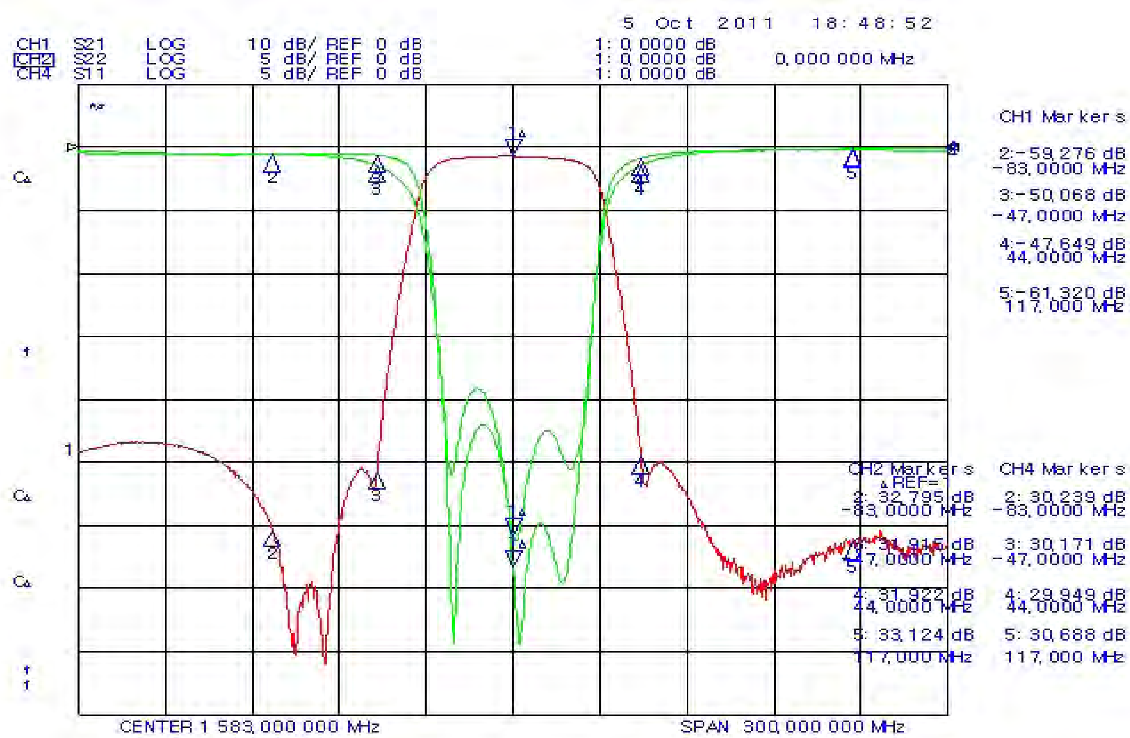

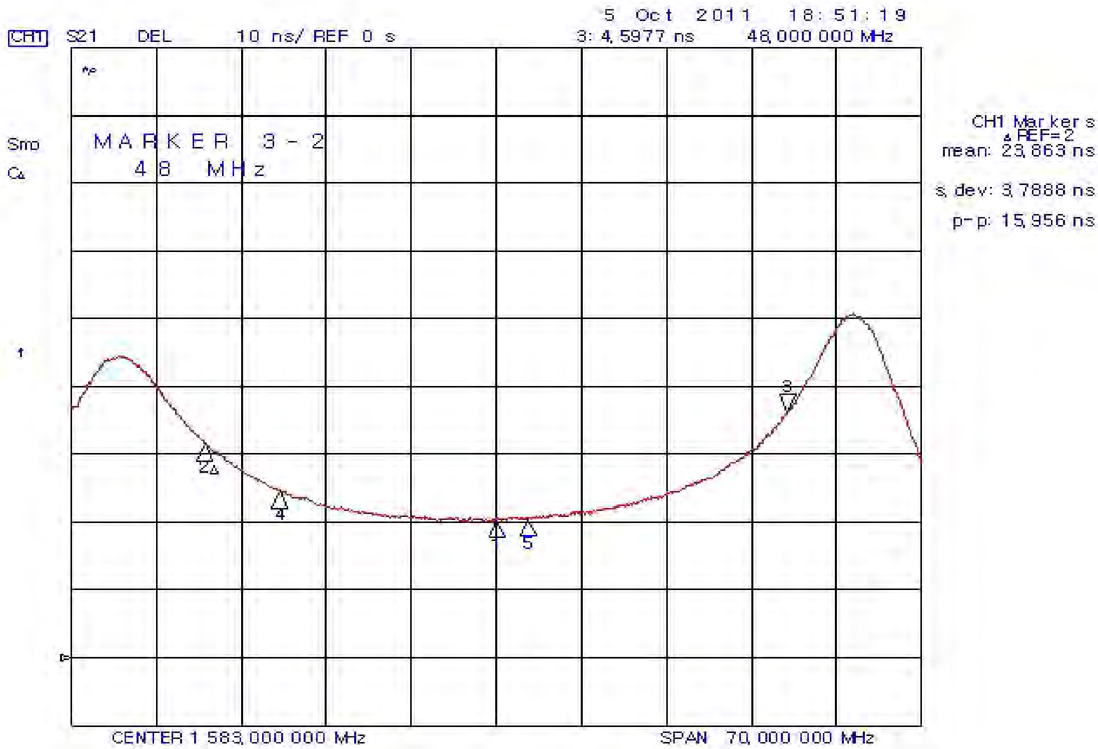
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3: 4.5977 ns 48.000 000 MHz
MARKER 3 - 2
48 MHz
Smo
Ca
CH1 Markers
REF=2
mean: 23.863 ns
s.dev: 3.7888 ns
p-p: 15.956 ns
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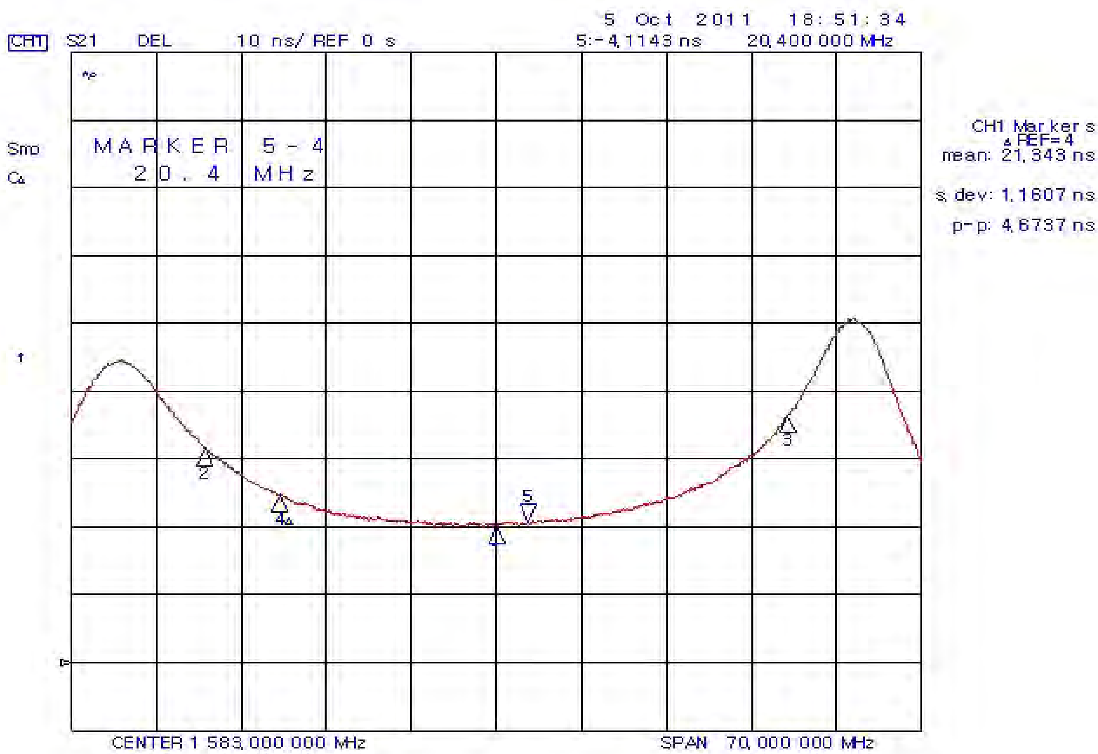
SPAN 70.000 000 MHz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5:-4.1143 ns 20.400 000 MHz
MARKER 5 - 4
20.4 MHz
Smo
Ca
CH1 Markers
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s.dev: 1.1607 ns
p-p: 4.6737 ns
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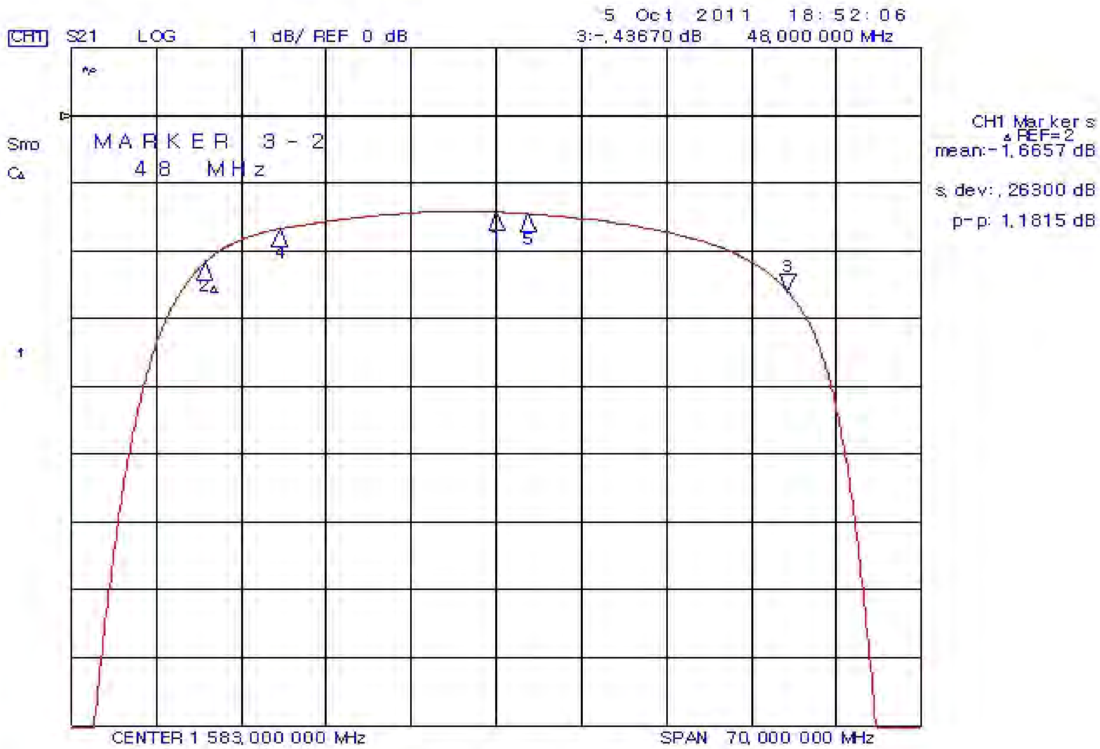
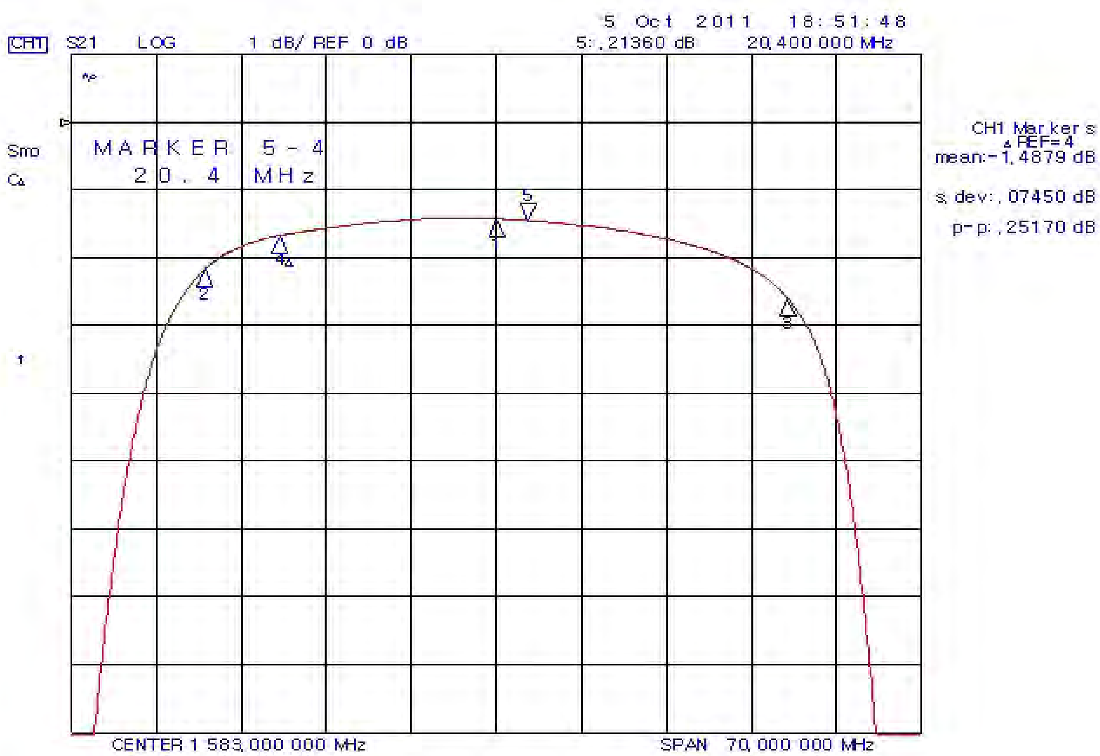
SPAN 70.000 000 MHz


5 Oct 2011 18: 52: 06
CH1 S21 LOG 1 dB/ REF 0 dB 3:-.43670 dB 48.000 000 MHz
MARKER 3 - 2
48 MHz
Smo
Cu
CH1 Markers
ΔREF=2
mean:-1.6657 dB
s. dev: .26300 dB
p-p: 1.1815 dB
CENTER 1 583.000 000 MHz
SPAN 70.000 000 MHz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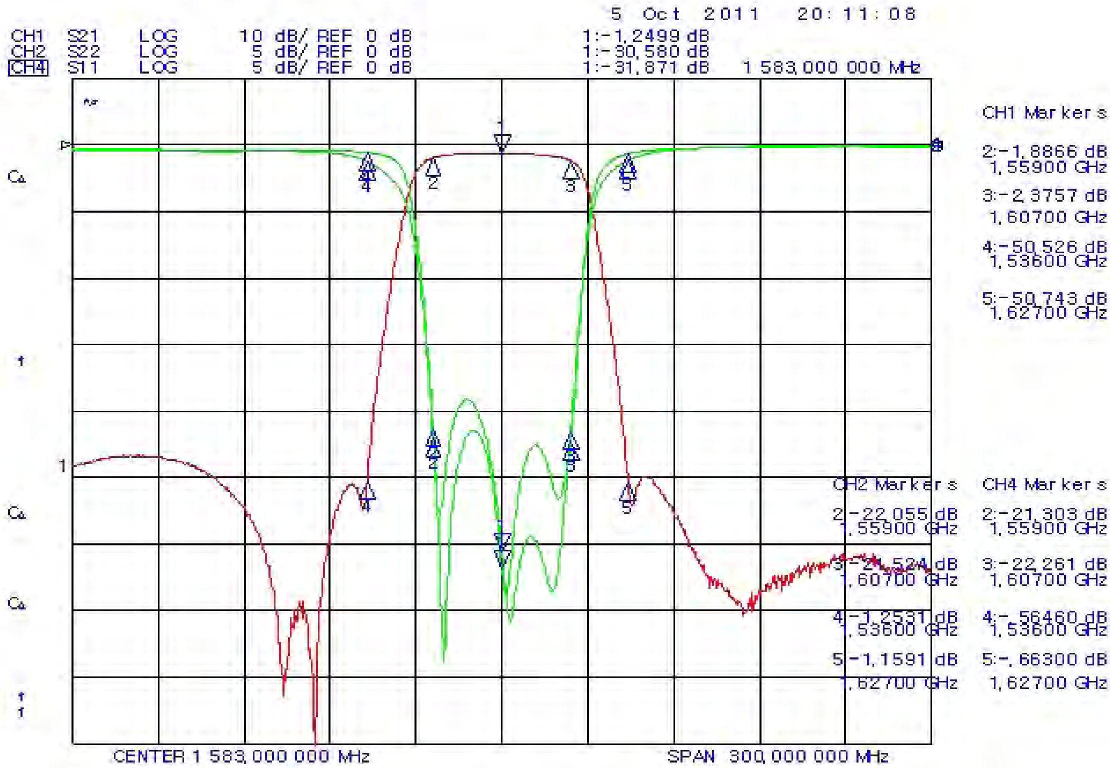
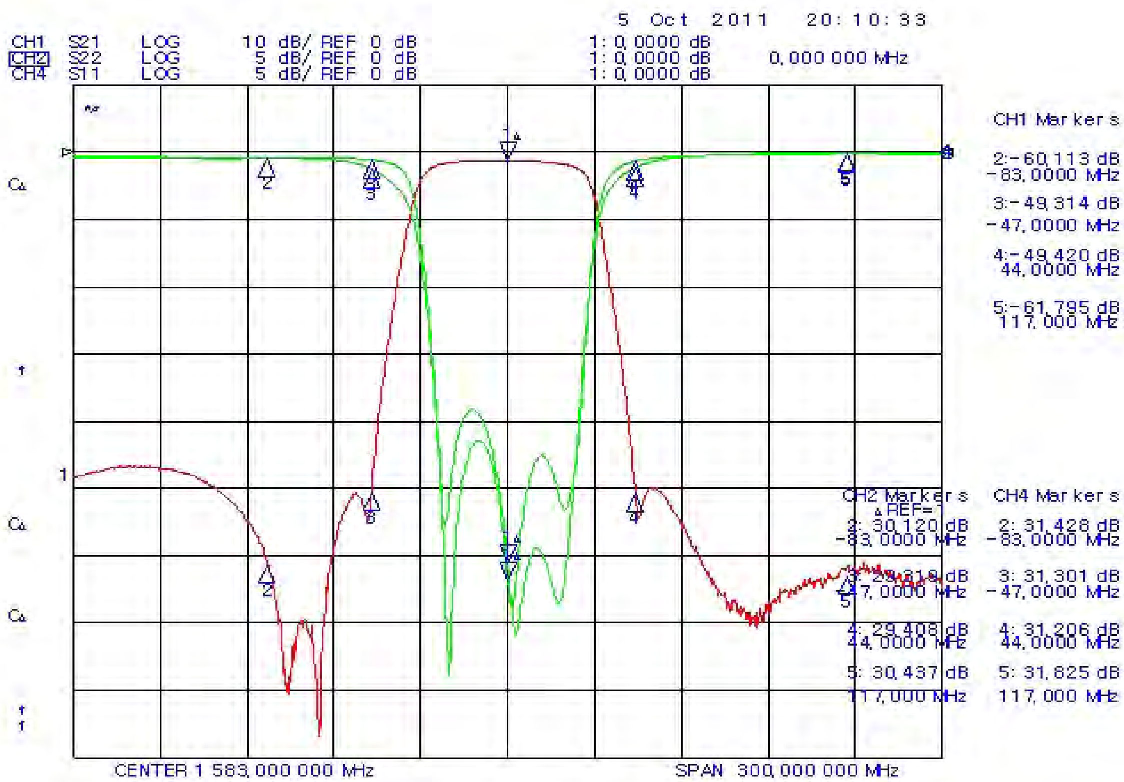
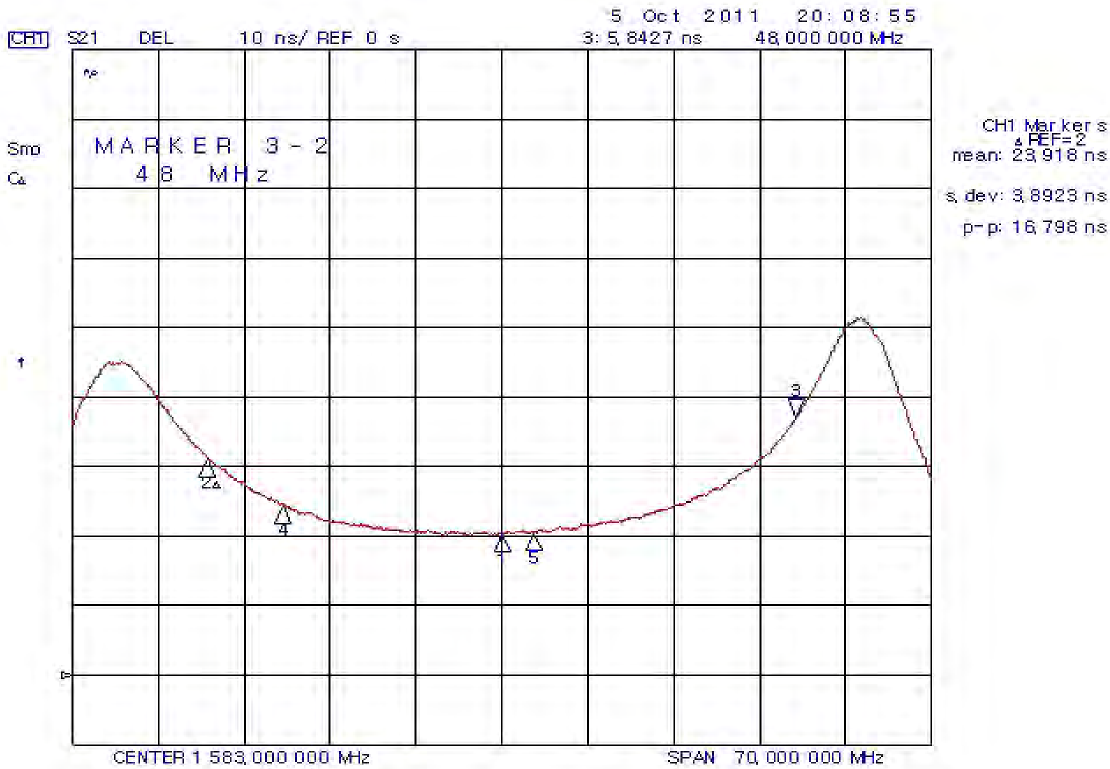
MARKER 5 - 4
20.4 MHz
Smo
Cu
CH1 Markers
ΔREF=4
mean:-1.4879 dB
s. dev: .07450 dB
p-p: .25170 dB
CENTER 1 583.000 000 MHz
SPAN 70.000 000 MHz

4. PLOT DATA (@ 40°C)



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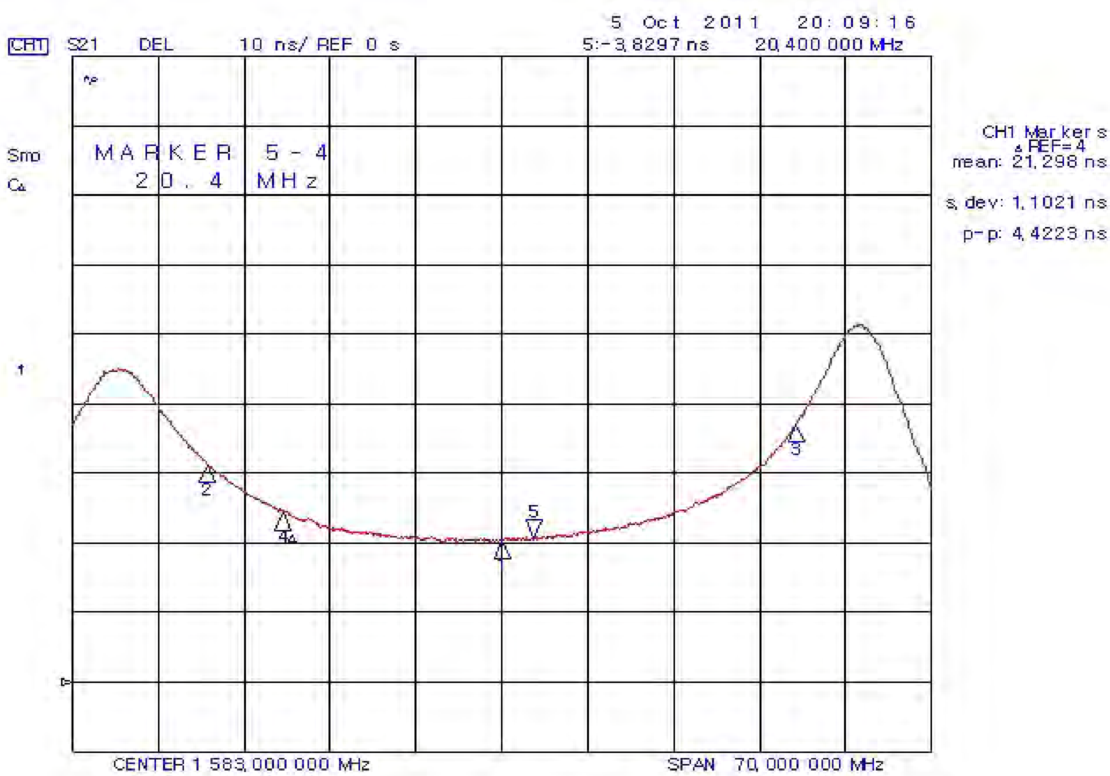
MARKER 3 - 2
48 MHz
Smo
Cl
CH1 Markers
ΔREF=2
mean: 23.918 ns
s.dev: 3.8923 ns
p-p: 16.798 ns
CENTER 1 583.000 000 MHz
SPAN 70.000 000 MHz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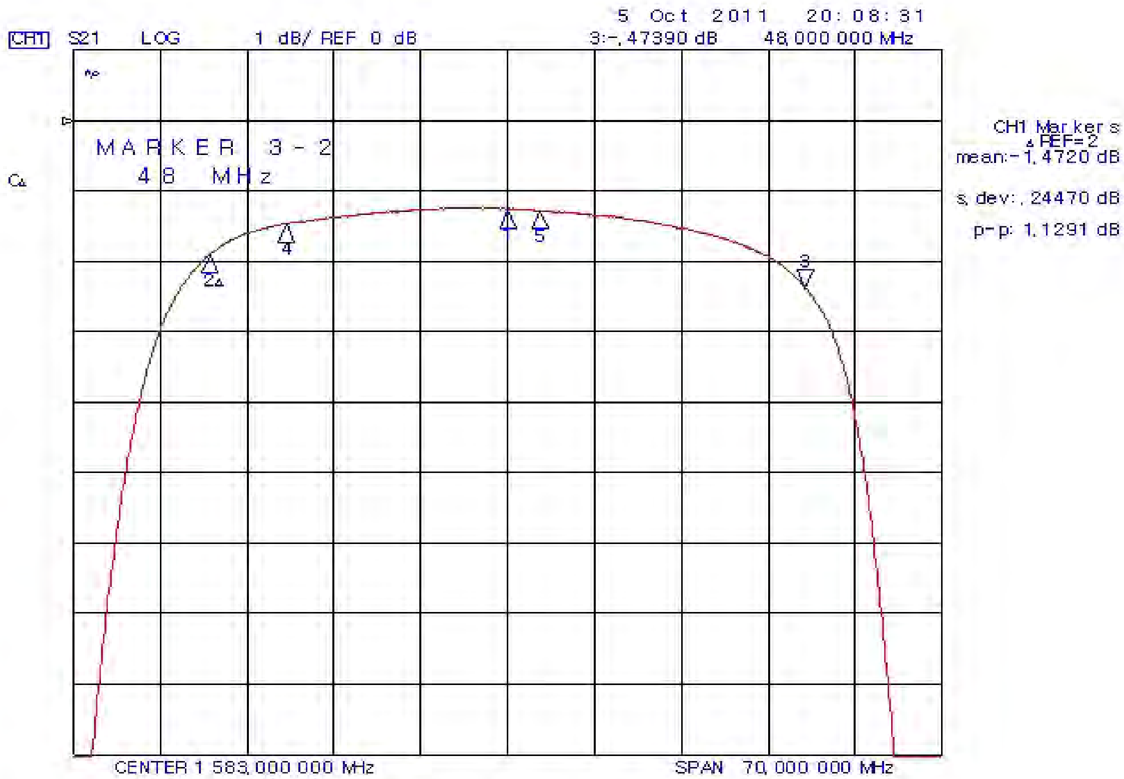
CH1 S21 DEL 10 ns/ REF 0 s
5:-3.8297 ns 20.400 000 MHz
MARKER 5 - 4
20.4 MHz
Smo
Cl
CH1 Markers
ΔREF=4
mean: 21.298 ns
s.dev: 1.1021 ns
p-p: 4.4223 ns
CENTER 1 583.000 000 MHz
SPAN 70.000 000 MHz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MARKER 3 - 2
48 MHz
CH1 Markers
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p-p: 1.1291 dB
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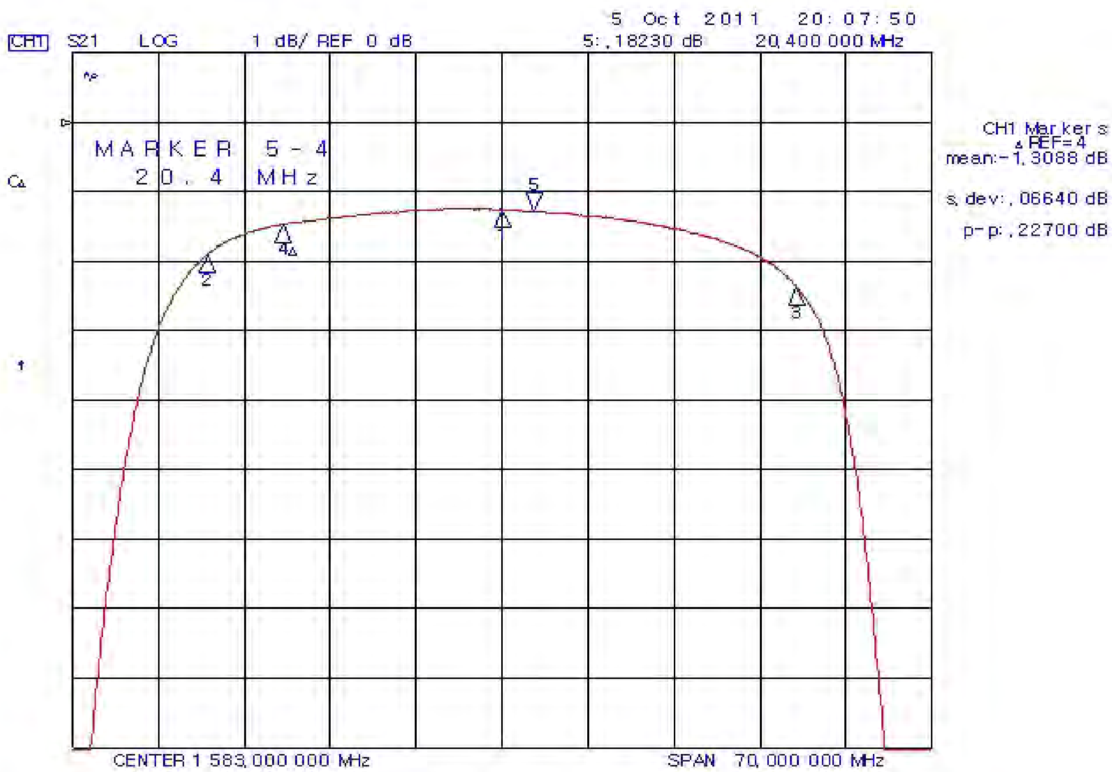
SPAN 70.000 000 MHz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MARKER 5 - 4
20.4 MHz
CH1 Markers
Δ REF=4
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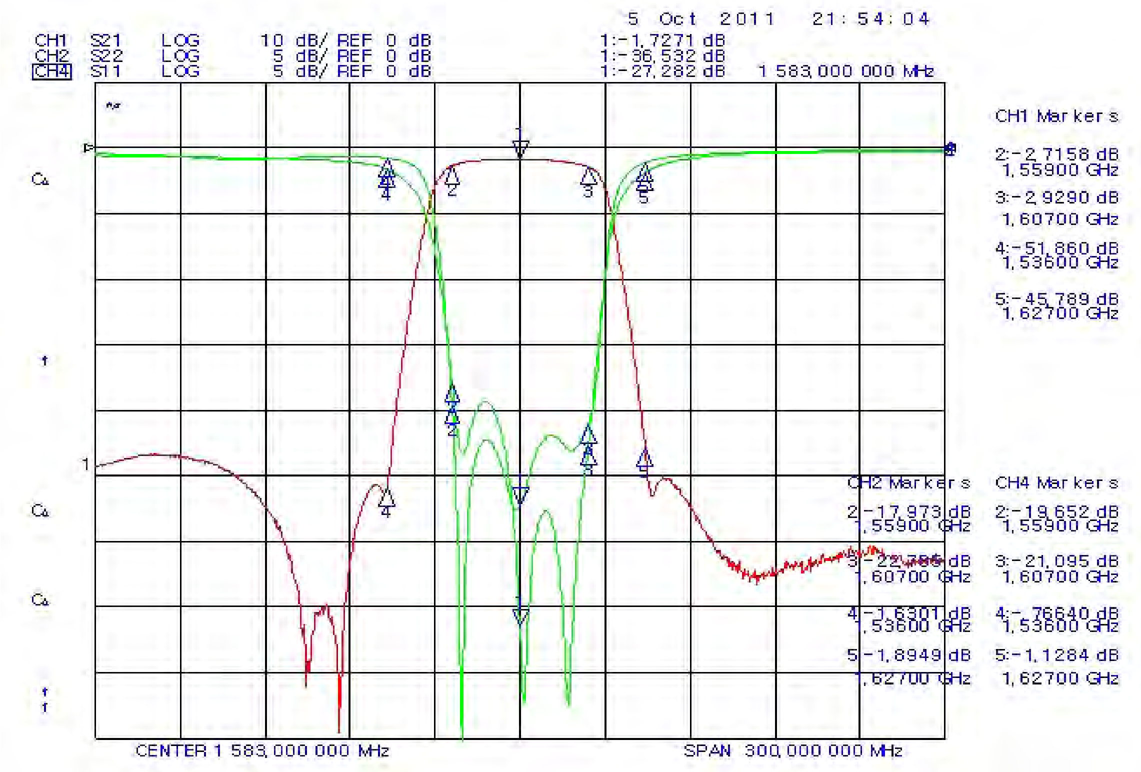
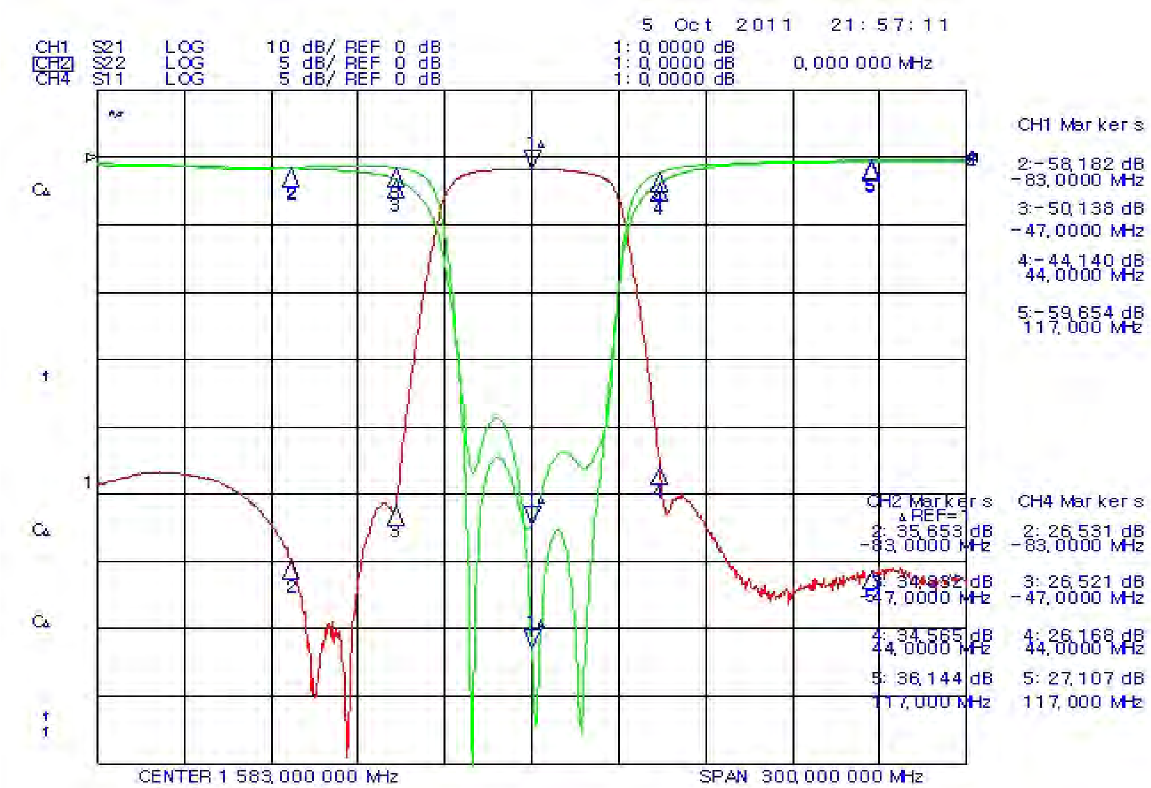
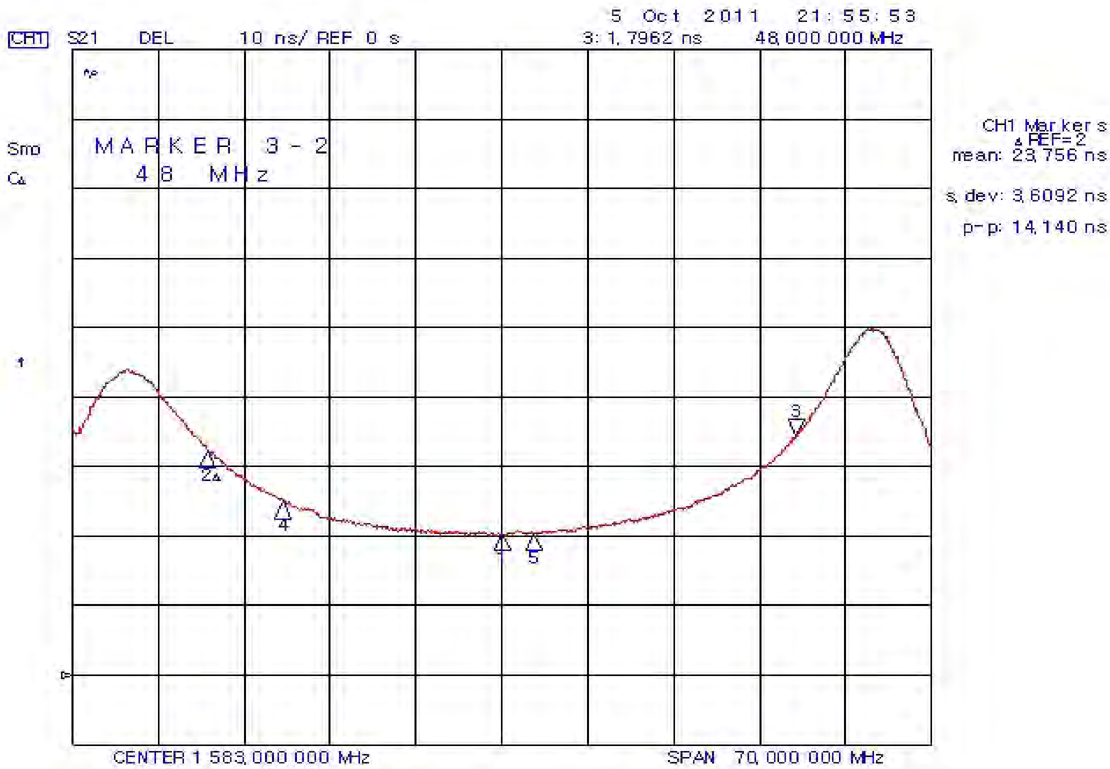
s.dev:.06640 dB
p-p:.22700 dB
CENTER 1 583.000 000 MHz
SPAN 70.000 000 MHz

5. PLOT DATA (@ +85°C)



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MARKER 3 - 2
48 MHz
Smo
CH1 Markers
REF=2
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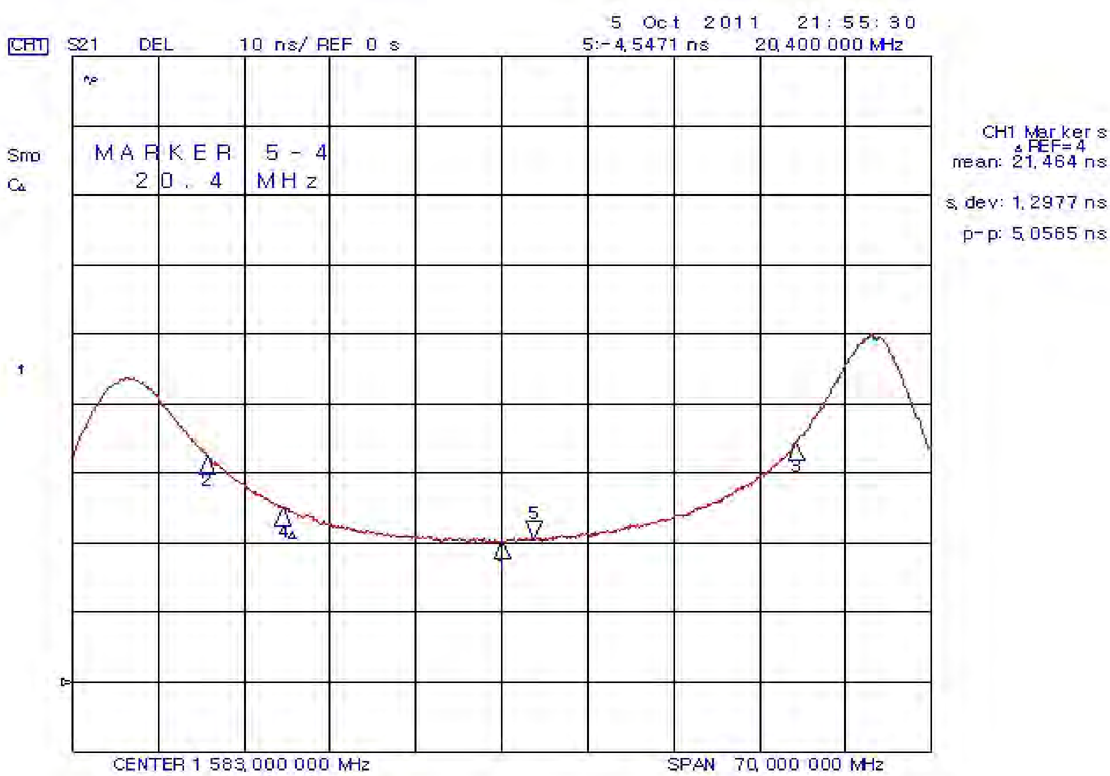
s.dev: 3.6092 ns
p-p: 14.140 ns
CENTER 1 583.000 000 MHz
SPAN 70.000 000 MHz


5 Oct 2011 21:55:30
CH1 S21 DEL 10 ns/ REF 0 s
5:-4.5471 ns 20.400 000 MHz
MARKER 5 - 4
20.4 MHz
Smo
CH1 Markers
REF=4
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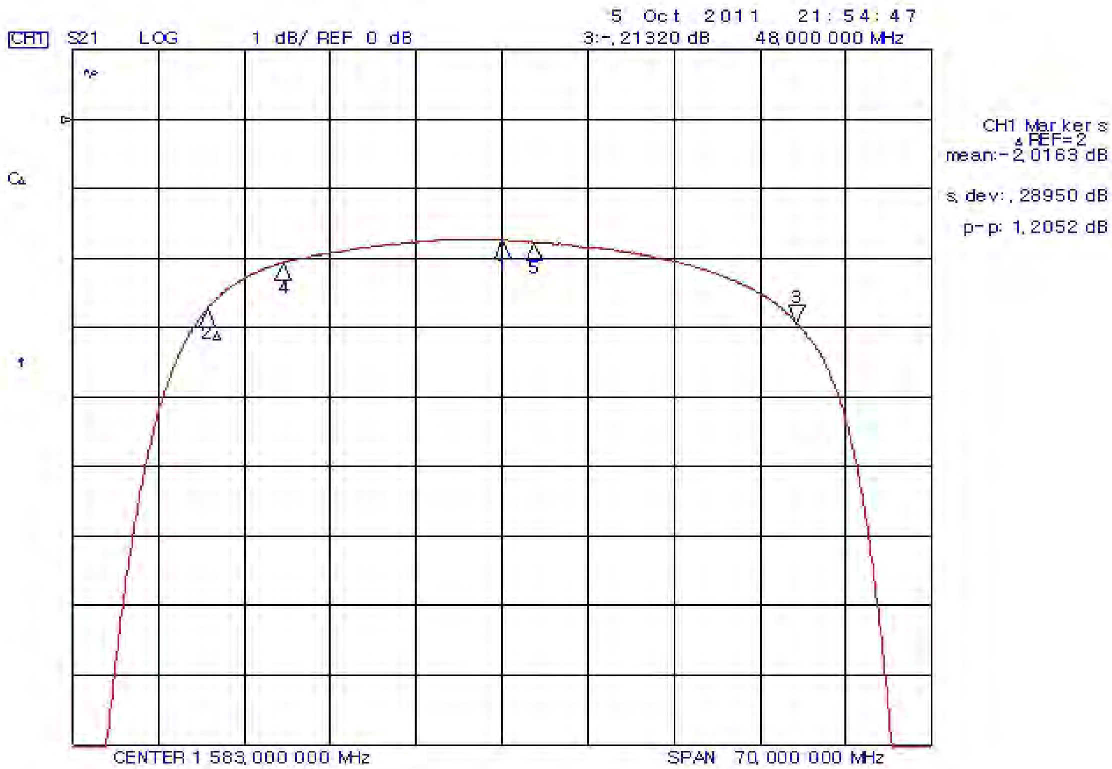
p-p: 5.0565 ns
CENTER 1 583.000 000 MHz
SPAN 70.000 000 MHz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CH1 Markers
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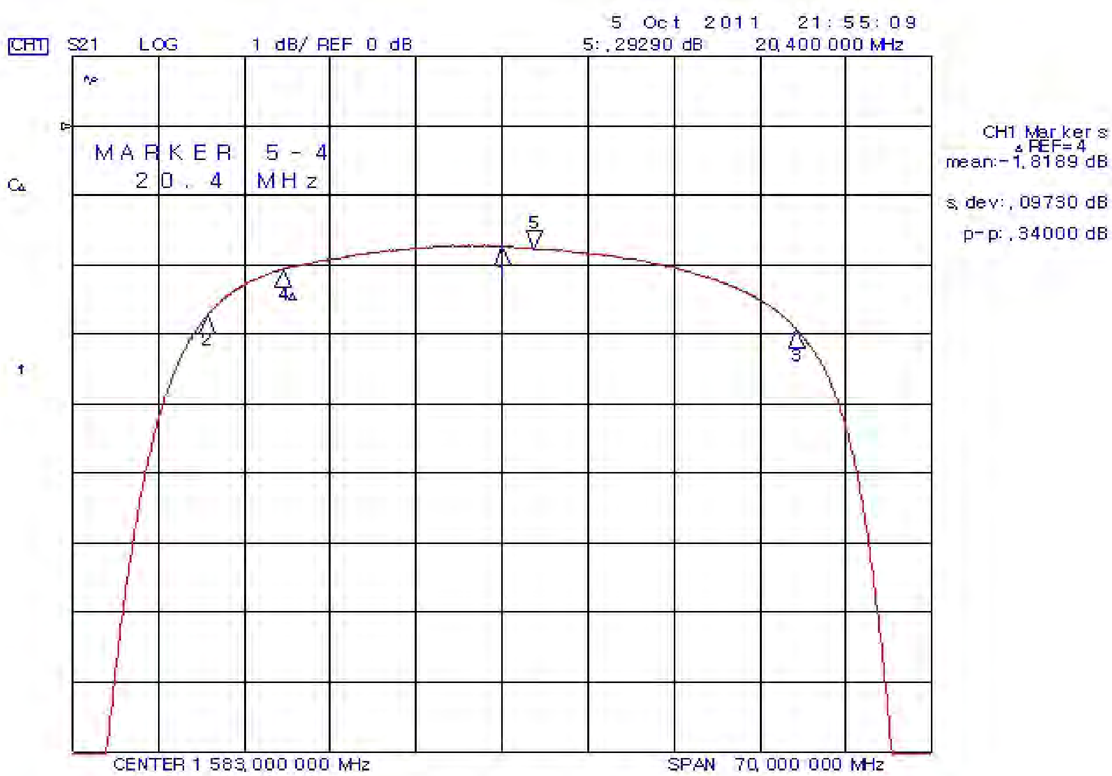
s.dev:.28950 dB
p-p: 1.2052 dB
CENTER 1 583.000 000 MHz
SPAN 70.000 000 MHz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MARKER 5 - 4
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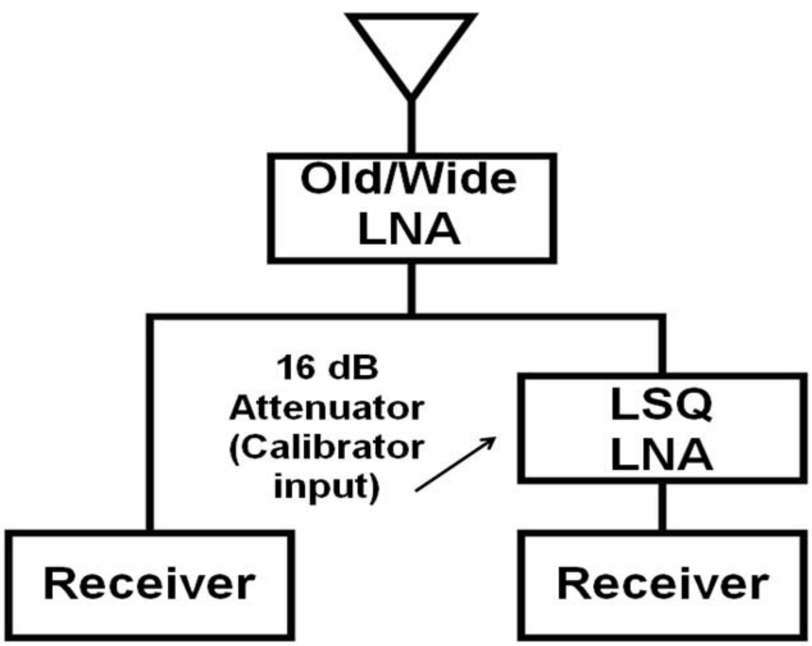
CH1 Markers
Δ REF=4
mean:-1.8189 dB
s.dev:.09730 dB
p-p:.34000 dB
CENTER 1 583.000 000 MHz
SPAN 70.000 000 MHz

Attachment C-2

Javad's Zero Baseline Tests comparing performances of modified and unmodified high precision GNSS antenna

A zero-baseline test was performed by Javad GNSS to test if the incorporation of the additional preselector filters in the modified degraded its performance relative to an unmodified antenna. The test set up is shown in Figure C-2.1 below. The position was calculated using signals coming directly from the unmodified wideband antenna as well as after undergoing the additional filtering in the modified, constrained bandwidth antenna. A 16 dB attenuator was used to reduce the signal power at the input to the modified antenna (output of the unmodified antenna) to the same level as at the input to the unmodified antenna. The advantage of the zero-baseline test set up is that propagation channel variations between the signals fed to the two receivers are completely eliminated.

Figure C-2.1 Zero-Baseline test to determine the effect of filtering on position accuracy



The results are shown below in Figure C-2.2

Figure C-2.2 Zero Baseline Test Results

Zero Baseline Results (Carrier Phase), cm		
Calibrator	Off	On
GPS L1	0.02	0.02
GPS L2	0.01	0.01
GLN L1	0.39	0.14
GLN L2	0.01	0.01

Zero Baseline Results (Code Phase), cm		
Calibrator	Off	On
GPS P1	4.22	4.86
GPS P2	5.73	4.08
GLN P1	60.36	7.38
GLN P2	2.03	1.36

The results show the position difference between the two receivers. The "calibrator" refers to the self-calibration (group delay equalization) capability of the receiver. The results show that, even for high precision receivers, where the position estimate is based on carrier phase, the difference between the two receivers is less than 0.2 mm. For the lower precision, code-phase based receivers, the error is also quite small (less than 5 cm) by the standard of such receivers. Furthermore, it is clear that group delay equalization, where advantageous, is not necessary to achieve the above accuracies for CDMA based GPS signals. The group delay equalization is more useful for the GLONASS (GLN) signals, which are of the FDMA type.

ATTACHMENT 1

DECLARATION OF SANTANU DUTTA, Ph.D.

I, Dr. Santanu Dutta, make the following declaration.

1. I am Senior Vice President of Radio Access Technologies and Chief Engineer of LightSquared Inc. ("LightSquared").

2. I am the technically qualified person responsible for the technical and engineering information contained in the foregoing Technical Appendix. I have either prepared or reviewed that information and certify that to the best of my knowledge and belief it is truthful and accurate.

I declare under penalty of perjury that the foregoing is true and correct.

Executed on March 15, 2012.

Santanu Dutta

Santanu Dutta

DECLARATION OF JEFFREY J. CARLISLE

I, Jeffrey J. Carlisle, hereby make the following declarations under penalty of perjury.

1. I am Executive Vice President, Regulatory Affairs and Public Policy of LightSquared Inc. ("LightSquared"). In that capacity, I am responsible for all domestic and international regulatory and policy matters on behalf of LightSquared, including those at the FCC.

2. I have reviewed the foregoing "Comments in Opposition of LightSquared Inc.", and certify that, to the best of my knowledge and belief, the factual assertions in that pleading are truthful and accurate.

/s/ Jeffrey J. Carlisle
Jeffrey J. Carlisle

Executed: March 16, 2012

DECLARATION OF SANTANU DUTTA

I, Santanu Dutta, hereby make the following declarations under penalty of perjury.

1. I am Senior Vice President, Radio Access Technologies and Chief Engineer of LightSquared Inc. ("LightSquared"), and am the technically qualified person responsible for the technical aspects of the foregoing "Comments in Opposition of LightSquared Inc."

2. I am familiar with Part 25 of the Commission's rules, and have either prepared or reviewed the engineering information submitted in this pleading. To the best of my knowledge and belief, the engineering information presented therein is complete, truthful, and accurate.

/s/ Santanu Dutta
Santanu Dutta

Executed: March 16, 2012