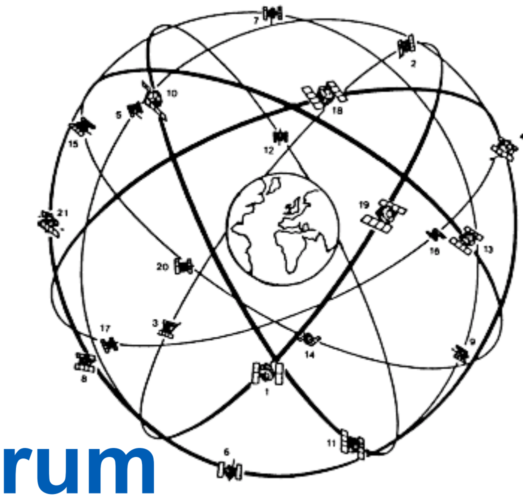


Protection of GPS Services for Public Safety Needs

The Genesis of L-Band Spectrum

Discussion, Analysis, and Cooperative Action Steps

Greg Buchwald
DMTS Engineer
CTO Organization
Motorola Solutions, Inc

History of L-Band Spectrum Allocations

■1500 / 1600MHz Bands

- Primary Allocation: Mobile Satellite Service (MSS)
  - GPS 1575.42MHz +/- 10MHz; other GNSS systems
  - Radioastronomy ~1610MHz
  - Inmarsat, Iridium; etc.
- **Weak Signal use-cases**

■2003

- FCC approves the use of Auxiliary Terrestrial Component (ATC) in the MSS spectral allocation bands; satellite component requirement removed
  - Action was essentially ignored by the industry
  - Allowed terrestrial power levels up to +72dBm EIRP / ~16kW
  - Protected 1559 – 1610MHz for GNSS (GPS) services

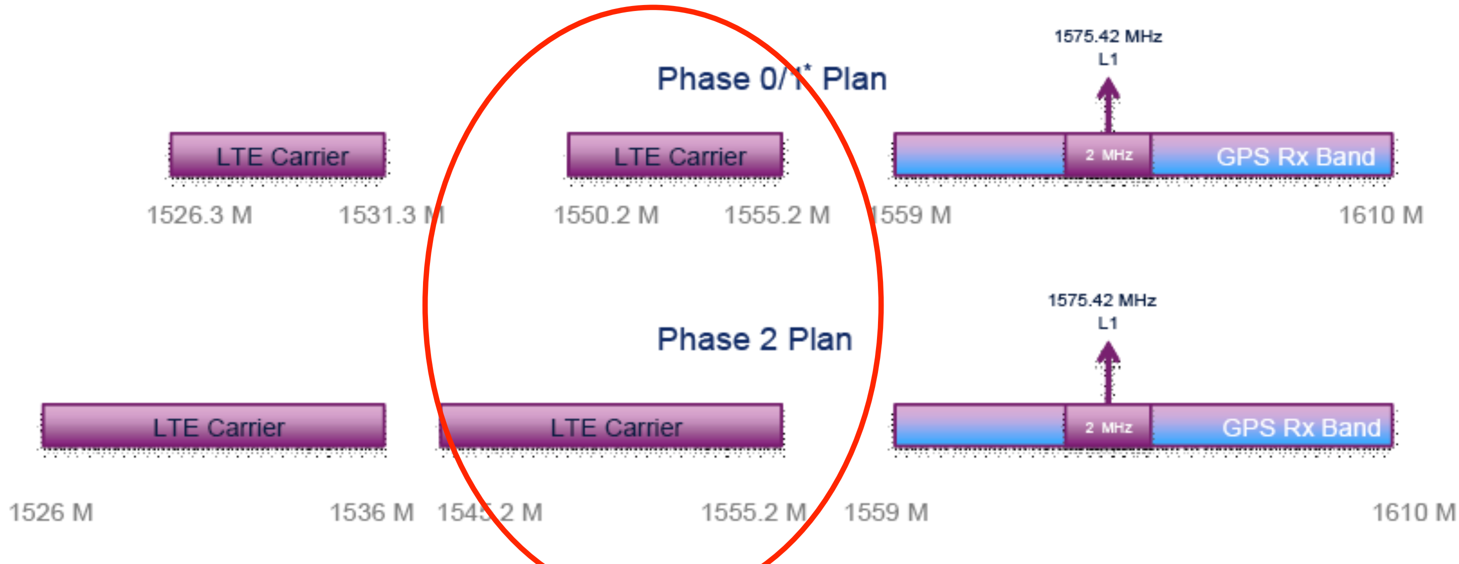
■2009/2010

- Next-Gen GPS-based aircraft assisted-landing system approved.
- Harbinger request approved (2010)
- GPS Industry awakens; realizes threat to currently-deployed GPS-based systems
- February, 2011: FCC reacts by temporarily withdrawing approval to deploy; orders Working Group formed to assess interference potential.

LightSquared Terrestrial Service Landscape in 2011

2.1. L-band ATC Frequency Plans GPS

Figure 1 describes the LightSquared's present ATC frequency plans by deployment phase. These plans are subject to coordination with other satellite operators and may change in the future. However, a change in the frequency plans would not change LightSquared's obligations to protect other services in adjacent bands, such as GPS.



*Only upper 5-MHz LTE carrier is used in Phase-0. Both 5-MHz carriers are used in Phase-1

Figure 1: Lightsquared Downlink LTE L-Band and GPS Band

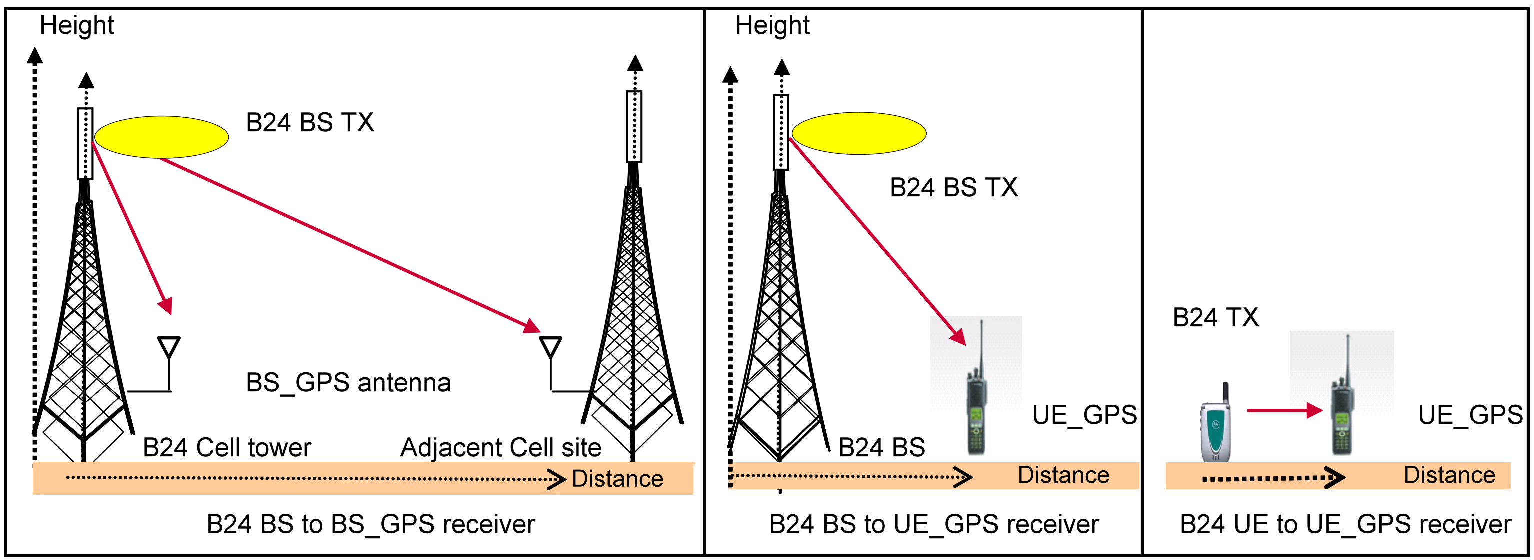
Round 1 Testing; Industry-wide 2010-2012

- Lab testing of Motorola Solutions Infrastructure Equipment Began December 2010. Initial test results reported to FCC early March, 2011
- Test program expanded to include mobiles, portables, MDTs, PTP, PTMP, accessories and older infrastructure
- FCC Working Group formed
  - Motorola Solutions:
    - Advisor status / participation on the Precision Timing and General Location and Navigation Sub-groups (FCC); daily calls 7 days a week for 6 weeks.
    - **Chaired above-listed sub-groups for NPSTC (National Public Safety Telecommunications Council) including FCC response / filings**
- Live Sky Testing
  - Las Vegas, NV: May, 2011
- Additional WG lab testing
  - Alcatel Lucent: Late May, Early June, 2011
- FCC WG report filed June 30, 2011
  - Comment period ended July 30, 2011
  - Reply Comment period ended August 15, 2011

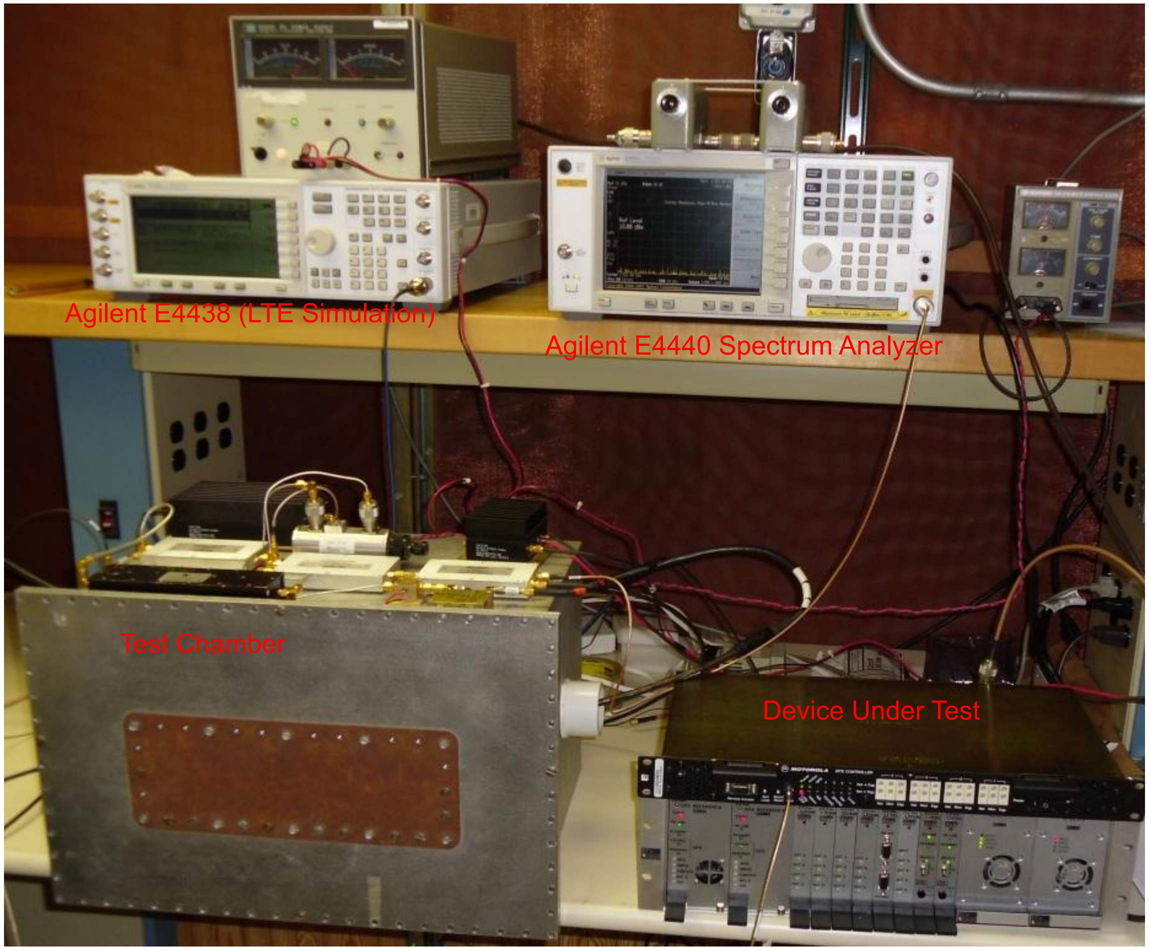
Interference Scenarios

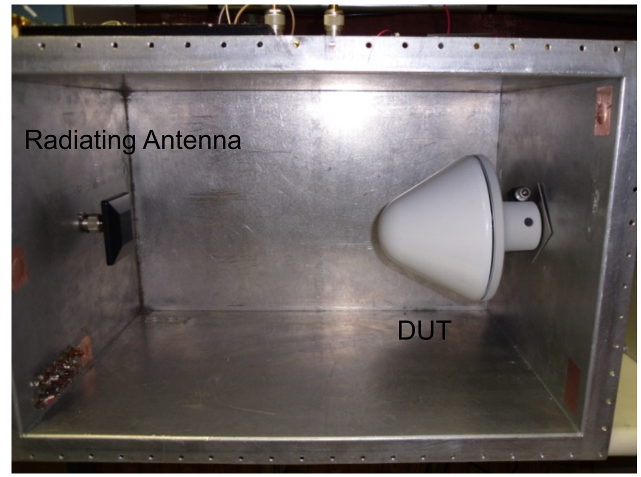
Two Interference Mechanisms

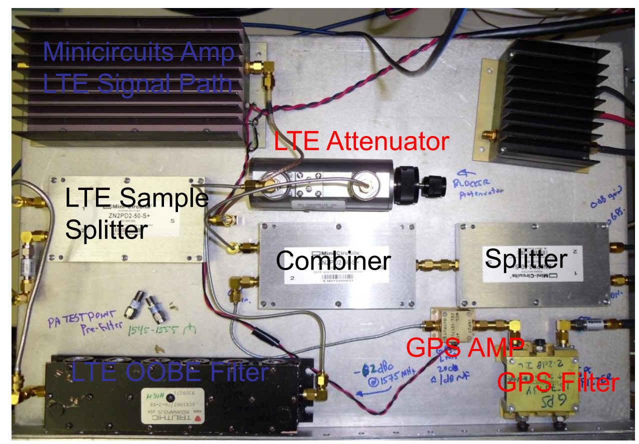
1) **OOBE into GPS receiver – can only be fixed at L.S. transmitter**
   - LightSquared is added filtering to mitigate
2) **GPS receiver blocking – <u>can only be fixed at receiver</u>**
   - Function of GPS receiver design and,
   - Distance between LightSquared Transmitter and Victim Receiver
   - Cross-Modulation Product-caused Interference.



L-Band Interference Test Fixture







Lengthy Test Procedure……

- Determine proper GPS level: -142dBm/2MHz at the receiver / DUT input.
- Increase interfering LTE signal until lock is lost. Reduce interferer level until lock is regained.
- Increase the interferer level by 10dB so that lock is lost.
- Reduce interferer level by 10dB; check receiver / DUT for reception and lock of at least 4 satellites within 60 seconds.
  - If lock is attained, record level.
  - If lock could not be attained, reduce interferer level by 1dB; re-check lock status.
  - Determines level at which the DUT recovers from a hold-off 10dB increase in interferer level
- A total of four measurements were made within a time span of 10 minutes to determine the maximum allowable interference level.
  - The worst case number was thrown out and the remaining 3 levels were retained.
- Repeat at <u>4, 8, and 16 hour intervals</u> after the initial measurement.
  - Conducted tests: composite test signal fed directly to the DUT.
  - Radiated tests: path loss between the passive, radiating antenna and the DUT antenna is measured.
- The above-listed tests are performed with a 10MHz BW LTE waveform (fc=1550MHz).

RIGOROUS; TIME CONSUMING

- **Calculate Denial of GPS Service Radius based on Free-space Path Loss (PLE = 2)**
  - Denial of GPS Service radius based on 1kW EIRP (+60dBm)

Primary Consequences of Interference

- **Base Station**
  - Simulcast Systems
    - Immediate alarm sent to dispatch or control office if tracked and locked satellites drops below 4
    - In as little as 4 hours or as much as 24 hours, site becomes disabled; taken off-line (lack of timing reference)
      - Lost timing accuracy
        - Alarm, system degradation, potential site deactivation
        - Collision avoidance, spectrum efficiency impacts…self-interference

- **Subscriber Units**
  - Reduction of location accuracy
    - Officer scenarios
      - Officer-down location: potential response time impact, etc.
      - Traffic stop location: important in escalated situation
    - Potential impact to location stamping of voice and video recording used for evidence
    - NPSTC: 10 – 15 meter accuracy required by most equipment contracts

Mitigation Methods Employed

- Redesign devices to utilize improved GPS chipsets, and
- Re-design the antenna to incorporate a narrowband filtering
  - Impact to sensitivity of GPS receiver due to additional insertion loss
  - Cost involved

- Infrastructure Timing: Utilize High-rejection Antenna / LNA equipment now offered

Device Number	LTE Level; RX Input	Distance A Bore-sight	Distance B -20dB
1	-20dBm	155 meters	15.5 meters
2	-20.5dBm	160 meters	16 meters
3	-24dBm	240 meters	24 meters
4	--48.5dBm	4.1 km	410 meters
5	-37.5dBm	1.1 km	110 meters
6	-18 dBm	120 meters	12 meters
7	-20dBm	155 meters	16 meters
8	-22dBm	190 meters	19 meters
9	--47dBm	3.8 km	380 meters
10	-35dBm	850 meters	85 meters
11	-38dBm	1.2 km	120 meters
12	-35dBm	850 meters	85 meters
13	-1.8dBm	19 meters	1.9 meters
14	-2.2dBm	20 meters	2.0 meters

APX6000 UHF (w/SAW)

APX7000

Device Number	LTE Level; RX Input	Distance A Bore-sight	Distance B -20dB
15	-36dBm	950 meters	95 meters
16	-37dBm	1.1 km	110 meters
17	-26.5dBm	325 meters	33 meters
18	-24dBm	245 meters	24.5 meters
19	-28dBm	390 meters	39 meters
20	-18dBm	110 meters	11 meters
21	-29dBm	435 meters	43.5 meters
22	-39dBm	1375 meters	137.5 meters
23	-33dBm	680 meters	68 meters
24	-30dBm	490 meters	49 meters
25	+11.5dBm	<3 meters	<<3 meters
26	+10.5dBm	<3 meters	<<3 meters
27	+5dBm	4.75 meters	<3
28	+4dBm	6 meters	<3 meters

High Rejection Infrastructure

Containment of the problem and designing for the anticipated deployment environment is critical to meeting the needs and expectations of public safety and the industry.

June, 2014 FCC Workshop on GPS… Signals Action on L-Band Spectrum

Home / News & Events / Events /

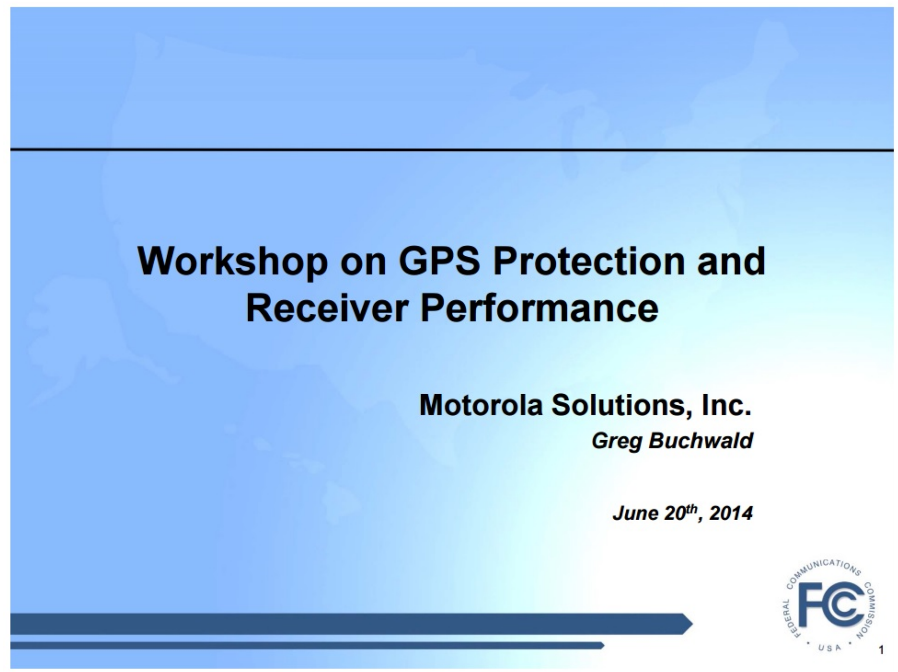
Workshop on GPS Protection and Receiver Performance

JUN 20 2014 | Workshop on GPS Protection and Receiver Performance

9:00 am - 5:00 pm EDT

Commission Meeting Room, FCC Headquarters, 445 12th Street, S.W., Washington, D.C.

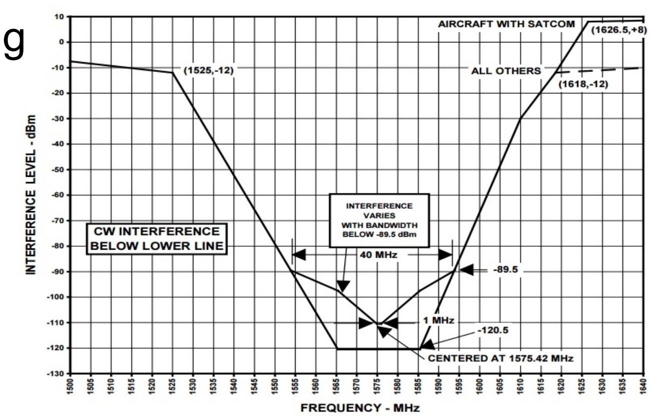
Begin to consider the impact to GPS from high power terrestrial signals in L-band spectrum once again; reach out to influence deployment criteria and regulatory environment



Renewed L-band Emphasis by LightSquared in 2015….

Revised LightSquared band-plan; Roll-out

- Downlink:
  - The “Upper” band (~1545 – 1555MHz) will not initially be deployed
  - “Lower” band (~1525 – 1535MHz) will be rolled out as a 10MHz LTE downlink channel
- Uplink:
  - 10MHz LTE profile; f_c between 1628 and 1631MHz; 1670 – 1680MHz
  - Standard LTE uplink power profile: +23dBm
- Mid-band ~1551MHz allocation still in long term plan; doubtful it will ever succeed.
- FAA / DoD and NWS resolution discussions on-going



MOTOROLA

Renewed Testing; New Era of Increased Cooperation and Industry Input

- Cooperative approach from Ligado (LightSquared)
  - Roberson and Associates retained to perform all tests
  - R/A reached out to NPSTC for input on test procedures and regulatory perspective
  - Ligado reached agreements with John Deere, other GPS manufacturers – again, extensive cooperation
  - NPSTC met multiple times face-to-face with R/A; inputs always openly taken and acted upon
    - Strongly Influenced Test Procedures
    - Measurement of re-acquisition of GPS signal methods,
    - Power Flux Density (on ground); PSD levels,
    - Several other concerns

NPSTC Actions and Initial Filing Q2/3/4 2015

Comments re: Ex Parte presentation in IB Docket 12-340; SAT-MOD-2010118-00239, 2012-0928-00160, 20120928-0161, 20121001-00872 filed 25 August, 2015

GPS Sensitivity Measurement Plan; revised

On August 11, 2015, I met with Roberson and Associates at their Schaumburg office at the request of Stu Overby on behalf of NPSTC. Stu Overby was present. At that time, we discussed issues identified within the then-current test plan proposed by Roberson and Associates. In the ensuing time since that meeting, a revised test plan was presented to the Commission by LightSquared through their Council, Gerald Waldron o f Covington and Burling.

Stu Overby asked that I review the revised document and comment on the revised test plan. My comments follow:

In general, the test plan accurately reflects the interests of the Public Safety community including NPSTC and its membership. There remain a small number of issues that require clarification and / or revision. These will be addressed by page number in the revised (25 August, 2015) test plan presented to the Commission.

On Page 4: There remain only two identified public safety devices that will be tested (as opposed to multiple additional items in the 2011 time frame testing): The MSI APX7000 subscriber device and the MW810 Mobile Data Terminal. MSI feels that these two devices sufficiently represent products currently in production and offered for sale to the Public Safety community. It would be better if these devices were called out in a separate category, or at a minimum, a footnote identify these as devices that are utilized for public safety / **critical life safety** applications. Categorizing them with "general location and navigation devices" suppresses the criticality of accuracy and reliability of such devices: Data recorded by these devices may be utilized for evidentiary purposes, is critical to fast response in the case of officer down and other life / safety issues, and for accurate response of limited resources through dispatch. The importance of GPS data in these use-cases must not be lost or reduced. MSI also notes that certain other law enforcement devices which are not manufactured by MSI but of critical importance to the law enforcement community seem to not be represented in the test plan. These include devices such as "ankle bracelet" tracking devices for those held on house arrest and limited release. Also, vehicular tracking devices, utilized for surveillance purposes, should also be included in the test plan. NPSTC should consider whether these devices should be added to the list for completeness and to insure that proper coverage is included. We also note that timing reference signal devices, such as those manufactured by Trak, are not represented in the Timing portion of the test plan; however, the devices listed adequately

NPSTC
National Public Safety Telecommunications Council

September 9, 2015

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

Re: IB Docket No. 12-340

Dear Ms. Dortch:

The National Public Safety Telecommunications Council (NPSTC) is a federation of public safety organizations whose mission is to improve public safety communications and interoperability through collaborative leadership. NPSTC pursues the role of resource and advocate for public safety organizations in the United States on matters relating to public safety telecommunications. Accordingly, NPSTC provides guidance on issues that can either negatively impact or benefit the operation of public safety communications.

On June 24, 2015 through its legal counsel, LightSquared, LLC submitted notice of an *ex parte* presentation made to Commission officials by its engineering consultant Roberson and Associates. The LightSquared filing addressed "an initial perspective on testing of the compatibility of terrestrial broadband and GPS."[1] LightSquared subsequently submitted a revised test plan on July 15, 2015. The *ex parte* statement that accompanied this revised plan noted "...we hereby renew the request for such comments and critiques and hope to receive feedback within the next week, since testing is anticipated to

Summary

- **NPSTC has remained vigilant on the issue of GPS protection**
  - It remains the industry-wide advocate of GPS protection for the Public Safety Community.
- **Terrestrial use of L-band will most likely occur**
  - The spectrum is far too valuable to allow it to lie fallow,
  - MSS services have proved to be useful in rural areas while urban areas can best utilize the spectrum for terrestrial use-cases,
  - The FCC is under tremendous pressure to open additional spectrum for broadband.
- **Spirit of Cooperation**
  - LightSquared was selectively cooperative in the 2011/2012 time frame,
  - The re-organized LightSquared, now Ligado, is attempting to cooperate industry-wide this time around: 2015/16,
  - Involvement of third party consultants that have interest in opening spectrum yet protection of incumbents and adjacent service users such as Roberson and Associates demonstrate their desire to find a fully workable solution.

We must all remain vigilant - trust but verify. NPSTC and its partners in this activity have public safety's best interest in mind.

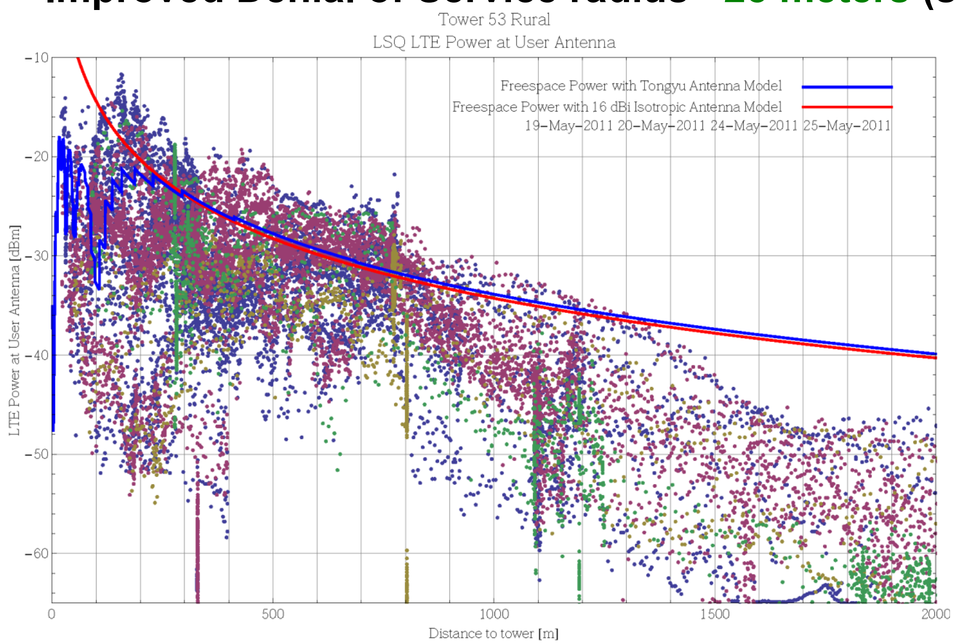
Additional Slides for Discussion and Q/A

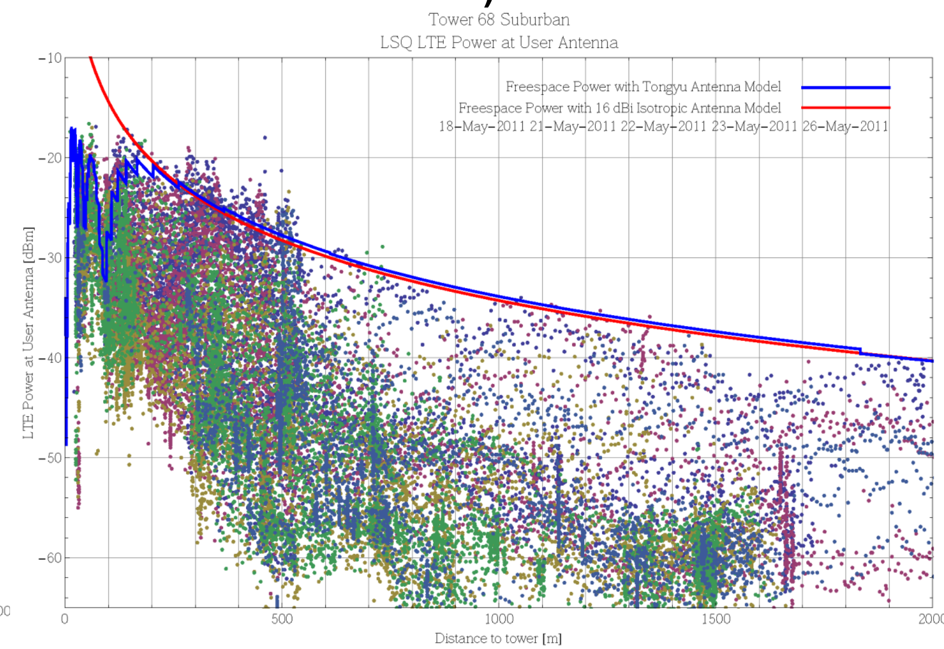
Live Sky Testing: Las Vegas, NV

Early Subscriber Denial of Service radius ~185 meters

MDT Denial of Service Radius ~610 meters

Improved Denial of Service radius ~25 meters (slant distance ~65 meters)



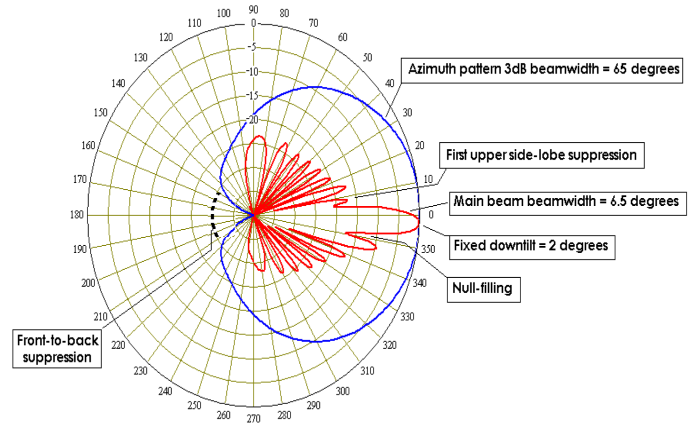


Received signal levels exceeded free space models in conjunction with published antenna power gain and pattern information in many cases. This is primarily due to efficient close-in reflecting objects (building, etc.) and “bounce” off the road causing constructive interference.

From the Working Group FCC filing June 30, 2011; combined data from 5 companies participating in Live Sky field testing.

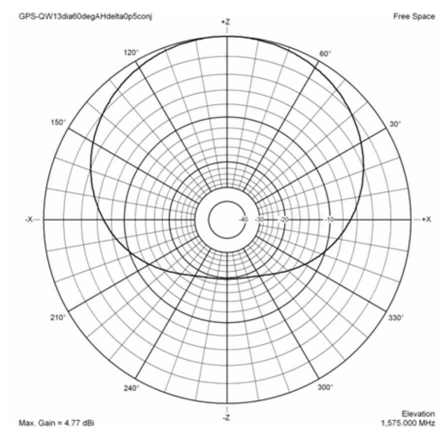
Interference Distance Calculations

- **Freespace Path Loss, FSPL is defined as:**
  - FSPL($_{dB}$)= 20log(d)+20log(f_{MHz}) - 27.55; where d is in meters
  - FSPL(dB)=20log(d)+36.25 @ 1550MHz
- **"Distance A" represents the LOS (Line of Sight) Denial of GPS Service radius assuming FSPL (Path Loss Exponent, PLE=2)**
- **"Distance B" represents the LOS Denial of GPS Service radius assuming an additional 20dB path loss (PLE=2) due to the elevation pattern of the L-Band base station antenna as well as the elevation pattern of GPS antenna**
  - Pattern loss can vary from <12dB to >25dB depending upon deployment; 20dB is a typical value.
- **Non-LOS path loss will be higher (ex: Base station to subscriber unit) in many instances. The PLE can vary from <2.8 to >3.6 for concerned range of separation distance.**
  - Example: A PLE of 3.3 will reduce the denial of service radius from 3600 meters to 145 meters
  - However, many services and deployment scenarios will endure LOS interference conditions



Single Column Antenna Patterns (dB) vs Angle (deg)
Elevation Pattern (red trace) Azimuth Pattern (blue trace)

PCS Antenna Pattern Example



Typical Elevation Pattern of a Quadrafilar GPS Antenna

Lead Paragraph of FAA Letter to NTIA From the FAA Introducing Their Report on LightSquared Impact Upon GPS

U.S. Department of Transportation
Federal Aviation Administration

Office of the Administrator

800 Independence Ave., S.W.
Washington, D.C. 20591

JAN 27 2012

The Honorable Lawrence E. Strickling
Administrator
National Telecommunications and Information Administration
U.S. Department of Commerce
1401 Constitution Avenue, NW.
Washington, DC 20230

Dear Mr. Strickling:

In June 2011, RTCA completed an assessment of the potential interference to certified aviation receivers resulting from the planned LightSquared long-term evolution (LTE) 4G network (RTCA, Assessment of the LightSquared Ancillary Terrestrial Component Radio Frequency Interference Impact on GNSS L1 Band Airborne Receiver Operation, RTCA/DO-327, June 3, 2011). This report concluded that their planned operation of the upper 10 MHz LightSquared channel would cause significant interference to GPS and should not be allowed. However, this report was inconclusive on the use of only the lower 10 MHz LightSquared channel, and the report recommended further study.

Section of FAA Report Discussing the Internationally-Harmonized Rejection Requirements for Adjacent Band Emissions Operating Near GPS Spectrum Allocations

The passband for this equipment is from 1565.42 MHz to 1585.42 MHz. Adjacent-band rejection requirements are specified for continuous waveform (CW) RFI below and above the GPS band, and all equipment is designed and tested to ensure that these requirements are met. The complete requirements are defined in Appendix C, RTCA/DO-229, which was first published in 1996. The same requirements are harmonized internationally (ICAO SARPs Annex 10 Volume I, paragraph 3.7.4) since 2001. For convenience, the CW filter rejection curve is shown in Figure 1-1. The adjacent-band rejection is enabled by filtering in the antenna and the receiver. As an example, for a CW signal at 1531 MHz 92.4 dB of rejection is designed into the aviation standards.

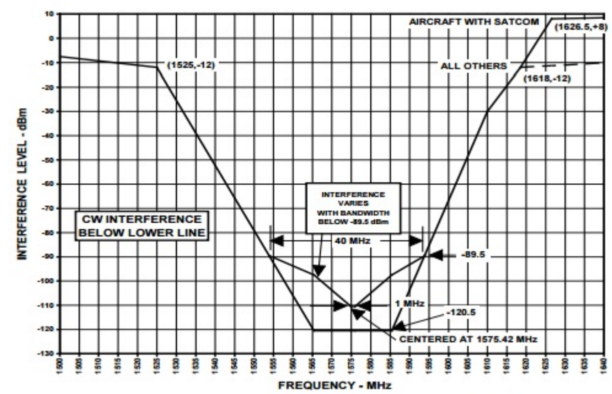
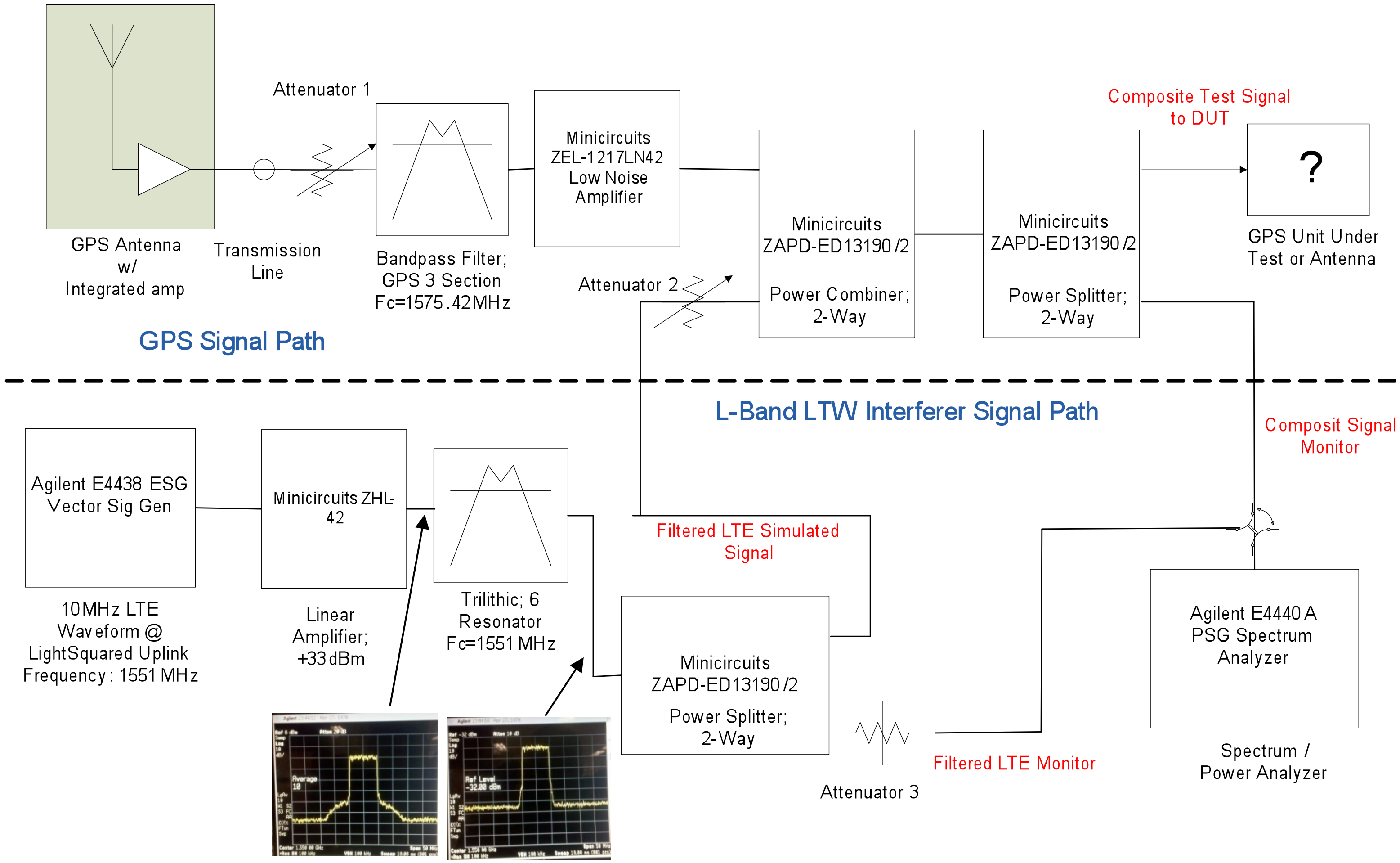


Figure 1-1 Out-of-band CW Interference Rejection Levels

The curve only specifies rejection of CW interference. Results from testing a limited number of certified receivers has indicated that tolerable interference levels are nearly equivalent for CW and a 10 MHz broadband noise signal centered at 1531 MHz. The

Laboratory Test Configuration



Lab Test Configuration
GPS Interference / Blocking Susceptibility to LightSquared L-Band Transmissions