GPS Adjacent Band Compatibility Assessment Topic Introductions

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Volpe The National Transportation Systems Center

Advancing transportation innovation for the public good

U.S. Department of Transportation
Office of the Secretary of Transportation
John A. Volpe National Transportation Systems Center

EXCOM Co-Chair Letter to NTIA

SPACE-BASED POSITIONING
NAVIGATION & TIMING
NATIONAL EXECUTIVE COMMITTEE

JAN 13 2012

UNITED STATES OF AMERICA

The Honorable Lawrence E. Strickling
Assistant Secretary for Communications and Information
U.S. Department of Commerce
Washington, DC 20230

Dear Assistant Secretary Strickling:

At the request of the Federal Communications Commission (FCC) and the National Telecommunications and Information Administration (NTIA), the nine federal departments and agencies comprising the National Space-Based Positioning, Navigation and Timing (PNT) Executive Committee (EXCOM) have tested and analyzed LightSquared's proposals to repurpose the Mobile Satellite Services (MSS) frequency band adjacent to Global Positioning System (GPS) frequencies to permit another nationwide terrestrial broadband service. Over the past year we have closely worked with LightSquared to evaluate its original deployment plan, and subsequent modifications, to address interference concerns. This cooperative effort included extensive testing and analysis of GPS receivers. Substantial federal resources have been expended and diverted from other programs in testing and analyzing LightSquared's proposals.

It is the unanimous conclusion of the test findings by the National Space-Based PNT EXCOM Agencies that both LightSquared's original and modified plans for its proposed mobile network would cause harmful interference to many GPS receivers. Additionally, an analysis by the Federal Aviation Administration (FAA) has concluded that the LightSquared proposals are not compatible with several GPS-dependent aircraft safety-of-flight systems. Based upon this testing and analysis, there appear to be no practical solutions or mitigations that would permit the LightSquared broadband service, as proposed, to operate in the next few months or years without significantly interfering with GPS. As a result, no additional testing is warranted at this time.

The EXCOM Agencies continue to strongly support the President's June 28, 2010 Memorandum to make available a total of 500 MHz of spectrum over the next 10 years, suitable for broadband use. We propose to draft new GPS Spectrum interference standards that will help inform future proposals for non-space, commercial uses in the bands adjacent to the GPS signals and ensure that any such proposals are implemented without affecting existing and evolving uses of space-based PNT services vital to economic, public safety, scientific, and national security needs.

ASHTON B. CARTER
EXCOM Co-Chair
Deputy Secretary of Defense

JOHN D. PORCARI
EXCOM Co-Chair
Deputy Secretary of Transportation

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Draft new "GPS Spectrum interference standards" to ensure that new spectrum proposals are implemented "without affecting existing and evolving uses of space-based PNT services"

EXCOM Letter

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GPS Adjacent Band Compatibility Assessment Plan (1 of 5)

U.S. Department of Transportation

Office of the Assistant Secretary for Research and Technology

FEDERAL AVIATION ADMINISTRATION

GPS ADJACENT-BAND COMPATIBILITY ASSESSMENT PLAN

December 2012

Cleared for Public Release

DOT GPS Adjacent Band Compatibility Assessment Plan (2 of 5)

History

- Based on the January 2012 EXCOM letter
- The DOT developed a "GPS Adjacent-Band Compatibility Assessment Plan" dated December 2012
- In August 2014 www.GPS.gov announced a September Adjacent Band Compatibility workshop and posted the Assessment Plan
- The first workshop was held at the Volpe Center on 18 September 2014
  - Workshop presentation materials are available at www.gps.gov/spectrum/ABC/#workshop
- The next workshop will be on December 4th 2014

DOT GPS Adjacent Band Compatibility Assessment Plan (3 of 5)

Development of Adjacent-Band Transmitter Power Limits

- "... initially deal with the frequency bands adjacent to ... GPS L1 ... once the initial GPS L1 task is complete ... iterated as necessary to address the other GPS civil signals as well as ... signals broadcast from future GNSS constellations."
- "Two ... sets of allowable adjacent-band transmitter power limits will be developed. The first set (Set 1) will protect existing GPS receivers ... based on measured GPS receiver performance. The second set (Set 2) will protect future GPS receivers designed to utilize modernized GPS signals and interoperable signals from other GNSS signals ..."
- The transition time between the two also will be determined

DOT GPS Adjacent Band Compatibility Assessment Plan (4 of 5)

Methodology – Four Technical Attribute Categories

GPS/GNSS Antenna/Receiver Susceptibility Defines the tolerable aggregate interference levels for an assumed type of adjacent-band signal, considering performance requirements, antenna/receiver architectures, and technology availability	**Adjacent-band Antenna/Transmitter** Defines the transmission characteristics, including modulation characteristics of the signal and type of antenna
GPS/GNSS Use Cases Defines the operational regions and applications of GPS/GNSS	**Adjacent-band Use Cases** Defines the operational locations, density and orientation of transmitters, considering the operational objectives for the use of the adjacent-band

- "Defining the type of application planned for deployment in the adjacent-band" "comprises the right-hand column of" the table and "Provided by the U.S. spectrum regulator(s) (i.e., the FCC and/or NTIA[4])"
- In the absence of clear definitions in the right hand column, the first analysis will be prototyped with an LTE type application with a clear set of assumptions. The purpose is to prepare and validate the analysis tools to when/if information become available.

DOT GPS Adjacent Band Compatibility Assessment Plan (5 of 5)

GPS receiver interference tolerance masks and use cases

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GPS/GNSS Use Cases Defines the operational regions and applications of GPS/GNSS	**Adjacent-band Use Cases** Defines the operational locations, density and orientation of transmitters, considering the operational objectives for the use of the adjacent-band

- "These elements comprise the left-hand column of" the table
- Known and likely types of interference will be evaluated
  - In order to establish susceptibility limits before having detailed transmitter filter, power, and deployment plans for single or multiple broadband systems
- GPS/GNSS use cases will be defined

GPS Interference Standards Criteria

- A received interference power mask such that the cumulative impact of all new broadband terrestrial signals, including from handsets, shall not cause more than 1 dB of C/N_0 loss to received GPS/GNSS signals
  - For CW interference
  - From a broadband interference such as 1 , 5, 10, 20 MHz bandwidths to address an LTE like signal interference
  - Including OOBE, overload, and intermodulation effects within the receiver
- Antenna gain pattern relevant to a particular GPS receiver (or a number of receivers)
  - To model the impact of received interfering signals in adjacent bands
- For (a) currently deployed GPS equipment and (b) planned future GNSS receiver designs
- Including propagation model

Approach

- Volpe will solicit inputs from the FCC, NTIA, GPS Manufacturers, wireless providers, and other stakeholders to inform and improve the Adjacent Band Compatibility assessment process with the primary 2 objectives:
  - Open as much adjacent band spectrum as possible for broadband wireless applications
  - “Without affecting existing and evolving uses of space-based PNT services”
- Volpe’s primary role as we currently see it:
  - Conduct analysis, using receiver and antenna data provided by the GPS industry (primarily by GNSS receiver designers) to derive transmit power limits for a given wireless application
  - Conduct limited independent testing (with coordination with the manufacturers) to validate (spot check) receiver test data provided
  - Conduct limited simulations using specs data when provided (and assumed otherwise) in order to assess potential variability of the mask from unit to unit within the same model as well as inferring masks for other broadband signals from the provided masks.
  - Independent rather than coordinated company inputs are desired
- Volpe will issue a final report documenting the objectives, approach, results, and recommendations

Rationale for this Approach (1 of 2)

- Without the details of a specific broadband proposal it is not possible to pre-assign allowed transmitter power levels, locations, antenna patterns, etc.
  - There are too many unknowns and variables, including future expansions
  - Transmitter variables: radiated power, signal waveform, transmit filter characteristics, antenna pattern, beam azimuths and elevations, density of transmitters, alternate providers, potential for intermodulation products, etc.
  - Terrain variables: location of GPS receivers, local terrain, local buildings and other structures, constructive multipath conditions, etc.
- However, as mentioned earlier, in the absence of these details, transmit power limits will be assigned for a LTE application with assumed set of parameters consistent with previous wireless proposal for prototyping purposes so that when a clear proposal comes along it can be quickly evaluated (proactive rather than a reactive approach).
- Most people tolerate variable cell phone coverage, dead zones, transitions between cell sites, etc.
  - "Can you hear me now?"
- Many commercial GPS applications require continuous service
  - A key reason being the long term filtering needed to obtain required accuracy

Rationale for this Approach (2 of 2)

- In order to "ensure that any such [adjacent band terrestrial transmitter] proposals are implemented without affecting existing and evolving uses of space-based PNT services"

- The government needs the strong participation from the GPS industry in terms of test and specification data, as well as feedback on our approach in order to define what signals would and would not adversely affect existing and evolving GPS services.

Additional Technical Considerations

- The practical need for sufficient receiver bandwidth to obtain centimeter-level code-phase (pseudorange) measurements
  - The issue is the rise and fall time of the spreading code transitions
- High precision access to L1/E1, L2, L5/E5 (a and b), and E6 signals as well as GLONASS L1/L2 signals
- Protection of Galileo PRS signals, which fall below 1559 MHz
- Access to MSS signals for StarFire, OmniSTAR, TerraStar, etc. GNSS differential correction services
- Potential OOBE interference from nearby handsets

Questions to GNSS Manufacturers

- What incident power levels as a function of frequency will cause your fielded products to lose 1 dB of GNSS C/N_0
  - For interference waveforms of CW and LTE-like 1, 5, 10, 15, or 20 MHz bandwidths (or a subset of these bands if available)
  - Will the 1 dB criterion protect code measurement precision
- What GNSS adjacent band antenna gain pattern and polarization should be assumed? Can you provide them in association with each receiver type?
- What propagation loss models should be used
- How would you limit multi-signal frequency spacing to prevent harmful intermodulation products within the receiver
- How would you recommend protection from multiple signal sources from one or more wireless services
- Define use cases for your products