GPS Adjacent Band Compatibility Assessment Workshop
U.S. Department of Transportation Volpe Center
55 Broadway Cambridge, MA 02142
Management Information Center (MIC), 12th Floor
September 18, 2014

WORKSHOP PRESENTATION SUMMARIES AND DISCUSSION NOTES

Presentation #1 "Overview of GPS Adjacent Band Compatibility Assessment", Karen Van Dyke

Presentation Summary: This briefing outlined the background of the DOT GPS Adjacent Band Compatibility Assessment program and the high-level attention and commitment to this effort within the U.S. Department of Transportation. The briefing also explained the need for partnerships in order to be successful – partnerships with the other civil departments and agencies, the Air Force GPS Directorate, and industry including all participants of today's workshop.

Discussion (Comments consolidated and paraphrased to the extent possible):

1. There was a question as to what the end product of this study will be and whether there will be recommendations for spectrum regulation.
    a. The GPS Adjacent Band Compatibility program will conduct a technical analysis and provide recommendations to prevent harmful interference to GPS and GNSS, but DOT is not authorized for any spectrum regulatory decisions.

2. There also was a question as to whether this program will consider future receiver technologies for improved filtering.
    a. In future phases of the program this will be considered, but the near-term portion of this effort is focused on current GPS receivers

3. There was discussion of whether this program will consider transmitter Out-Of-Band Emissions (OOBE) and the answer is "yes".

4. Finally there was a question on whether the process outlined is open to first evaluating adjacent compatibility on the uplink portion of the Mobile-Satellite Services (MSS) band between 1610-1660 MHz since this portion of the band that may initially have more service capability from handsets.
    a. The answer is "yes", but it likely will be worked in parallel with the lower portion of the band.

Presentation #2 "The Volpe Center GPS Adjacent Band Compatibility Program Plan", Hadi Wassaf

Presentation Summary: The presentation provides the approach and outline of a proposed implementation plan for the GPS Adjacent Band Compatibility Assessment Plan focus on all civil GPS applications other than certified aviation.

The Government's approach is of openness and transparency by finding avenues, such as the current workshop, to encourage public participation to address implementation of the GPS Adjacent Band Compatibility issues.

The near term implementation plan goals are 1) Identification of current representative GPS receivers and use cases, 2) Development of interference tolerance masks, 3) Development of interaction scenarios, and 4) Specifying the adjacent-band application transmitter power limits.

Discussion of the effort included the goals of gathering GPS receiver and antenna characteristics, conducting GPS receiver and antenna testing, developing GPS receiver mask models and analysis and transmit network modeling, implementing deterministic and probabilistic propagation models, and collecting future and multi-channel GNSS receiver specifications.

Finally, it is important to identify any potential issues moving forward and possible mitigations.

Discussion (Comments consolidated and paraphrased to the extent possible):

1. There was discussion of whether the 1-dB SNR Loss is an acceptable criterion for receiver performance degradation due to RFI. There were differing points of view on this topic.

   One view is that this criterion was used in the past as a matter of expediency, but additional work is needed in this area going forward. The other view is that the 1-dB SNR Loss criterion was used in the previous studies after lengthy discussion, which we cannot afford to restart in the present program.

   It was noted that the 1-dB SNR Loss criterion has been accepted by National Telecommunications and Information Administration (NTIA) and International Telecommunication Union (ITU).

2. Will the Interaction Scenario consider the previous work by the LightSquared Technical Working Group (TWG)?
   a. Yes. The difference between the previous RFI modeling and the RFI modeling of the GPS Adjacent Band Compatibility program is that the previous effort addressed a fixed network as the source of interference,

whereas now we try to characterize the interference from any network design, as specified through several design parameters.

Presentation #3 "GPS Receivers Use-Case Information", Hadi Wassaf

Presentation Summary: This presentation describes the information and specification that is needed from receiver manufacturers to support the development of maximum acceptable transmit power level from an adjacent band application. The primary data of interest is the interference power levels that result in 1 dB degradation in SNR as a function of frequency offset from GPS. The band over which this mask is planned to be defined is the 1500-1700 MHz band. Additional test data such as power levels that cause loss of tracking and loss of lock, as well as specification information that helps with sensitivity analysis as well as extending the narrowband interference results to more general broadband sources via modeling is also desired.

The presentation included initial GPS use-case information collected from the civil departments and agencies with recognition that feedback is needed from industry on the use cases and representative receivers since the initial government agency responses are NOT representative of all use cases. It is important to understand the GPS receiver applications that are important from an industry perspective. The collection of use case information from Department and Agencies is expected to be completed by October 15th. Future workshops will be set up where industry presents on use case information, as well as current representative GPS receivers, to ensure no critical applications of GPS are left out.

Discussion (Comments consolidated and paraphrased to the extent possible):

1. There was discussion that probabilistic models of interference are not appropriate for navigation. You can be in an alley and lose your fix, and then turn around the corner and get your fix back (this was precipitated by the reference to terrain modeling characteristics affecting the interference)
    a. The type of probabilistic interference considered in this program refers to the uncertainty on the propagation loss which depends on the expected spatial diffraction characteristics along the transmitter/receiver path. Reference to propagation loss that may be x-dB off its median value means there is a probability of having at least X-dB propagation loss all the time. The median path loss ($X_{Median,dB}$) means that there is a 50% probability that the actual path loss is greater than or equal to $X_{Median,dB}$.

2. There was a request for a Blank Use Case Template. The Use Case Template will be made available on the www.gps.gov website.

3. It was noted that fishing vessels use GPS and communication devices. It is an environment with multiple use of signals.

Presentation #4 "Description of Needed Manufacturer GPS Receiver Data", Hadi Wassaf

Presentation Summary: This presentation describes the information and specifications that are needed from GPS receiver manufacturers to support the development of maximum acceptable transmit power level from an adjacent band application. The primary data of interest is the interference power levels that result in 1 dB degradation in SNR as a function of frequency. The band over which this mask is defined is planned to be the 1500-1700 MHz band. Additional test data such as power levels that cause a loss of tracking and loss of lock, as well as specification information that helps with sensitivity analysis as well as extending the narrowband interference results to more general broadband sources via modeling is also desired.

Discussion (Comments consolidated and paraphrased to the extent possible):

1. There was a question on how a 1-dB SNR Loss affects the navigation accuracy of GPS.
    a. There is no direct connection between the 1-dB SNR loss criterion and navigation accuracy, because the accuracy depends on the absolute SNR rather than the drop in SNR. The 1-dB SNR loss is an agreed-upon criterion which attempts to address loss of tracking as well as loss of signal acquisition.

2. There was discussion that just because the 1-dB criterion was used in the past, does not mean that it should be accepted as a standard going forward.

3. It was noted that the 1 dB SNR degradation was the U.S. position at ITU and coordinated with the NTIA and State Department.

Presentation #5 "Description of GPS Antenna Data Needed", George Dimos

Presentation Summary: This presentation discusses the required information about the GPS receiver antenna needed for RFI modeling and for Receiver Interference Mask modeling. For all receiver antennas (passive and active), there is a need to generate an antenna mask for one or more GPS application categories; this mask will be used in the RFI modeling for the corresponding group of GPS applications. In addition, for the active receiver antennas, there is a need for information about the preamp (i.e., noise figure, filter characteristics, 1-dB compression point), which is useful for the modeling of the Receiver Interference Mask modeling.

In order to generate the antenna mask, information is needed on: (i) antenna directivity patterns which show the relative reception in one direction with respect to zenith, and (ii) the reference gain of the antenna at zenith with respect to an isotropic antenna. In addition, it is useful to know the polarization loss for receiving vertically polarized interference in a typically circularly polarized GPS antenna. The presentation described

several examples of GPS antenna patterns obtained from publicly available sources, corresponding to various antenna technologies and GPS applications.

Regarding the preamp information for active antennas, it is useful in the likely case that the Interference Mask for a certain receiver is not available and it needs to be estimated based on other information about the receiver noise and filter characteristics. In that case, the receiver data must be combined with the antenna preamp data. Therefore, it is necessary to know which receiver models use a certain active antenna.

Discussion (Comments consolidated and paraphrased to the extent possible):

1. There was discussion that the 1-dB compression point for weak signals, such as GPS, occur a few dB before the 1-dB compression point for strong signals, such as the RFI.
    a. If the nonlinear system degradation (compression) occurs before the linear system degradation (noise increase), the 1-dB SNR loss criterion will be triggered at the weak signal threshold.

2. It was noted that the receiver antenna gain will also depend on the frequency of the RFI, which is outside the GPS band in which such antennas are specified.
    a. The effects of the offset frequency of the RFI on the receiver antenna pattern complicates significantly the matter.
    b. The problem by using the receiver antenna specifications in the GPS band, since this is the worst-case RFI.
    c. To make the analysis more accurate, estimates of the gain loss for offset frequencies, similar to the requested estimates of polarization loss in a RHC polarization antenna.

3. The shown transmitter antenna pattern was provided from LightSquared during the initial RTCA study of June 2011. The later FAA study of January 2012 uses a more comprehensive transmitter antenna model, which includes both vertical and horizontal polarization.
    a. It would be good to perform first a simplified analysis covering a smaller number of dominant parameters, by assuming for example vertical polarization RFI, and then proceed with refinements, to include for example horizontal polarization RFI.

4. Regardless of the number of RFI sources the worst-case RFI is determined by the nearest RFI source.
    a. This is true in sparse networks. In dense networks though the total RFI is dominated by the aggregate RFI of the other sources, rather than the nearest source.

Presentation #6 "Timeline, Proprietary Data, and Next Steps", Steve Mackey

Presentation Summary: This presentation provides a proposed schedule outlining the next 6 months, brief proprietary discussion, and the near-term next steps.

The schedule outlines dates for soliciting participation in other Workshops, the possibility of forming a Working Group, one-on-one meetings with interested participants, development of use cases and a list of representative GPS receivers, and the initial data gather results to be presented.

The first priority, over the next few months, is to have industry define "use cases" and provide a list of representative GPS receiver, which will be down selected for possible testing.

Those who have indicated an interest to participate will be contacted to have a follow on "one-on-one" discussion. This meeting will focus on the willingness to participate in the data gather effort, opportunity to ask additional questions, and understand the data sensitivity. Lastly, a condensed version of the information needed, will be provided.

It is the intention to hold another workshop in which industry has an opportunity to discuss and present use cases and list of representative GPS receivers. In addition, discussion from industry can focus on feedback to the Government's proposed implementation plan for GPS Adjacent Band Compatibility.

The near-term next steps reflect the items needed/completed over the next couple of weeks prior to the one-one-one meetings.

Discussion (Comments consolidated and paraphrased to the extent possible):

1. There was discussion that if GPS receiver manufacturers identify information as proprietary, it doesn't gel well with a transparent process. Evaluating the device performance generically without the ability to compare them openly goes against the idea of transparency. The use of coded data in previous efforts did not lead to a good public discussion.
    a. It is the intent for this effort to be open and transparent as possible. From a government perspective, it is the intent to be as transparent as possible, but we recognize there are sensitivities on the manufacturing side and the transparent process has practical limits. Design characteristics such as architectural information, filtering front end and amplifiers and antenna characteristics are most likely proprietary information. From a practical perspective, one can take the position to not use proprietary data and end up with no data to use or one can decide to take proprietary data and be able to get results. It's not that the data is not available.
2. There was discussion that performing tests to generate receiver masks between 1500-1700 MHz should cover the uplink and MSS bands.

3. Manufacturers provided very specific data on the receivers that were entered into the testing. Anonymity encourages maximum participation and ensures that the data would not be exploited. In terms of the previous efforts although the devices were coded and not publicly identified, the codes were given to the DOT, NTIA, LightSquared, as well as other participating agencies as part of the transparent process.
4. There is a need to keep proprietary information away from competitors.

Name	*Company*	*Attendance Type*
elshazly abd elraouf	Thuraya Thuraya Telecommunications Company	WebEx
Dennis Akos	University of Colorado	WebEx
Maqbool Aliani	LightSquared	On-Site
Nathan Anderson	Minnesota Department of Transportation	WebEx
scott anderson	Maxim Integrated Products	WebEx
Dee Ann Divis	Inside GNSS	WebEx
Jim Arnold	OST-R	On-Site
Alberto Arredondo	The Aerospace Corporation	WebEx
Jeff Auerbach	Department of State	WebEx
brad badke	Hemisphere GNSS	WebEx
Elliott Baskerville	USDOT/OST-R/Volpe Center	WebEx
Frank Bauer	Emergent Space Technologies (for NASA HQ)	WebEx
Michael Bergman	DHS	WebEx
Michael Biggs	FAA	WebEx
Ronald Borsato	Spirent Communications	WebEx
Timothy Bransford	Bingham McCutchen	WebEx
James Campion	DoD	On-Site
Mark Cato	Air Line Pilots Association (ALPA)	WebEx
David Choi	The MITRE Corporation	On-Site
Ann Ciganer	GPS Innovation Alliance (GPSIA) / Trimble	WebEx
Clark Cohen	PNT Holdings, Inc	WebEx
Paul Crampton		WebEx
Bronson D. Hokuf	Garmin International	On-Site
Keith Davis	KLJ Instruments Inc.	WebEx
George Dimos	USDOT/OST-R/Volpe Center	On-Site
Jenny Doctor	LightSquared	WebEx
William Doolan	NTIA	WebEx
Rashmi Doshi	FCC	WebEx
Edward Drocella	NTIA	WebEx
Santanu Dutta	LightSquared	On-Site
Tiange Fan	The Aerospace Corporation	WebEx
Neal Fedora	Spirent Federal Systems Inc.	WebEx
John Fischer	Spectracom Corp.	On-Site
catherine fitch		WebEx
John Foley	Garmin AT, Inc.	WebEx
Russell Fox	Mintz Levin	WebEx
Shawn Furgason	Applied Research Laboratories, University of Texas at Austin (ARL:UT)	WebEx
Ismael Garcia	LightSquared	WebEx
Trevor Garner		WebEx
Joe Grabowski	Zeta Associates Inc.	WebEx
michael ha	FCC	WebEx
Gary Hallbauer	USDA NRCS NGCE	WebEx

Andrew Hansen	USDOT/OST-R/Volpe Center	On-Site
Ron Hanson	Florida Department of Transportation	WebEx
Jonathan Hardis	National Institute of Standards & Technology	WebEx
Christopher Hegarty	MITRE	On-Site
Heather Hennessey	GPS Innovation Alliance	WebEx
Larry Hothem	U.S. Geological Survey	WebEx
Mark Hunter		WebEx
Joseph Iaquinto	Exelis	WebEx
Bruce Jacobs	Pillsbury Winthrop Shaw Pittman LLP	WebEx
David Jiang	Silver Point Capital	WebEx
Thomas Johnson		WebEx
Steve Jones	FCC/OET/LAB	WebEx
Sai K. Kalyanaraman	Rockwell Collins Inc	On-Site
Richard Keegan	John Deere	WebEx
Usman Khawar	Thuraya Telecommunications Company	WebEx
Jason Kim	NOAA	WebEx
Jim Kirkland	Trimble Navigation	On-Site
Satoshi Kogure	Japan Aerospace Exploration Agency (JAXA)	WebEx
Chris Kurby	Greenwood Telecommunications Consultants,LLC	WebEx
rob kursinski	PlanetiQ LLC	WebEx
Antonio Lavarello	NTIA	WebEx
John Lavrakas	Advanced Research Corporation	WebEx
Rich Lee	Iposi Inc	WebEx
James Litton	Litton Consulting Group, Inc.	WebEx
Jina MacEachern	Industry Canada/GNSS Coordination Office	WebEx
Stephen Mackey	USDOT/OST-R/Volpe Center	On-Site
Scott Martin	California Department of Transportation	WebEx
Dr. Michael Janezic	NIST	On-Site
tim munson	Jet Propulsion Lab	WebEx
Joe Newell	BI Incorporated	WebEx
Masoud Olfat		WebEx
Dave Olsen	FAA	WebEx
Scott Pace	George Washington University	WebEx
Tony Park	LMG, Inc.	WebEx
James Quan	NovAtel Inc	WebEx
Mark Rentz	John Deere	On-Site
anthony russo	HQ NASA	WebEx
Frank Schmidt	USAF	On-Site
Kathleen Scott	Wiley Rein LLP	WebEx
Mark Settle	FCC	WebEx
Karl Shallberg	Zeta Associates Inc.	On-Site
Trent Skidmore	Ohio University	WebEx
Tom Stansell	Stansell Consulting	On-Site

Geoff Stearn	LightSquared	On-Site
Dan Stillman	PlanetiQ LLC	WebEx
Norimasa Sugiura	National Institute of Information and Communications Technologies, (NICT)	WebEx
Paul Swain	Covington & Burling LLP	WebEx
Carol Swan		WebEx
Anne Swanson	Cooley LLP	On-Site
Michael Swiek	GPS Innovation Alliance	WebEx
Jarrett Taubman	Latham & Watkins LLP	WebEx
Edwin Todd	KENWOOD USA CORPORATION	WebEx
Michael Tucker	LMG, Inc.	WebEx
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Cou-Way Wang	NTIA	WebEx
Hadi Wassaf	USDOT/OST-R/Volpe Center	On-Site
Kyle Wesson	Zeta Associates Inc.	WebEx
Joe White	Sotera Defense Solutions Inc	WebEx
Steve Wilson	John Deere	WebEx
Daehee Won		WebEx
Denise Wood	Bingham McCutchen	WebEx
Larry Young	Caltech's Jet Propulsion Laboratory	WebEx
Victor Zhang	NIST Time and Frequency Div.	WebEx
Kurt Zimmerman	GPS Innovation Alliance (GPSIA) / Trimble	On-Site