Description of Needed Manufacturer GPS Receiver Data

GPS Adjacent Band Compatibility Workshop
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Program Objective

- Determine transmit power limit for compatible operation between GNSS receivers and wireless applications.

- Primary/near-term focus is on GPS receivers

What Drives GPS Receiver Performance in the Presence of Interference?

- Interference Information
  - Specific wireless application
- Environment/Propagation Effects
- GPS Application Requirements
- GPS receiver Information:
  - Receiver characteristics
  - Antenna Characteristics

Specific Wireless Application

- Topology:
  - Single transmitter
  - Transmit network

- Transmitter characteristics:
  - Fixed or mobile
  - Antenna gain pattern
  - Location, height, orientation
  - Peak power

- Signal Characteristics
  - Bandwidth (including OOBE)
  - Power spectrum: Transmit power per channel, number of channels
  - Range of transmit powers based on:
    - Number of occupied channels at a given time
    - Transmit signal structure: protocol, modulation.

Environment / Propagation Effects

- Environmental factor that affects the selection for the parameters of the propagation model(s):
  - Urbanization level
  - Terrain Attributes:
    - Open/impeded
    - Flat/sloped
    - Dry land/Open water

What Drives a GPS Receiver Performance in the Presence of Interference?

Part of the aggregation modeling treatment

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  - Specific wireless application
- Environment/Propagation Effects
- GPS Application Requirements
- GPS Information:
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Governed by the use case information

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Discussed in a later brief

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- GPS Information:
  - **Receiver characteristics**
  - Antenna Characteristics

Focus of this brief

GPS Receiver Characteristics

Manufacturer Receiver Data

GPS Receiver Characteristics

- Within the current framework ,the most relevant GPS receiver information is an SNR degradation mask (or receiver interference mask)

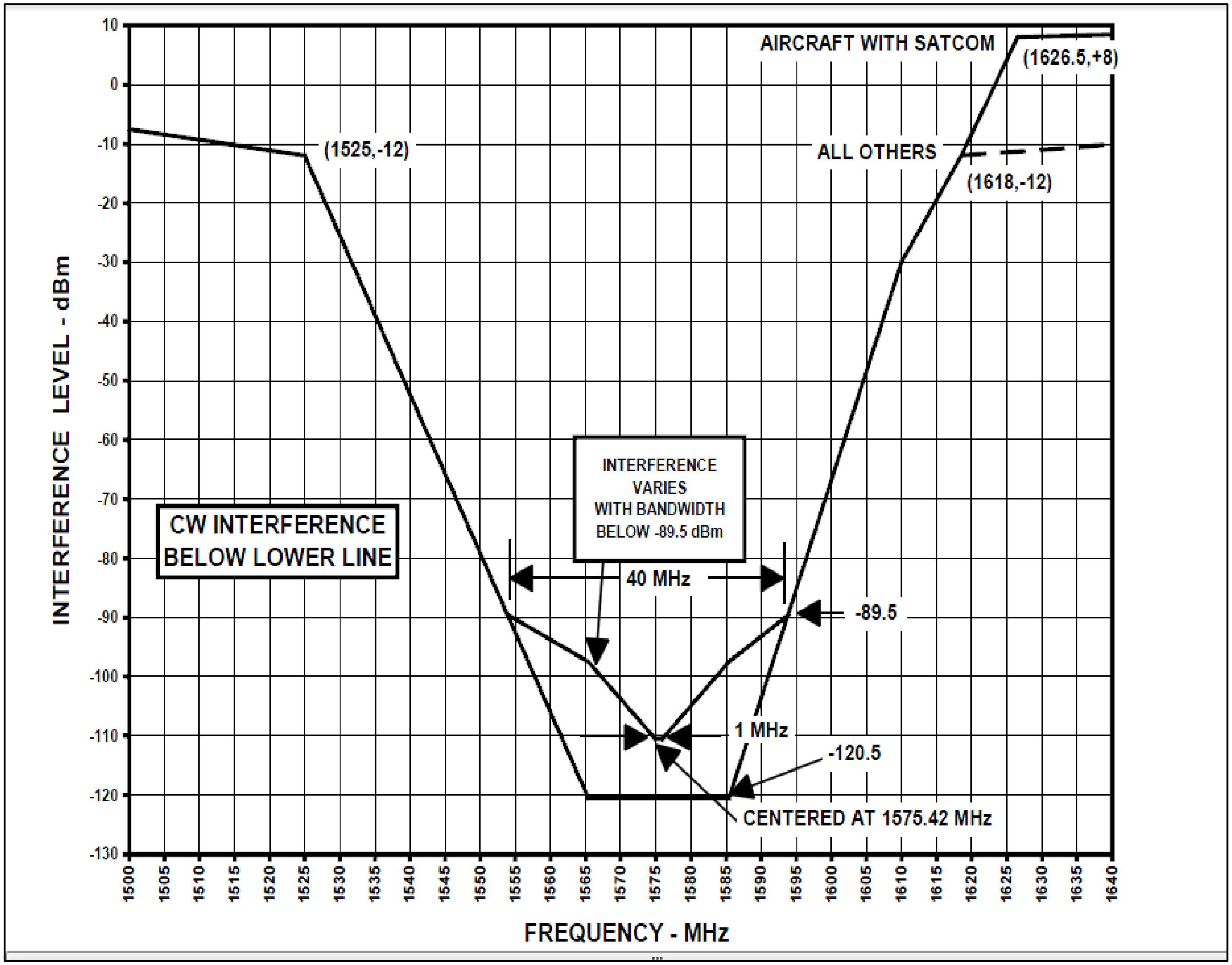
- In particular, for tracking mode, the 1 dB SNR degradation has been established as an acceptable metric in assessing harmful interference levels (Ref. NPEF 2011 report).

- Therefore, the primary data of interest is the 1 dB SNR degradation mask over a large frequency band straddling both sides of the GPS band (for example 1525 – 1675 MHz)

- It might also be desirable to supplement the SNR degradation mask in tracking mode with an acquisition interference mask based on the interference level that prolongs acquisition time by a predefined percentage.← at least on a small set of receivers

Example Receiver Interference Mask (Not necessarily the mask used by FAA in current/future analysis)

Example of receiver interference mask: the mask for certified aviation GPS receivers [ref: RTCA DO 327, fig. C-1]



Definition of Receiver Mask

- The GPS receiver mask characterizes the maximum tolerable received interference power levels vs. frequency over a predefined band.

- For the generation of a mask the following must be defined:
  - Metric for assessing interference effects
  - Threshold of harmful interference
  - Type of interference waveform

- The definition of the receiver mask must provide a good representation of the performance degradation caused by the interference. In addition, it must admit relatively simple testing in order to generate it.

Definition of Receiver Mask

- ***Metric*** **→SNR Degradation in the tracking state**
    - Does not address directly the signal acquisition behavior, which is more sensitive to interference than tracking but harder to test

- ***THRESHOLD*** **→1 dB**
    - Corresponds to increasing the effective receiver noise by 26%
    - By using relatively low threshold, we attempt to cover indirectly the signal acquisition effects

- ***INTERFERENCE WAVEFORM*** **→ CW Tone**
    - Broadband interference effects can be captured by modeling

Approaches to Generate GPS Receiver Masks

1. Receiver Testing Under the Current Program
2. Manufacturer Receiver Test Data
3. Modeling Using Manufacturer Receiver Specification Data

Approaches to Generate GPS Receiver Masks

1. **Receiver Testing Under the Current Program**

2. Manufacturer Receiver Test Data

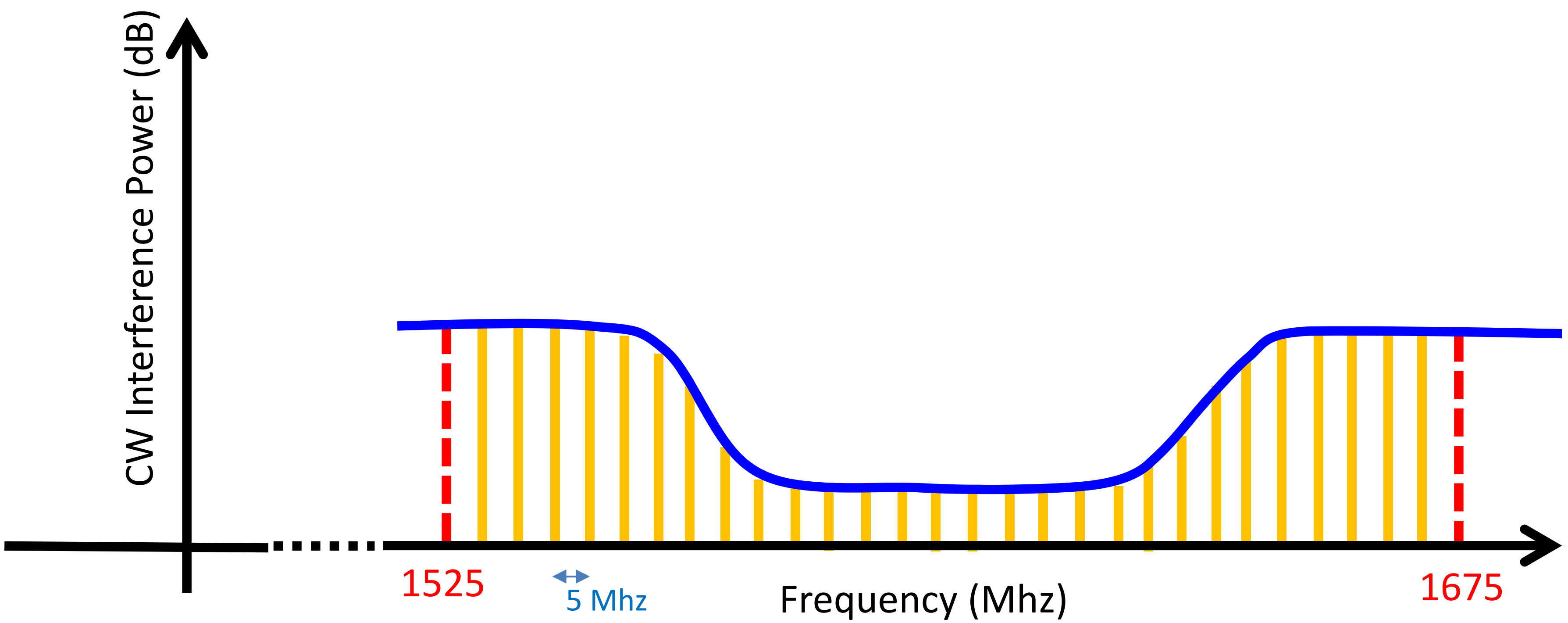
3. Modeling Using Manufacturer Receiver Specification Data

Approaches to Generate GPS Receiver Masks

- Under current funding to the Adjacent Band Compatibility program we intend to consider a set of representative receivers for laboratory testing:
  - Testing will be conducted at an institution(s) with recognized expertise in GPS receiver testing. This will be part of the discussions under the Adjacent Band Working Group
  - The number of receivers will be governed by resources
- This effort requires receiver manufacturer involvement:
  - Physical access to RF input port(s)
  - Access to receiver output data and diagnostic data that might be considered factory data not usually available to users (SNR, and others)
  - Other information relevant to the RF test

High Level Test Procedure for the 1-dB SNR Mask Data (1/2)

- ***Mask Frequency Definition:***
  - (i) [1525-1675 MHz], but [1500-1700 MHz] is preferable
  - (ii) Interference frequency stepped in increments of 5 MHz



High Level Test Procedure for the 1-dB SNR Mask Data (2/2)

- ***General guidelines 1-dB SNR loss measurement for wired test:***
  - (i) RF considerations must be taken care of – e.g., Good characterization of couplers and cables as well as impedance matching
  - (ii) The RF input consists of GPS signal plus CW interferer at -100 dBm;
  - (iii) The RF input is applied at the RF input of a Receiver Under Test (RUT) using passive antenna, or at the RF input of the active antenna associated with the receiver;
  - (iv) The receiver is in tracking state, and the initial SNR (SNR_0) is measured in absence of any interference
  - (v) The interferer power is raised by 5-dB increments until the SNR drops below SNR_0
  - (vi) The interferer power is lowered, and then raised by 1-dB increments until the SNR falls 1-dB below SNR_0 $\rightarrow$ this is the mask power at the tested frequency.

Approaches to Generate GPS Receiver Masks

1. Receiver Testing Under the Current Program
2. **Manufacturer Receiver Test Data**
3. Modeling Using Manufacturer Receiver Specification Data

Approaches to Generate GPS Receiver Masks

- In the best case, the receiver manufacturers have available receiver masks for representative models which have relatively a large footprint in the GPS user community.

- Otherwise, the receiver manufacturers provide other relevant information of representative models, to help estimate their corresponding masks by modeling. ←Discussed in later slides

Primary GPS Receivers of Interest

- The needed manufacturer data is for receivers fitting the following criteria
  - Used in large numbers, and/or
  - Having significant economic impact and/or
  - Are expected to be in use in the next 5 years, and/or
  - Service critical safety and infrastructure applications

- For the manufacturer collected data these determinations are based on manufacturer's knowledge of their customer base

- For the DOT testing effort it is based on more general input including manufacturers and users

Testing General Procedure and Guidelines

- Same as discussed in the previous section

Approaches to Generate GPS Receiver Masks

1. Receiver Testing Under the Current Program
2. Manufacturer Receiver Test Data
3. **Modeling Using Manufacturer Receiver Specification Data**

Use of Receiver Modeling

- Estimating receiver masks in the absence of receiver mask data
  - Requires receiver detailed specifications and information from the manufacturers (Discussed in the next slide)
- Sensitivity and relative analysis
  - Estimating broadband interference mask given the measured CW interference mask
  - How different waveforms, signal structures can affect the SNR 1 dB mask.
  - Effects of different filtering front ends on performance and SNR degradation mask
- Future GPS and GNSS receivers

Modeling-Related GPS Receiver Data From Manufacturers

- RF filter frequency response (composite or individual stages)
- Noise Figure of RF front-end or individual stages (including Loss in filtering stages)
- 1-dB RF compression power of receiver RF amplifier
- RF section design of receiver model
- Carrier tracking loop order and bandwidth
- Code tracking loop bandwidth
- Early/Late gate separations.
- Type of multipath mitigation correlator and spacings
- A/D Information (Number of bits and sampling rate)
- Special architecture and any other info that a manufacturer thinks is relevant to improving the model fidelity.

Supplemental Test Data

- Why? More data saved reduces the risk of retesting

- Although we consider mask data to be sufficient to go forward with the analysis it would be beneficial to have additional data to look at special cases as well as validate some of the analysis and modeling extensions
  - **Acquisition**: Interference level that prolongs the acquisition time by x% or to a some predefined maximum (example 1minute) as function frequency. Basically a form of a degradation mask for acquisition
  - **Loss of Lock:** Interference mask
  - **Wideband (10MHz) 1 dB Interference Mask:** Same process but use BB instead of CW
  - **Time series with and without interference**: position, position residuals, Pseudo ranges, Pseudo-range uncertainty...
  - **Other specialized data**

Summary

- Developing 1 dB interference masks for bounding GPS receivers representative of all receiver categories is key for the Adjacent Band Compatibility

- Masks consistent with the testing guidelines discussed previously are expected to be:
  - Available from manufacturers
  - Generated under current funding of the GPS Adjacent Band program.←Limited by available resources + still requires support from receiver manufacturers
- Modeling is used to estimate masks for which test data is not available, perform sensitivity analysis, and prepare for addressing future GNSS receivers.←Also requires significant support from receiver manufacturers

What is Next?

- We plan to provide condensed information summarizing the desired receiver data and specifications to help streamline the data collection process.

- This also applies to antenna data, as will be seen in the next brief