Testing Requirements Discussion

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Background

- The Adjacent Band Compatibility assessment aims at developing a framework, to determine adjacent-band aggregate transmitter power limits for assumed new applications necessary for the protection of GPS and other space-based GNSS signals

- The assessment is developed to address frequency bands adjacent to the GPS L1 band (i.e., adjacent to 1559-1610 MHz). The resulting framework can then be revised as necessary to address the GPS signals in other bands as well as to address signals broadcast from other GNSS constellations.

- A major component of the assessment is determining the adjacent band interference mask as a function of offset frequencies

Test Frequency Band

- The testing frequency selection criteria:
  - Consider the bands that are proposed to be made available for wireless broadband applications as outlined by the 2010 NTIA 10 year plan to make 500 MHz available for wireless broadband applications
  - Determine the intersection between the bands and the window is the [1475-1675] MHz window. i.e. +/-100 MHz from the center of the GPS L1 Band.
  - The min and max frequencies of this intersection are taken to be the test frequency limits

- The following is a subset of table 2-1 from the Department of Commerce 2010 plan to free up 500 MHz for wireless use.

Table 2-1 Initial Band Candidates that NTIA and the National Broadband Plan Identified

Frequency Band (MHz)	Amount (Megahertz)	Current Allocation/Usage (Federal, Non-Federal, Shared)
(Broadcast TV)** VHF/UHF Frequencies****	120	Non-Federal
406.1-420****	13.9	Federal
(D-Block)** 758-763**** 788-793****	10	Non-Federal
1300-1390****	90	Federal
(MSS)** 1525-1559 1626.5-1660.5	40	Non-Federal
(MSS)** 1610-1626.5 2483.5-2500	10	Non-Federal
1675-1710*	35	Federal/non-Federal Shared

- Applying the selection criteria from the previous slide results in a test band of: [1525-1675]

Test Methods

We believe that the following complementary tests are needed to a varying degree

A. Radiated Emissions Test

B. Wired Emissions Test

C. Antenna Pattern Characterization

Radiated Emissions Test

- Involves radiating both the RNSS and interfering wireless signal in an anechoic chamber (Use NPEF test approach as guideline to develop the Adjacent Band test plan)

- <u>Role of this test</u>: This test employs the minimum set of assumptions about the receiver-antenna system and is therefore expected to generate the primary data used to generate the receivers masks

Wired Emissions Test

- Involves coupling the RNSS and the interference signals into an RF cable connected to the RF input port of the receiver bypassing the passive antenna element or the whole active antenna.

- Role of this test:
  - Used in the development and validation of the test plan
  - Develop masks with antenna characteristics integrated via analysis prior to the chamber being available. Since this is a controlled lab test it can be fast and automated and repeatable.
  - Perform the time consuming cold acquisition tests (to be discussed later)
  - In the case it was determined that additional type of test signals should be looked at after the radiated tests are completed, the wired test can be used to derive the difference in power levels between the masks for a Narrowband signal and the new test signal.
  - If additional critical receivers are identified after the radiated tests are completed, the wired tests can be used to test these receivers.

Antenna Pattern Characterization

- Analysis of a particular adjacent band interference scenario requires calculation of the aggregate power coupled into the receive antenna element so it can be compared against the mask

- The accurate aggregation requires information about the antenna pattern

- Since it is impractical to predict and emulate interference scenarios as part of the radiated test, the radiation pattern (or equivalently receive pattern) of the antenna should be known.

- In the case of radiated tests, only the normalized radiation pattern is needed. In the case of wired tests the radiation pattern in dimensional units is needed.

Test Requirements Shared Between Radiated and Wired Tests

Interference Protection Criteria (IPC)

- Define the degradation in CNR in the presence of interference as:

$$CNR_D = -10.\log\left[\frac{CNR|Interference\ ON}{CNR|Interference\ OFF}\right]$$

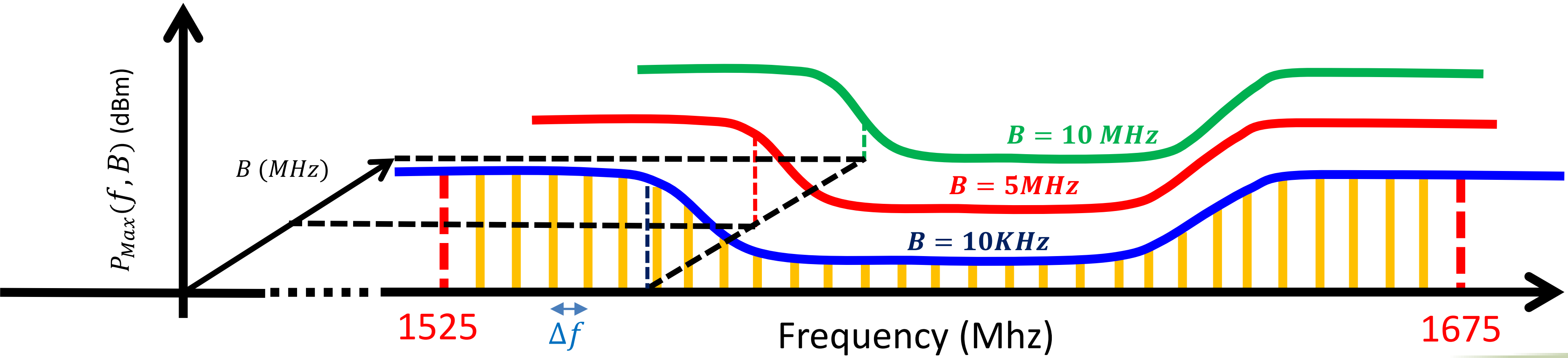
- Primary criterion for tolerable interference is:

$CNR_D \leq 1\ dB$ (or ~26% rise in the receiver noise floor)

- Verify cold acquisition times are not affected at these interference levels (might be more effective to do with wired tests)

- Given the choice of the metric and threshold, the relevant interference model is a CNR degradation mask representing the interference power $P_{Max}(f, B)$ as a function of the interference frequency and bandwidth that would result in $CNR_D = 1dB$

- For radiated tests, masks should be developed from measurements for narrowband interference at a minimum. If possible using different interference signals (additional 5 and 10 MHZ Bandlimited noise signals masks are desirable)



Interfering Signal Specification

- Interferring signal type : Bandwidth, Modulation, etc…
- Interferer EIRP (or equivalent Power at RF input port in the case of a wired test)
  - o P_{min}= A value resulting in a received power below the noise floor of the quietest receiver (~<-110 dBm)
  - o P_{max1}= a Value large enough to cause more than 1 dB degradation without causing a loss of code tracking
  - o P_{max2}= Large enough to guaranty loss of tracking on all units

- Frequency band limits
  - o F_{min}=1525 MHz
  - o F_{max}= 1675 MHz

- Δf = Interference signal Bandwidth (MHz)
- ΔP= 1 dB
- T_{Step} = Duration of each frequency, power level combination in order to achieve a stable SNR measurement

RNSS Signal Specifications

- Pre-specified Almanac with a constellation state that has the following characteristics:
  - At least N_{sv} satellites in view (N_{sv}=6)
  - Spatial diversity: At least one satellite is near Zenith one between 5 and 10 degrees from the horizon.
  - Diversity in SV power levels: 2 SV at minimum, 2 SV at nominal, and 2 SV at max signal powers.
  - In the case of radiated test: Define the look angle to the RNSS radiating antenna (does it matter?). It is assumed that the RNSS signals will all be radiated from the same antenna. Otherwise the location of the antennas will conform to the pre-specified almanac data.

IPC Test Dynamics (to be performed for each type of interfering signal)

- Set the interference signal center frequency at $F_i = F_{min} + i.\,\Delta f$
  - Start with zero Interference power, turn receivers on and wait till all receivers have acquired all satellite signals and are in tracking mode.
  - With zero interference power establish baseline CNR(P=0,f,B)
  - Set interference power level to p_{min} (verify with power meter / reference receiver measurement) and increase power incrementally by ΔP until P_{max1} is reached
  - Reduce the power with the same power and time increments until it is back at p_{min}
  - Repeat the process N_{cycle} times. To allow for rejection of bad/outlier measurements in the analysis phase
  - Criteria for accepting a measurement (such as stipulating that the rise and drop in CNR be monotonically increasing/decreasing when the interference power level is increased/decreased respectively
  - Continue increasing the power levels till P_{max2} is reached. This is done to determine the loss of tracking power limits as a function of frequency.

Acquisition Test Dynamics

- Power down the GNSS receiver
- Ensure no communication links are available to the receiver has no memory of the ephemeris data from the previous tests to ensure cold start conditions.
- With interference signal off: Turn receiver(s) on and record acquisition time.
- Repeat this process at least N_A times.
- With the interference power set at a level that produces 1 dB CNR degradation Repeat the same process N_A times
- Repeat the process for 2 additional power levels 3 dB and 6 dB above the 1 dB degradation levels. This is done to determine if there is at least a 6 dB margin for cold acquisition.
- This is a lengthy test and is therefore more suited for an automated bench test (wired test).
- Coarser frequency steps of 1, 5 or 10 MHz can be used to reduce test duration.

Data Collection for IPC test

- **Primary Data (Must have)**
  - $CNR_i(t)$ (where for i^{th} SV)
- **Secondary Data (Nice to have)**
  - Time
  - Location : Lat(t), Lon(t), h(t) (relative to WGS84 or another clearly defined Datum)
  - Pseudorange: $R_i(t)$
  - Carrier Phase
  - Cycle Slips

Data Analysis for IPC Test

- Using the CNR time series data with the time aligned interference power and frequency information produce $CNR_i(P, f, \mathrm{B})$ and calculate $CNR_{D,i}(P, f, \mathrm{B})$ corresponding to SV_i signal
- Perform quality control on the data such as:
  - Accepting only the data that show monotonic progression in CNR vs. Interference power
  - When available the secondary data can be used for further quality control.
- Determine the IPC power level via interpolation of the up and down power progressions for each RNSS. Assess the sensitivity of this result to RNSS power levels by looking at variability from one power level to the next relative to the variability from up and down progressions for the same power level (statistical testing can be an appropriate tool for this kind of analysis)
- In the case of low sensitivity the averaged $CNR_{D,Avg}(P,f,B)$ averaged over all satellites and interpolate to derive the $P_{Max}(f, B)$ mask for each receiver.

Data Analysis for Acquisition Tests

- Consider the distribution of acquisition times for the baseline with no interference as well as with the three different interference levels.

- Calculate the difference in means (or medians) of acquisition times as a function of transmit power levels.
  - Observe if a monotonic trend exists
  - Determine at what power level (if any) the change in acquisition time is significant (25 to 50% of baseline Acquisition time), as well as statistically significant relative to the uncertainty on the mean (or median) as estimated from the data.
- This power level minus the IPC power level is an estimate of the margin for cold acquisition

Additional Test Signals

- Other then the previously mentioned test signals it is desirable to consider a combination of signals in different bands to capture the effects of 3rd order intermodulation products.

- Are the test signal proposed good enough to represent LTE down-link results? Is there reason to believe that OFDM modulation as well as details of LTE frames and payloads will produce very different results than band passed white noise?

- How to use the collected data to estimate masks with non-uniform power spectral densities with or without, OOBE (such as handsets)? Is there no way around testing those specific signals? Are clear specifications available for these types of signals

Requirements and Details Specific to Each Test Method

Other Requirements to workout specifically for Radiated Emissions test

- Geometric information:
  - Location and orientation of interference transmit antenna
  - Location and orientation of RNSS radiating antenna
  - Map (grid locations) of GNSS receiver locations (UUTs)
  - Orientation of GNSS receiver antennas (Max gain is towards Interfering transmitter)
- Transmit equipment configuration and capabilities:
  - Signal Generator(s)
  - Filters flexibility and characteristics
  - Antenna characteristics and calibration requirements (with V and H polarizations) over the test frequency band
- Test equipment
  - Spectrum analyzers
  - Reference receivers for calibration of receive power at each GNSS location prior to testing as well as to estimate the EIRP during the test
- Calibration process

Other Requirements to Workout Specifically for Wired Emissions Test

- Test equipment:
  - RF Signal Generators (similar specification or the same as what is used in the Radiated Test)
  - Filters (same as radiated tests)
  - Shaping filter that can take a broadband noise input and emulate a signal with a prespecisfied Power Spectral Density (such as a spectrum of hypothetical handset with out of band emissions)
  - Couplers and RF adapters with the attenuation with characterized port-to-port transfer function over the frequency of interest
  - Characterized cables (known transfer function or attenuation as a function of frequency over the test frequency band)
  - Spectrum Analyzer (up to 2 GHz)
  - Power meter with an operational frequency up to 2 GHz band.
- calibration process

Antenna Characterization Tests

- Scope (number of antennas to test), test requirements, as well as test procedures need to be developed.

- Alternatively, if representative antenna characteristics can be provided (V & H Polarizations) at the frequencies of interests, from other sources this test can be bypassed.

Testing Framework

- Performing the Adjacent Band assessment hinges on the ability to access the collected data and perform the analysis

- Delay in instituting such a framework will severely slowdown progress on the execution of the assessment plan

Conclusion

- Test requirements are being drafted to guide the development of a test plan.

- Primary source of data is expected to be generate by the Radiated Emissions Testing. When applicable, Elements of the NPEF test plan will be preserved and expanded on to meet the need of the Adjacent Band effort.

- Some wired tests are still needed to validate test plan and fill the gaps

- A framework for DOT to be able to obtain and analyze the data is key for the success of this effort