SPACE-BASED POSITIONING NAVIGATION & TIMING

NATIONAL ADVISORY BOARD

National Space-based PNT Advisory Board Recommended Criteria for Spectrum Assessments

Initial Draft of a "Check List"

Positioning, Navigation, and Timing Advisory Board, 17th Meeting
May 18-19, 2016

PNT Advisory Board Purpose:

Assure that Position, Navigation, and Time (PNT) are available with required ***accuracy*** and ***integrity*** for ***all current and future GNSS Applications***

A few (64!) Example Applications---

Areas	Example applications
Aviation	Area navigation, approach, landing up to Cat III, NextGen
Agriculture	AutoFarming: crop spraying, precision cultivating, yield assessment
Automotive	Turn-by-turn guidance, OnStar, driverless cars
Emergency and Rescue Services	911, ambulance, fire, police, rescue helicopters, emergency beacons, airplane and ship locaters, OnStar
Intelligent Transportation	Train control and management, UAVs, Intelligent Highways
Military	Rescue, precision weapon delivery, unit and individual location
Recreation	GeoCaching, control of models, hiking, outdoor activities
Robotics and Machine Control	Bull dozers, Earth graders, mining trucks, oil drilling
Scientific	Earth movement and shape, atmosphere, weather forecasting, climate modeling, ionosphere, space weather, tsunami warning, soil moisture, ocean roughness, wind velocity, snow, ice, and foliage coverage, ……
Survey and GIS	Mapping, environmental monitoring, tagging disease outbreaks
Timing	Cell phone towers, banking, power grid
Tracking	Fleets, assets, equipment, shipments, children, Alzheimer's patients, wild life, animals, law enforcements, criminals, parolees, ……

Innovation and the GPS Signal - Current and Future Dependency

- 1983 – 2016, Civil GPS community exploits GPS signal and system reliability/availability to ***create applications that go way beyond the nominal "system characteristics",*** including:
  - **Monitoring Techtonic Plate motion to fractions of an inch in 3 dimensions**
  - **Fully automatic landing of Airplanes**
  - Safety of Life - First Providers
  - **Automatic control of land vehicles – Cargo Cranes to bulldozers**
  - **Robotic Farming and many more**

Red – Precision, Wide Band Receivers

- These innovations led to estimate by USG of over $55B per year of tangible economic benefits

Future – Documented Expectation – Literally 10s of B$ savings per year

- FAA's NextGen is totally dependent on GPS availability
- Intelligent Highways Program - GPS has essential role

We strongly believe: Any significant degradation to the GPS System that would damage these benefits, ***Independent of any stated original characteristic, would be greatly detrimental to the US interest***

A Short Checklist of Issues

1. Meeting the ***1 dB*** Degradation Criteria
2. Assessing ***All GNSS Signals***
3. Assessing ***all classes of Precision Receive***rs
4. Fully Understanding the ***Assumptions*** behind Analysis and Test Parameters
5. ***Ensuring Compliance*** with Authorized Transmitting Power Levels
6. ***Phase-out Time*** for Legacy Equipment

Burden of proof should be on the proposers of repurposing - And should Address All User Categories

1) The 1 dB C/N_0 Degradation Criterion

- 1 dB C/N_0 is Longstanding International Standard

  (Consensus at WRC 2012)

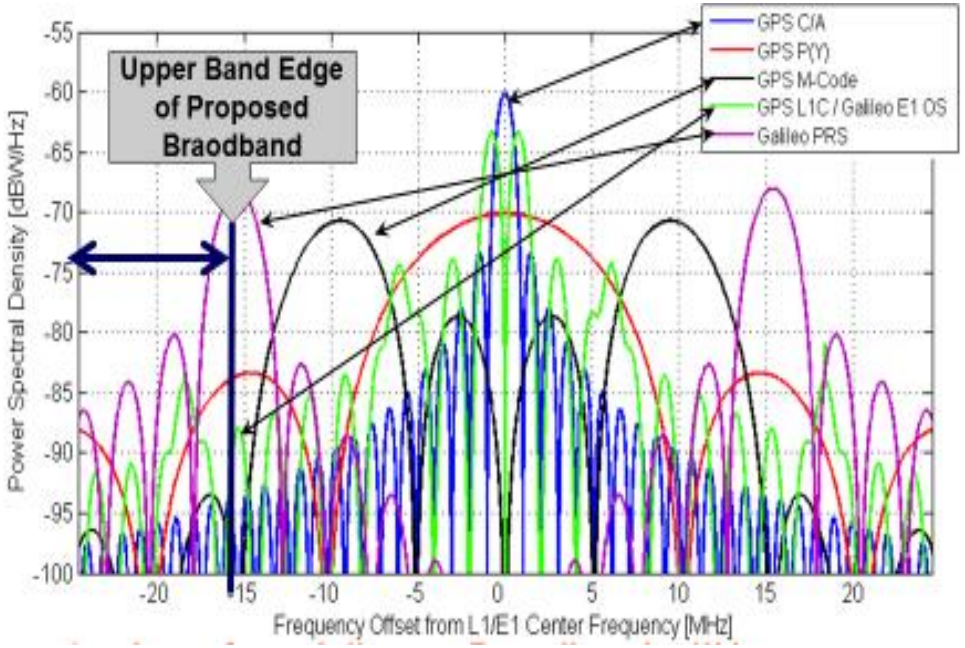
  - Only one contributor to Noise Floor (add scintillation and other sources)
  - In particular, it is well understood for radar systems - another faint timing signal application.
- 1 dB criterion designed to protect all modes of GPS operation – Loss of Lock, but- -
  - ***Acquisition is the most fragile and difficult operation***
  - ***For Precision – a major issue is pico-second jitter***
- 1 decibel (dB) degradation of carrier-to-noise ratio (C/No) = reducing satellite power by 21%,
- Impacts are very situationally dependent – example aircraft reacquisition problem
- NTIA, in the past, has defended this standard

Any change to 1 dB criterion would

- **be reviewed by PNT community and require good justification**
- **establish a domestic and international precedent**
- **apply to other space systems, domestic and international, including all U.S. government satellite systems.**

2) Assessing All GNSS Signals

- Analysis of Civil Interference to date only focussed on L1 C/A, rather than new, more capable GPS (and international) signal L1C (centered at same frequency)
- Galileo (European) will also broadcast a wide-band civil signal at this center frequency.
  - Cell phone chip manufacturers already include the Galileo, plus FAA's WAAS et.al..
- Users in the U.S. can greatly benefit from using all civil satellites and signals. Enables integrity crosscheck and ***system diversity***
- "All-GNSS" also increases availability in cities and under foliage
- Spectrum for most new, higher-precision, GNSS signals is much closer to edges of adjacent bands
- Imperative to assess impact on All GNSS



Question: What interference tests or analyses are proposed against *all civil GNSS signals*?

3) Assessing Precision Receivers

- Over two billion GNSS receivers worldwide - small percentage classified as *precision receivers*.
  - But these, over a million users, enable 30.1B$ of 55.7B$ in annual (US) economic benefits.
  - These include, for example, precision real-time measurements of earth-fault movement in three dimensions (with accuracies better than 1 millimeter)
  - precision control of bulldozers and road grading equipment in cities and rural areas.
- Precision receivers must use very wide bandwidth for accuracy
  - More susceptible to interference than ordinary GNSS receiver.
  - Not just Tracking - impact on ***measurement jitter is more critical***
- New Designs may somewhat reduce (but not eliminate) susceptibility
  - Receivers are retained for many years . Repacement and renewal timing a very real issue.
  - To completely understand impacts - carefully evaluate representative wide-band (precision) receivers.

Question: What analyses and tests have been performed or proposed for the many classes of precision users – for *both signal acquisition* and tracking?

4) Fully Understanding the Assumptions behind Analysis and Test Parameters – Relate to real Operational Conditions

- Many critical PNT operations potentially very near Wide-Band Transmitters
  - Usually vectored and tracked using PNT from GPS
    - Includes Emergency Services - police, fire, and ambulance operations
    - Critical control of airplanes during airport taxiing operations.
  - Urban Rescue/Police Helicopters may be a particularly vulnerable example
- Location of 911 emergency calls referenced back to GPS position -more accurate than position triangulation from cellular towers.
- To avoid destructive interference, essential for decision-makers to fully understand the assumptions used in analysis and testing. Including:
  - the line of sight distance between potential source of interference and critical users (3D Users).
  - frequency separation from all GNSS bands
  - Proposed repurposing geographical laydown (Transmitter density)
  - Signal structure and characteristics

Question: What assumptions and constraints have been placed on the parameters (such as power, frequency, and distance) used in existing or proposed analyses?

5) Ensuring Compliance with Authorized Transmitting Power Levels

Question: What methods and processes are offered to monitor and ensure that terrestrial transmitters operate within authorized power and deployment constraints?

6) Phase-out Time for Legacy Equipment

- Existing GPS equipment designs were based on assurances by the FCC that adjacent bands would be reserved primarily for Space-to-Earth communications with correspondingly weak signals.
- To repurpose the adjacent bands would dictate a different GNSS receiver front end.
- Future equipment could be designed to be more resilient to strong terrestrial transmissions, if they are to be authorized, but there would still be millions of users with equipment designs that were based on previous FCC assurances and precedent.

<u>Question</u>: What phase in or delay time could be expected before initiation of higher power terrestrial transmissions?

Summary: Addressing All Users

- GPS is a dual-use system, providing PNT for both military and civilian users.
  - New applications continue to emerge must be considered – NexGen and Intelligent Highways
- GPS for all users has been acknowledged and affirmed by multiple Four-Star Commanders of the U.S. Air Force Space Command.
- Must understand Technical Modifications since last denial of repurposing

Protections or regulatory decisions affecting GPS should continue to address the needs and concerns of all users:

- **Military,**
- **Civil,**
- **Commercial, and**
- **Scientific.**