Resilient Navigation and Timing Foundation Comments On

DA 16-442 and IB Docket No. 11-109

Ligado's Modification Applications

Summary

- The GPS signal is so widely used by the population for a wide variety of functions that any degradation in the current ability to use it will result in a reduction in safety, security, and efficiency, and an increase in harm to human life and the environment.
- Navigation and timing signals and services are distinct and significantly differ from communications services. The FCC must recognize these differences and establish principles and procedures for assessing proposals to transmit in frequency bands adjacent to those designated for Global Navigation Satellite Systems. We propose some criteria and principles to be included in such and evaluation process.
- The FCC should hold this proposal in abeyance pending the outcome of additional studies. The Department of Transportation is conducting an Adjacent Band Compatibility (ABC) Study to determine what levels of transmitted power may be allowed in bands adjacent to GPS without causing harmful interference. This study was undertaken at the behest of the inter-department National Space-Based Positioning, Navigation, and Timing Executive Committee. In coordination with NTIA, the FCC should analyze the report and public comments before making a final recommendation or undertaking any rule-making affecting the adjacent bands. The FCC should adhere to the findings of the ABC Study.
- The less than 1 dB Carrier/Noise degradation criterion must be preserved. This criterion has long been used in assessing interference for GPS and for other communications, navigation and timing and radar systems and we see no evidence that it should be modified. Applicant rejects this criterion and asserts that testing of a number of specific GPS receivers under test conditions chosen by Applicant is sufficient to establish that no harm will occur. This does not establish "no harm" on a *general* basis or protect future GPS devices and services from possible harm. The United States has used the 1 dB criterion regularly in international negotiations to protect the spectrum used by all GNSS systems, not just GPS.
- Any change in the current actual performance of the GPS system and signal must be preceded by an extended notice and phase-in period, and must include provision for the potentially hundreds of millions of users with legacy equipment that would be impacted.
- Establishing a large network of transmitters operating in an adjacent band as proposed, even if they did not interfere with GPS/GNSS while operating within specification, would place the nation at risk. Minor system malfunctions, human error, cyberattack or other malicious activity, could easily cause harmful disruption to GPS/GNSS services. Such a system would create conditions that would make it easy to harm America's national, economic and homeland security. It would be an "attractive nuisance" for any number of hackers, terrorists, criminals, and national actors who would do America harm.

I. Background

The Resilient Navigation and Timing Foundation is a 501(c)3 scientific and educational non-profit supporting policies and systems that contribute to resilient positioning, navigation and timing services, especially for critical infrastructure. The information provided herein is based upon input from our corporate and individual members who have extensive experience and expertise in navigation and timing systems and policy. It also builds upon work done by the National Space-based Positioning, Navigation and Timing Advisory Board at their May 2016 meeting.

The economic value of Global Positioning System (GPS) signals as now broadcast, received and used is nearly impossible to gauge. Since 1983 GPS has been incorporated into virtually every technology and is essential for much of our critical infrastructure and key resource sectors. It has become a silent utility that is an integral part of our technological, economic and human eco-systems. Rather than attempt to put a numerical value on its benefit, it is more appropriate to try to envision life and our economy if GPS were suddenly taken away. Every technology would be impacted and the results to society and our economy would be catastrophic. Any degradation of the current performance of GPS/ GNSS, no matter how slight, will have a negative economic impact.

Non-"Safety of Life" applications impact safety of life. GPS receivers of varying quality and capability have been incorporated into a wide variety of critical infrastructure and personal applications that are not formally designated "safety-of-life" but, if they malfunction, could easily result in one or more deaths. Drivers navigating highways at 70 mph using the receiver in their cell phone, GPS-guided industrial machinery, and multiplexing for first responder communication systems based on GPS time are several examples.

Any degradation in the ability to access and use GPS services will endanger lives, degrade the quality of life and harm the environment. GPS enabled efficient navigation and timing among a myriad of other benefits:

- is essential for first responders and enables thousands of lives to be saved each year,
- makes transportation safer and more efficient,
- minimizes the consumption of fossil fuels and CO_2 emissions, and
- minimizes the amount of fertilizer and pesticides used in agriculture.

The "Precautionary Principle," long used when considering actions that could harm human health or the environment, should also be used when considering proposals that could negatively impact the GPS/GNSS spectrum. If there is any doubt as to the impact, the action should not be taken. Before proceeding with any proposal, we must be absolutely sure there will be no negative impact.

II. Evaluating Proposals for Adjacent Band Transmissions

Space-based digital navigation and timing systems and communications systems are fundamentally different. Communications systems send comparatively powerful signals in bursts while navigation and timing systems continuously transmit very weak signals. The messages sent by communications systems are completely unknown and must be discovered by receivers through determining which bits are ones and which are zeros. Navigation and timing receivers know precisely what the messages they seek look like, but they must find them in and amongst the noise floor. Then the navigation or timing receiver must precisely determine the time of the transition between the ones and zeros in order to calculate its location or precise time.

Because the two systems are so fundamentally different, evaluation criteria for potential impacts on navigation and timing systems must be fundamentally different from that used for communication systems. While the following is not an exhaustive list, these principles should be incorporated into any set of evaluation criteria and procedures developed by the FCC or used by applicants for use of bands adjacent to those for GPS/GNSS.

1. Ensure the sum of existing and proposed adjacent band transmissions does not increase the in-band noise floor by more than 1 dB C/N_0. The less than 1 decibel (dB) degradation standard is long standing and recognized domestically and internationally (see for example the 2012 World Radio Conference consensus). It is important to all civil and government space systems, not just those used for navigation and/or timing. This is a standard the U.S. government has long supported internationally for protecting the entire Global Navigation Satellite System spectrum.

Limiting interference/degradation from all sources to a less than a 1 dB increase helps avoid:

- Inability to acquire or re-acquire the signal (the most difficult challenge for receivers), and
- Loss of lock – failure of the receiver to continuously interpret and use the signal.

It is important to also note that:

- For precision receivers, total noise level is especially important as every rise increases the potential for jitter at the pico-second level. This can be debilitating.
- Impacts are very user- and situationally-dependent. Loss of lock and the need to reacquire could have very little impact on a driver on a highway. For a 747 aircraft approaching an airport, it could require that a landing attempt be aborted, and the aircraft spend another 20 minutes in the air burning an additional 1,200 gallons of fuel.
- As noted before, GPS satellites transmit very weak signals. A 1 dB degradation of carrier to noise ratio is equal to reducing the power of the satellite by 21%.

2. Assess the impact on all GNSS signals. Users in the United Sates can greatly benefit from using all civil satellites and signals. Doing so provides system diversity which:

- Enables integrity cross-checks between systems
- Increases the ability for users to continue to operate in difficult locations
- Provides a degree of increased resilience in the event of difficulties with one system. While exceptionally reliable, all Global Navigation Satellite Systems, including GPS, have experienced system outages and faults.

Analysis of adjacent band interference to date has only focused on the L1 C/A signal, rather than the newer, more capable GPS and international L1C signal which is centered at the same frequency. Europe's Galileo satellite navigation and timing system will also broadcast a wide-band civil signal at this center frequency. Cell phone manufacturers already include the capability to receive these signals in their handsets. This capability has been incorporated into other systems as well, such as the FAA's Wide Area Augmentation System used for air traffic safety.

It is also important to note that the spectrum used by most newer, higher-precision GNSS signals is much closer to the edges of adjacent bands than the signals that have been considered to date. They are therefore more susceptible to interference from out-of-band transmissions

We note that it has long been the policy of the United States government to protect the entire GNSS spectrum.

3. Pay particular attention to the impact on precision receivers. Of the more than two billion GPS/GNSS receivers world-wide, a small percentage can be classified as precision receivers. These are used for highly precise measurements, often with accuracies of better than a millimeter. Examples of these applications include precision bulldozing, agriculture, and manufacturing, real-time measurement (in three dimensions) of geological faults and dams, and surveying. Together, precision applications are estimated to be responsible for about half of the economic value of all geospatial services.

These receivers must use very wide bandwidth to obtain the accuracy they need. As such they are much more susceptible to interference than other receivers. In addition to being able to maintain lock and track the signal, these receivers depend on signal stability. Any minor jitter induced by even faint interference causes measurement errors.

Newer receiver designs may somewhat reduce the susceptibility of these receivers to interference, but this vulnerability will never be eliminated. Additionally, this equipment is very expensive and therefore is replaced over a very long life cycle. As a result, the community's sensitivity to interference will remain high for many years to come.

Precision receivers and applications are varied. Any assessment of possible interference must include an examination of the impacts on a wide range of precision equipment.

4. Fully understand the impact of a proposal to real-world use of GPS signals. This requires clearly articulating the assumptions behind analyses and test parameters. The following should be clearly articulated in the test plan and results so that decision-makers may assess the potential for destructive interference:

- Line of sight distances between potential sources of interference and critical users, including 3D users (ex: first responder helicopters)
- Frequency separation from all GNSS bands
- Proposed geographical laydown and transmitter density
- Signal structure and characteristics

We are particularly concerned about the potential for interference with GPS signal use that can be critical to emergency responses. These include:

- Determination of location for 911 calls (GPS provides much more accurate location information than triangulation from cell towers)
- Police, fire, and ambulance operations
- Urban police, EMS, and other helicopter and unmanned aircraft operations (these may be particularly vulnerable to even minor interference)
- Airport ground control operations (taxi and runway positioning, etc.)

5. Identify how compliance with proposed transmitting power levels will be ensured and enforced. Transmissions above authorized levels in bands adjacent to those allocated for GNSS have great potential to harm human life and the environment if authorized power levels are exceeded. Evaluations and any approvals of proposals must include methodologies for monitoring and enforcement to safeguard against this.

6. As appropriate, identify how new transmissions will be phased-in and user equipment will be phased-out. If a proposal that would interfere with the use of some GPS/GNSS receiver equipment is to be approved, detailed and exacting provisions for protecting users and the public as a whole must be implemented concurrently. Existing equipment designs and usage are based on assurances by the Federal Communications Commission that bands adjacent to GPS/GNSS would be reserved primarily for Space-to-Earth communications which use relatively weak signals. New usage for the larger spectrum segment will require different GPS/GNSS receiver designs. Safeguarding human life and the environment will require that provisions be made for the millions of users with legacy equipment.

"Gauging the overall value of GPS is nearly impossible... It has become difficult to untangle the worth of GPS from the worth of *everything*… Placing an economic value on GPS has become nearly as impossible as pegging the value of other utilities. How much money do electricity and telephones generate? How much is oxygen worth to the human respiratory system?"

Pinpoint – How GPS is changing technology, culture, and our minds - Greg Milner, W. W. Norton & Company, 2016