GPS Innovation Alliance

TESTIMONY OF THE GPS INNOVATION ALLIANCE
SUBMITTED FOR THE RECORD
OCTOBER 7, 2015 HEARING – IMPROVING FEDERAL SPECTRUM SYSTEMS
U.S. HOUSE OF REPRESENTATIVES COMMITTEE ON ENERGY AND COMMERCE
SUBCOMMITTEE ON COMERCE AND TECHNOLOGY

October 16, 2015

The GPS Innovation Alliance ("GPSIA") appreciates the Subcommittee's continued leadership on United States telecommunications policy and spectrum management. We watched with interest the recent hearing the Subcommittee conducted on Improving Federal Spectrum Systems. GPSIA supports the Subcommittee's efforts to consider ways to increase the efficiency of spectrum usage. While the hearing included discussion of the potential for repurposing spectrum currently reserved for use by satellite applications, there was limited discussion of the specific technical issues presented by such proposals, including issues raised by repurposing spectrum adjacent to spectrum designated for Global Satellite Navigation System ("GNSS") and the U.S. GNSS, the Global Positioning System ("GPS"). We are pleased, therefore, to be able to supplement the record so that the Subcommittee has a more thorough understanding of how one of the nation's most important national utilities – with services that are integral to economic growth, transportation, safety, and U.S. national security – operates.[1]

1. **Repurposing Satellite Spectrum for Terrestrial Broadband Uses in Close Proximity to Ubiquitous Satellite Based Uses such as GNSS Presents Formidable Technical Challenges.**

While the testimony before the Subcommittee suggested that spectrum reserved for satellite applications represents a significant opportunity to repurpose spectrum for terrestrial broadband use,[2] it did not address in detail the specific technical challenges of repurposing satellite spectrum that is in close proximity to ubiquitous applications such as GNSS. These challenges are formidable, and given the ubiquity and importance of both technologies and their importance to our nation's economy, changes in

[1] Today, there are millions of GPS users, ranging from individuals, to federal, state and local governments, to businesses engaged in agriculture and construction. For example, intelligent transportation systems depend on GPS to improve safety, efficiency and environmental impact; utilities depend on GPS for network timing and synchronization; earthquake, volcano, dam and bridge GPS-based measurement and monitoring systems detect tiny movements used in risk analysis and disaster prediction; construction and surveying applications of GPS enable fewer lane closures, less traffic disruption and faster project completion; and farmers use GPS to reduce waste in chemical and fuel use. Critically, our nation's first responders use GPS to respond to E911 calls and to map disasters and coordinate relief efforts.

[2] *Hearing: Improving Federal Spectrum Systems Before the House Comm. on the Energy and Commerce , Subcomm. on Communications and Technology*, 114th Cong. (2015) (statement of Dennis A. Roberson, Vice Provost, Research Professor in Computer Science, Illinois Institute of Technology), *available at* http://docs.house.gov/meetings/IF/IF16/20151007/104037/HHRG-114-IF16-Wstate-RobersonD-20151007.pdf. Dr. Roberson has appeared before the FCC on behalf of LightSquared LLC. *See, e.g.* LightSquared LLC Notice of *Ex Parte*, IB Docket No. 12-340 (filed May 29, 2015); LightSquared LLC *Ex Parte* Presentation, IB Docket No. 12-340 (filed Jul. 15, 2015); LightSquared LLC Notice of *Ex Parte*, IB Docket No. 12-340 (filed Jul. 24, 2015); LightSquared LLC *Ex Parte* Presentation, IB Docket No. 12-340 (filed Aug. 25, 2015); LightSquared LLC *Ex Parte* Presentation, IB Docket No. 12-340 (filed Sep. 30, 2015).

policy and technical standards present unique risks of imposing unknown and unknowable costs, distorting technological developments and beneficial innovation, and potentially disrupting critical infrastructure and safety-of-life systems.

While GPSIA has consistently supported the more complete use of under-employed spectrum where technically feasible, managing potential interference between divergent spectrum uses represents a very complex problem, requiring multiple levels of detailed engineering analysis. A few general parameters, however, tend to dominate the equation; namely, the relative technical characteristics of the uses (e.g. similarity or dissimilarity of transmitter power and receiver sensitivity between the systems), and the proximity of the uses in space (or geography) and frequency. Similar uses are easier to coordinate, while dissimilar uses are more difficult to coordinate to the extent that they are in adjacent or nearby frequency bands, particularly where transmitters and receivers are operated in close spatial or geographic proximity.

Two common scenarios illustrate the basic relationships. First, mobile carrier base station downlink transmissions can be proximate in frequency and use transmitters located on the same tower (that is, proximate in space), but can be operated together with relative ease because they have very similar technical characteristics (power levels, common timing, signal characteristics) and because there are longstanding engineering techniques for coordinated operation of such fixed facilities. High powered television or radio stations can operate on the same frequencies, if they have sufficient geographic separation. Even radio and television stations operating on different but proximate frequencies must be separated geographically to avoid interference to television or radio receivers.

In contrast, management of potential interference between carrier-based mobile broadband operations and the reception of low-power satellite to earth transmissions, such as GNSS signals, as considered in the recent LightSquared proceedings, presents an entirely different and far more challenging scenario. First, the relative technical characteristics of the uses could not be more different. Mobile broadband base station (downlink) transmissions are very high powered relative to the satellite signals as received on earth – literally billions of times stronger. Even mobile broadband handset (uplink) transmissions can be billions of times stronger than GPS satellite signals as received on earth when a mobile handset is transmitting in close proximity to a GPS receiver (for example, when the passenger in the front seat of a car with a GPS navigation system is using his or her cell phone).[3]

While the "undesired" (potentially interfering) mobile broadband signal is very strong, on the one hand, GPS receivers, on the other hand, must be extraordinarily sensitive to pick up the "desired" GPS signal. These divergent power levels make coordination between these systems exceedingly difficult due to the fact that GPS signals as received on earth are below the thermal noise floor (the level of noise occurring naturally and apart from manmade sources) which prevails in the GPS frequency band, and GPS receivers perform an extraordinary engineering feat to extract the signals from the noise

[3] This difference between satellite and terrestrial use of spectrum is another reason why any evaluation of the "use" of a satellite band likely understates the occupancy of the band. GPS devices are receivers – they generate no RF signal at all. So, listening to activity in a spectrum band used by GPS would not reveal the millions of GPS devices in operation serving a variety of critical applications. The only detectable RF emission that corresponds to those devices is from a series of satellites, which produce a constant level of low-power RF transmissions, regardless of how intensely the signal is used by GPS devices. Those satellite signals are very weak by the time they reach earth. So, any analysis that concludes that the use of a satellite band is low based only the number and strength of transmissions measured – without taking into consideration the scope of associated, non-transmitting receivers – is deeply flawed.

and then process them to provide accurate location information. To do this, GPS receivers must have extremely sensitive receiver front ends, employ very sophisticated signal processing functions, and utilize multiple signal processing stages, all of which are adversely affected by interfering "noise," whether this noise comes from in-band or out-of band transmissions.

The proximity variables involved in avoiding interference between terrestrial and satellite services are as challenging as any the FCC has faced in the past. Spatially, mobile broadband networks must be effectively ubiquitous from a user standpoint – users will take mobile handsets everywhere, so uplink transmissions are ubiquitous, and carriers design their networks to have downlink cell coverage where the vast majority of the people are the vast majority of the time. GPS, which is almost exclusively a mobile spectrum use, has an even more ubiquitous footprint. GPS satellite signals are available nearly everywhere, and, with over a half a billion GPS devices in everyday use in the US, including GPS receivers in almost every cell phone, GPS receivers will be in close proximity to fixed or mobile broadband transmitters the vast majority of the time.

2. It Is Highly Simplistic and Inaccurate to Attribute Difficulties in Coordinating Terrestrial and Satellite Spectrum Uses To "Poor" Receiver Design

Given the technical challenges described above, attempts to attribute GNSS interference issues mainly to poor receiver design are misguided. The FCC has long understood that receivers designed to receive one set of frequencies can be "overloaded" by transmissions in adjacent frequencies.[4] The risk is especially high when the difference between the power levels of the "desired" in-band signals and the "undesired" adjacent band signals is great. The risk becomes even higher the closer the adjacent band signals are in frequency to the desired signals.

The issue of overload interference is not unique to GPS – in fact, virtually any radio receiver can be overloaded if the adjacent frequency signals are in close enough spatial and spectral proximity and the disparity in power is sufficiently great. GPS receivers are typically designed to withstand adjacent band transmissions hundreds of millions of times stronger than GPS signals, and compare favorably to other common types of mass market receivers. Recent carefully controlled tests conducted by Aerospace Corporation demonstrated that three typical GPS receivers were better able to withstand adjacent band transmissions, on a relative basis, than digital television and FM radio receivers from reputable television and radio manufacturers.[5]

The possibility of receiver overload and the need to provide spectral separation to avoid overload and protect receivers is routinely taken into account in spectrum planning in other contexts, including mobile services. One common example is the separation of downlink and uplink frequencies

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4 *See, e.g.*, *Amendment of Part 27 of the Commission's Rules to Govern the Operation of Wireless Communications Services in the 2.3 GHz Band; Establishment of Rules and Policies for the Digital Audio Radio Satellite Service in the 2310-2360 MHz Frequency Band*, Report and Order and Second Report and Order, 25 FCC Rcd. 11710 (2010) (evaluating the potential for overload interference to Satellite Digital Audio Radio Service receivers from Wireless Communications Service ("WCS") mobile devices and adopting conditions on WCS devices to help mitigate the potential for such interference); *Service Rules for Advanced Wireless Services in the 2155-2175 MHz Band*, Notice of Proposed Rulemaking, 22 FCC Rcd. 17035, ¶ 16 (2007) (expressing concern with overload interference to adjacent channel mobile receivers from AWS-3 operations and proposing to limit the transmitting power of the AWS-3 mobile transmissions to protect such receivers).

5 T.D. Powell, "Adjacent Band Interference to Consumer Radio Receivers," Aerospace Corporation Study No.TOR-2013-00046, May 2013.

in paired mobile spectrum blocks used for frequency division duplex ("FDD") mobile technologies, which are by far the most common form of mobile technology. FDD LTE frequency bands are paired to allow simultaneous transmission on two frequencies. The bands must have sufficient spectral separation in order to prevent the transmitted signals from unduly impairing the receiver performance. If the signals are too close in frequency, the receiver will be "blocked" and its sensitivity impaired. The separation between receive and transmit frequencies must be sufficient to enable the antenna and filters to attenuate the transmitted signal within the receive band. As a result, the standard separation (or "band gap") between paired uplink and downlink spectrum is significant. In the case of GPS versus mobile downlink operations, the power differential is much higher than the mobile to mobile case, requiring even greater levels of separation than those required to protect mobile receivers under normal operating conditions.

In other words, there is no expectation in the mobile world generally that receiver filtering must be capable of tolerating high powered transmissions in closely adjacent spectrum in normal operations. This reflects a rational balancing of considerations of cost and sound engineering practice for devices (mobile handsets) that are aimed at the mass consumer market. When viewed in this context, it is clear that the susceptibility of GPS receivers to high powered transmissions in adjacent bands is in no way a "problem" with GPS receivers; rather, such a suggestion reflects either disregard of basic engineering principles, application of a double standard to GPS receivers, or both. Adoption of receiver standards on this basis would be arbitrary and unfair to GPS, and would effectively hold GPS devices to a higher standard than other consumer electronic devices.

3. The Difference Between Communications and Navigation Affects Potential Spectrum Sharing

As described above, in determining whether services can exist in adjacent bands, it is critical to know the type of service supported in those bands. Systems that operate communications services can be less sensitive to adjacent band operations than systems that support navigation functions. GPS is a navigation system. The primary measurement in GPS is the timing of bit transitions in the navigation signal. Precise positioning requires sub-nanosecond measurement of bit edges.[6] Accurate measurement of bit edges in turn requires wide receiver bandwidth, and effective multipath rejection also requires wideband signals. In addition, unlike communications systems which operate above the noise floor spread spectrum GPS signals are below the thermal noise floor when they are received. The cumulative effects of in-band interference can easily increase the noise floor and degrade performance.

Unlike interference between mobile communications networks, where the user can observe the results of interference in dropped calls or poor call quality, the positional accuracy of a GPS device can be degraded by interfering noise in a way that is not detectable, can mislead users about their location, and, in the case of automated guidance applications, cause poor performance or outright malfunctions. In extreme cases of interference, where a GPS receiver "loses lock" on available GPS satellites

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[6] This is a very different type of function from that typically performed by terrestrial communications receivers, and traditional means of analyzing and mitigating interference in the communications realm may have little relevance to GPS, or may adversely affect receiver performance. For example, terrestrial mobile networks can use techniques such as dynamic power control and can trade off communications speed and reception quality to maintain viable communications sessions. GPS receivers must work with satellite signals that are fixed in nature and make the most of the data that can be extracted from very low power signals buried in the thermal noise and any interfering signals.

altogether, the user is left with no means of determining location until the interference is abated. While the testimony suggests that interference should be determined on the basis of "discernible" impact on receivers, it ignores just how problematic this concept is in the case of GNSS.

Because GNSS operates below the noise floor, the most appropriate means by which to assess the potential of new adjacent band systems is whether the new service causes a 1 dB degradation in a receiver's Carrier-to-Noise Ratio ("CNR"), or a 25% increase in the noise floor in GNSS bands. The 1 dB standard has a long and well-established history in both international and domestic regulatory proceedings as the appropriate interference protection criteria ("IPC") for GPS receivers. Other interference metrics – such as those contemplated by Dr. Roberson – are based on interference levels that seriously degrade the GNSS spectrum environment and will cause devastating disruption to GPS receivers. Therefore, any evaluation of the potential use of bands adjacent to GNSS for terrestrial services must use the 1 dB degradation standard.

Use of a 1 dB standard is vastly superior to an approach that attempts to assess whether there is "actual" harm to an incumbent service, which wrongly assumes that you can accurately predict the impact of a new service across a heterogeneous series of devices in adjacent spectrum. Defining harmful interference by reference to a level of degradation to a particular key performance indicator among a limited universe of devices and applications fails to account for and support future innovation, including known and currently unknown applications which could take advantage of ever increasing accuracy of the position, navigation and timing functions of GPS. Use of a defined change in the noise floor (1 dB) provides a readily identifiable and predictable metric that all interested parties can take into account now and in the future.

4. Policy Makers Should Engage in Rational, Long Term Spectrum Planning to Reconcile Dissimilar Spectrum Uses, Rather than Simply Attempting to Specify Receiver "Standards"

Since multiple factors affect the likelihood of interference between highly dissimilar spectrum uses, focusing solely on regulation of receiver characteristics is likely to have limited usefulness and may very well be inefficient and harmful to continued innovation in affected spectrum uses. Forward looking receiver performance standards will not solve interference to existing receivers, and a mandated transition to upgraded receivers has clear costs which need to be weighed carefully and would be difficult to enforce. On the other hand, having clearly defined receiver protection criteria, which are soundly formulated on a technology neutral basis and which are forward looking in applicability, could enhance predictability in spectrum use. However, incremental improvements in receiver design are unlikely to substantially change receivers' susceptibility to interference in the case of highly dissimilar spectrum uses. More fundamental re-engineering of a successful receiver technology such as GPS to accommodate a highly dissimilar use is very likely to lead to losses in performance and a slower pace of innovation in the underlying technology due to the need to adapt designs to engineering challenges unrelated to the purpose of the devices in question.

Receiver regulation would also impede innovation. Establishment of receiver standards by the FCC will be very difficult under any scenario, and administration and enforcement of these standards present formidable challenges, especially in the case of GPS.[7] Devices that use GPS for location based

[7] For example, the "harm claim thresholds" approach recently proposed by the FCC, while it avoids the need for detailed regulation of receiver design, would be very difficult to implement. Comments of the GPS Innovation Alliance, ET Docket No. 13-101, at 16-22 (filed Jul. 22, 2013) (explaining that harm claim thresholds present serious administrative challenges, particularly for "decoupled" devices such as GPS receivers).

applications come in a great variety of form factors and support an immense variety of hardware devices and software applications that rely on GPS, from baseball sized precision devices to smart phones to tiny receivers embedded in watches or running shoes. As a result, design changes intended to mitigate interference from undesired signals, such as including more elaborate filtering, may be possible for some devices, but may simply be impractical for other applications. Over the long term, we believe that the public will be best served by allowing companies to innovate with a wide variety of form factors, rather than implicitly or explicitly requiring engineering changes which effectively limit when and how GPS receivers can be used.

A more straightforward approach, and one which is more likely to be effective than exclusive reliance on mandated receiver standards, is to minimize the number of dissimilar spectrum applications in close spectral proximity to each other. Put another way, similar spectrum uses should be grouped together to the greatest extent possible to minimize the number of band edges or "border areas" where dissimilar uses in close proximity create serious interference challenges. This would involve more use of a "zoning" approach to spectrum management, as opposed to a "good fences make good neighbors" approach that requires the FCC to engage in extensive rule making and standards development to balance the interests of dissimilar spectrum uses in every spectrum "border" area.

Applying such a "zoning" approach to GPS and adjacent satellite spectrum bands would involve maintaining the historical "quiet neighborhood" and avoiding authorization of high powered uses in this band now or in the future.[8] It is clear that the FCC may have over-allocated spectrum for satellite use in prior decades, and in appropriate circumstances, the FCC and interested government stakeholders should carefully consider repurposing satellite spectrum for high value terrestrial use determined on an objective basis. These considerations however, go to the size of the quiet neighborhood, not the merits of having one. It would also be extremely short-sighted to extrapolate current technology trends in determining the amount of spectrum reserved for satellite applications. As a general matter, the FCC's ability to make predictive judgments about future technological developments is limited. That is why the FCC is generally reluctant to make technological mandates.[9] In fact, the limitations of the FCC's ability to make predictive judgments are highlighted by the fact that an earlier set of technological predictions created the current spectrum conundrum.

In addition to GPS, two other highly successful spectrum uses are satellite based: direct-to-home satellite video and digital satellite radio. In the future, with the advent of unmanned vehicles and the "Internet of things" with their attendant need to access to data literally everywhere (as opposed to the expansive but still limited footprints of high powered cellular based networks), it is not hard to imagine substantially increased demand for mobile services which take advantage of the ubiquitous coverage of satellites.

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[8] Reserving the Mobile Satellite Service ("MSS") band for satellite use would not prejudice existing spectrum rights since MSS license holders never had rights to use MSS spectrum for terrestrial purposes other integrated services to "fill-in" gaps in satellite coverage.

[9] *See, e.g.*, *Amendment of the Commission's Rules with Regard to Commercial Operations in the 1695-1710 MHz, 1755-1780 MHz, and 2155-2180 MHz*, Report and Order, GN Docket No. 13-185, FCC 14-31, ¶ 105 (rel. Mar. 31, 2014) ("Mandating a particular industry standard such as LTE would hamstring innovation and development and be contrary to the Commission's policy to preserve technical flexibility and refrain from imposing unnecessary technical standards."); *Expanding Access to Broadband and Encouraging Innovation Through Establishment of an Air-Ground Mobile Broadband Secondary Service for Passengers Aboard Aircraft in the 14.0-14.5 GHz Band*, Notice of Proposed Rulemaking, 28 FCC Rcd. 6765, ¶ 101 (2013) (explaining that the Commission "strive[s] to establish technology neutral rules that allow for competing technologies and changes in technology over time").

For example, autonomous automobiles will require truly ubiquitous access to both satellite navigation and satellite communication signals (GNSS signals augmented for precision with satellite delivered corrections data). Motorists can currently tolerate lack of cellular coverage on long trips through lightly populated areas, since the worst case is the inability to make a call or access the Internet for a limited period of time. The same cannot be said if your vehicle is relying on data signals for navigation, collision avoidance, and route optimization. While the FCC may have over-allocated spectrum for satellite applications in the past, GPSIA respectfully submits that it is equally dangerous to swing the pendulum to the opposite extreme and assume that new high-value satellite services will not develop in the coming decades. Wholesale reallocation of spectrum near critical satellite uses such as GPS for terrestrial broadband use, rather than preserving appropriately sized "quiet neighborhoods" for satellite, is likely to prove a costly mistake.

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GPSIA appreciates the ability to provide the Subcommittee with the foregoing information and looks forward to continuing to work with it on these important issues.