February 18, 2020

Marlene H. Dortch, Secretary
Federal Communications Commission
445 12th Street, SW
Washington, DC 20554

Re: Written Ex Parte Presentation Regarding 1 dB Standard, **IB Docket Nos. 11-109 and 12-340; IBFS File Nos. SES-MOD-20151231-00981; SAT-MOD-20151231-00090; SAT-MOD-20151231-00091; SAT-AMD-20180531-00044; SAT-AMD-20180531-00045; and SES-AMD-20180531-00856**

Dear Ms. Dortch:

The GPS Innovation Alliance ("GPSIA") hereby responds to Ligado Networks, LLC's ("Ligado's") recent letter criticizing three aspects of GPSIA's most recent explanation as to why the FCC should apply the "1 dB Standard" to evaluate pending applications filed by Ligado.[1] As shown in detail below, each criticism is specious. A 1 dB degradation in C/N_0 is a direct indicator of interference and is a metric supported in precedent. The 1 dB Standard remains the only reliable mechanism to ensure adequate protection for the continued functioning of Global Positioning System ("GPS") and Global Navigation Satellite System ("GNSS") receivers and the multitude of aviation, public safety, and other uses that depend on GPS and GNSS on a daily basis.

I. Temporal Fluctuations in GPS/GNSS Signals Are Not the Same as Persistent Degradation.

Ligado argues that, because GPS receivers at times experience fluctuation in C/N_0 of more than 1 dB, GPS receivers will not be harmed by the 1 dB or greater degradation that its proposed operations will cause to them.[2] As GPSIA has explained in previous comments, this

[1] Letter from Gerard J. Waldron, Covington & Burling LLP, to Marlene H. Dortch, Secretary, FCC, IB Docket Nos. 11-109 *et al.* (filed Jan. 13, 2020) ("Ligado January 13 Ex Parte"); Letter from J. David Grossman, Executive Director, GPS Innovation Alliance, to Marlene H. Dortch, Secretary, FCC, IB Docket Nos. 11-109 *et al.* (filed Dec. 20, 2019) ("GPSIA December 20 Ex Parte").

[2] Ligado January 13 Ex Parte at 2-3.

argument conflates temporal signal fluctuations with the persistent degradation bias associated with Ligado's proposed service.[3]

Ligado's argument ignores that a variety of routine factors can lead to fluctuations in GPS-received signal levels that, in turn, affect the reported C/N_0. For instance, as a satellite moves across the sky, the strength of the signal received from the satellite varies; the received signal from a GPS satellite is stronger when the satellite is directly overhead, but weaker when the satellite is on the horizon. Multipath, foliage, and blocking from adjacent structures, such as buildings, also cause fluctuations in GPS signals. In addition, receiver bandwidth and averaging, receiver parameters that are use-case dependent, affect observed fluctuations in C/N_0.[4] Rather than demonstrating problems with the 1 dB Standard, these routine fluctuations actually show why the 1 dB Standard is essential to protecting GPS accuracy, availability, integrity, and continuity.

The system margin in GPS receivers is already budgeted or designed to accommodate such routine factors. It is unreasonable to insist that system margins be doubled to accommodate

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[3] *See, e.g.*, GPSIA December 20 Ex Parte at 8 noting, "the variations in measurement to which Ligado now alludes are short-term, relatively instantaneous fluctuations that occur when measuring any physical phenomenon – fluctuations that scientists and engineers routinely deal with and successfully measure. By contrast, the effect of interference on GPS signals represents a persistent degradation bias – a phenomenon easily observed and measured, as multiple tests have shown."

[4] The plot that Ligado includes in its discussion of C/N_0 fluctuations obscures the facts. (*See* Ligado January 13 Ex Parte at 2.) This plot lacks not only proper citation or supporting documentation but, more importantly, lacks critical test details such as antenna location, multipath environment, bandwidth, averaging, receiver mode, etc. In describing this test in an earlier *ex parte* filing, Ligado indicates that "[a] high quality GPS antenna will be installed on the roof of the building where the RF anechoic chamber is located. The GPS signal will be amplified and connect to the GPS source antenna in the chamber to produce the 'Live Sky' signal." (*See* Letter of Gerard J. Waldron, Covington & Burling, LLP to Marlene H. Dortch, FCC, IB Docket Nos. 11-109 *et al*. (filed Feb. 24, 2016), "GPS Sensitivity Measurement Plan at Section 2.5.1.3) It is highly likely that some of the variance in the data came from Ligado's own test setup, not the receiver itself. The changes in C/N_0 over the time period of the test can easily be attributed to changes in received satellite power due to varying angles of reception, antenna gain patters, atmospheric effects, and multipath, with respect to the GPS antenna on the roof. Moreover, as GPSIA already explained and establishes in detail again in this filing, temporal C/N_0 variation in excess of 1 dB does not diminish the relevance and importance of the 1 dB Standard in evaluating the persistent degradation bias that would occur in GPS receivers as a result of Ligado's proposed operations.

new spectrum uses such as Ligado's proposal that will cause persistent or ongoing degradation and was never envisioned when the margins were established.[5]

Use of the 1 dB Standard is in no way precluded by the aforementioned fluctuations in C/N_0. In fact, such measurements have been conducted by GPS designers for decades and have been a part of every credible test regime that has taken place over the last 10 years to measure potential interference from Ligado's proposal. Temporal fluctuations are easily averaged or controlled in the test environment, enabling measurement of the persistent or ongoing degradation bias introduced by Ligado's proposed operations.

An analogy, based on another routine physical phenomenon, shows the speciousness of Ligado's contention that the persistent degradation bias in its system should be disregarded as unmeasurable (and deemed irrelevant) because fluctuations already exist in the GPS signal. Ocean waves vary; they can easily exceed many feet in height from peak to trough. These ongoing, temporal fluctuations do not mean, however, that changes in sea level or tides are irrelevant or unmeasurable. Rather, the measurement of tides and sea level is absolutely critical for coastal populations that depend on levees and seawalls to protect them from flooding. A one-foot increase in sea level may not always cause immediate, catastrophic problem on a calm, sunny day, but when a storm surge hits, that one-foot erodes precious margin that can represent the difference between life and death. Although a one-foot rise in mean sea level may be visibly obscured from time to time by waves of more than one foot in height, its effect is still measurable and of great impact.

Ligado similarly paints a "sunny day" picture, an idealistic one, in which it shows C/N_0 fluctuations under optimal signal conditions; Ligado ignores that the very serious implication of its proposal is persistent degradation bias on GPS receivers, such as those used in aviation and other safety-of-life applications. Naturally occurring, routine fluctuations in the GPS signal that have already been taken into account do not mean the 1 dB Standard is not an essential and effective measurement for purposes of gauging the deleterious effect of interference on GPS systems and services.

II. Variance in Different C/N_0 Measurement Techniques Does Not Invalidate the Utility of the 1 dB Standard.

Ligado further contends that variance in different C/N_0 measurement techniques invalidates the utility of C/N_0 in assessing interference to GNSS receivers.[6] Temporal fluctuations in physical phenomena have never stopped scientists from measuring those phenomena. As with the marine analogy above, scientists and others have been measuring tides for thousands of years, despite the presence of waves (fluctuations) on the ocean, and have

[5] As the GPSIA December 20 Ex Parte stated, "[i]t is critical that the margin established in the design of the GPS system for effects such as these not be eroded by allowing persistent interference levels that may have less impact under ideal conditions."

[6] *See* Ligado January 13 Ex Parte at 3.

likewise developed various methods for estimating mean sea level. In fact, even a young child with a stick in the sand can observe tidal changes despite the presence of waves.

Over the last decade, multiple linearity tests have been run on GPS receivers. These tests ensure that a 1 dB change in the actual received signal level is correctly reported as a 1 dB change in C/N_0. Ligado is well aware that the results of this extensive testing have demonstrated linear behavior in the particular GPS receivers under test;[7] these receivers showed that they accurately and consistently reported a 1 dB change in C/N_0. Ligado's latest attempt to obfuscate and ignore these studies does nothing to undermine the sound scientific principles supporting the tests.

For example, in the 2011 tests at the White Sands Missile Range ("WSMR"), great care was taken to ensure that every GPS receiver that was tested consistently reported a 1 dB change in C/N_0 whenever the radiated GPS signal level changed by 1 dB.[8] As the report concluded, "[t]his test provided confidence that a receiver's C/N_0 changed in a linear fashion."[9] Of the 94 General Navigation receivers tested at WSMR that yielded usable data, all had a linear response. In other words, all 94 receivers, no matter the manufacturer or use case, were able to measure and then consistently and accurately report a 1dB change in C/N_0.

Similarly, the tests conducted as part of the Department of Transportation GPS Adjacent Band Compatibility Assessment measured receiver linearity. The results showed that the receivers that were tested accurately reported a 1 dB change in signal power as a 1 dB change in C/N_0.[10] As part of the planning process for the DOT tests, all stakeholders, including Ligado, had discussed the purpose and procedures of these tests.[11]

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[7] To try to make its point, Ligado includes a plot indicating a static offset in the C/N_0 reported from various computation algorithms. (*See id.*) This plot is irrelevant; a static offset has no impact on the linearity of the reported C/N_0 – a fact attested to in multiple test regimes and described in these comments. Regardless of the computation algorithm used, receivers accurately and consistently report a 1 dB change in C/N_0.

[8] *See* Memorandum for Administrator, NTIA, from Teri M. Takai, Department of Defense, and Joel M. Szabat, Department of Transportation, Jan. 18, 2012, and attached report ("Follow-on Assessment of LightSquared Ancillary Terrestrial Component Effects on GPS Receivers") at Sections 5.1.2.1 and 3.4.3.1, *available at* https://www.ntia.doc.gov/files/ntia/publications/npef_cover_memo.pdf.

[9] *Id.* at Section 5.1.2.1.

[10] U.S. Department of Transportation, *Global Positioning System (GPS) Adjacent Band Compatibility Assessment*, Final Report (2018), at Section 3.1.5.1.

[11] *See*, for example, Slide 5 of one such presentation given at a DOT ABC Workshops: https://www.gps.gov/governance/advisory/meetings/2017-11/vandyke.pdf.

As GPSIA recounted in its December 20 Ex Parte, over the last decade, numerous tests have been conducted, and they successfully applied the 1 dB Standard.[12] Except for Ligado and its advisors, no one participating in these tests and evaluations has had any trouble measuring a 1 dB change in C/N_0 for GPS receivers.

III. The Record Belies Ligado's Claim That the 1 dB Standard Lacks Adequate Precedent With Respect to Evaluating Adjacent Band Emissions.

Ligado's January 13 filing also repeats past arguments that GPSIA has already conclusively refuted. Ligado again mistakenly claims that inadequate precedent exists "for the use of a 1 dB C/N_0 degradation as the basis of setting transmit power limits in an adjacent band."[13] Ligado then lists International Telecommunications Union ("ITU") documents that it claims support its point.[14]

However, Ligado ignores a well-reasoned U.S. Air Force Report that discussed this issue, along with material that GPSIA has already submitted. The Air Force Report, which GPSIA endorses, provides that the 1 dB Standard is the appropriate determinant of harmful interference to GPS and other Radio Navigation Satellite Service ("RNSS") receivers, applied to either of two types of interference: (i) out-of-band emissions ("OOBE") that emanate from services in adjacent bands but that fall within the RNSS band; or (ii) overload interference that emanates from services in adjacent bands and that falls outside the RNSS band.[15] In the past, much more focus has been directed to ensuring OOBE interference does not occur, since traditionally regulators have sought to group like services with similar power characteristics together in the same or adjacent band(s), separating them from other services with extreme power differences.[16]

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12 GPSIA December 20 Ex Parte at 8 & n.23.

13 Ligado January 13 Ex Parte at 4.

14 Id. at 5.

15 *See* U.S. Air Force, SMC/GP (GPS Directorate), "Background Paper on Use of 1-dB Decrease in C/N_0 as GPS Interference Protection Criterion," June 2017, at 2, 6-9, *available at* www.gps.gov/spectrum/ABC/1dB-background-paper.pdf ("Air Force Report"). GPS and other GNSS, such as GLONASS and Galileo, operate in the RNSS band (1559-1610 MHz).

GPS experts have also supported the primacy of a C/N_0 measurement: "An accurate measure of C/N_0 in each receiver tracking channel is probably the most important mode and quality control parameter in the receiver baseband area." HEGARTY & KAPLAN EDS., *Understanding GPS, Principles and Applications*, 2nd Ed. (Artech House, Boston, 2006), Section 5.11.1.

16 *See* ITU Radio Regulation 4.5, which sets forth this general policy: "the frequency assigned to a station of a given service shall be separated from the limits of the band allocated to this service in such a way that, taking account of the frequency band assigned to a station, no harmful interference is caused to services to which frequency bands immediately adjacent are allocated."

When both types of interference occur, GPSIA finds it surprising – if not remarkable – that anyone would suggest that regulators considering system-level interference from a single service to GPS and other RNSS receivers could somehow separate OOBE concerns from overload interference concerns.[17] Indeed, as technologies have proliferated, contrary to Ligado's claims, experts and regulators have applied the 1 dB Standard to govern both OOBE and overload interference from services into adjacent bands, including the RNSS band.[18] In these instances, it is essential to evaluate the aggregate effect of such distinct types of interference originating from a common source.

As the Air Force Report explained, sufficient basis exists to apply the 1 dB Standard to GPS performance degradation that results from "*all interference mechanisms*" imposed by adjacent band interference.[19] According to this same source, "[a]s a practical matter, the effects of such an interference source [*i.e.*, aggregated OOBE and overload inference from adjacent services] on the RNSS receiver must be kept at least as low as the effects caused by emissions falling in the RNSS bands [*i.e.*, OOBE from adjacent services] or the existing criteria used for protecting the noise floor … [are] effectively invalidated and rendered useless."[20]

In short, the 1 dB Standard is not only supported by precedent, but it remains the appropriate metric for evaluating harmful interference from adjacent band sources because it successfully aggregates increases in the noise floor from OOBE alongside degradation from overload interference. It does so in a manner even more generous than some existing ITU recommendations cited by the Air Force. Clearly, a holistic approach is a more effective and reasonable regulatory approach to resolving this issue than a piecemeal regime. GPSIA

Examples of instances in which the 1 dB Standard has been applied to ensuring OOBE occurring within the GPS band from services outside the band include ITU-R M.1903 and ITU-R M.1904, which are intended for performing analyses of radio frequency interference impact on RNSS and ARNS receivers from the emissions of non-RNSS sources. (The Aeronautical Radio Navigation Service ("ARNS") is a specialized terrestrial service restricted to safety-of-life use, while the RNSS is for space-to-earth and space-to-space use. Both share a co-primary allocation in the 1559-1610 MHz band.)

[17] In its January 13 filing, Ligado at least acknowledges that it "has long agreed that a 1 dB change is a reasonable guideline for cochannel (in-band) emissions (*i.e.*, emissions into the GNSS band). Ligado January 13 Ex Parte at 4.

[18] *See* ITU-R M.1461-1 at Annex 1, Section 3; ITU-R M. 2059-0 at Annex 3, Section 2 *generally,* and *specifically* Sections 2.1, 2.2; Air Force Report *generally* at 2-4, 6-9. *See also* ITU-R M.2458 at 2.1b) ("Many RNSS receivers, which are ubiquitously deployed, are designed to acquire and track their associated satellite signals in the presence of interference *from all non-RNSS sources* that degrades C/N_0 by no more than 1 dB." (emphasis supplied)

[19] Air Force Report at 8 (emphasis in original).

[20] *Id.*

encourages Ligado to revisit the precedent cited in the Air Force Report as well as in this filing to quell its latest concerns.

IV. Conclusion.

Contrary to Ligado's continued claims, temporal fluctuations in GPS/GNSS signals do not change the conclusion that naturally occurring fluctuations are not the same as persistent degradation. Equally important, variance in different C/N_0 measurement techniques does not invalidate the utility of the 1 dB metric; extensive testing has shown a 1 dB change in actual signal level to be accurately and correctly reported as a 1 dB change in C/N_0. Finally, adequate precedent supports use of the 1 dB Standard for measuring "overload interference" emanating from services in adjacent bands that fall outside the RNSS band. The 1 dB Standard remains the only reliable metric to guide this proceeding.

Sincerely,

David Grossman

J. David Grossman
Executive Director
GPS Innovation Alliance

cc by email:

The Honorable Ajit Pai
The Honorable Michael O'Rielly
The Honorable Brendan Carr
The Honorable Jessica Rosenworcel
The Honorable Geoffrey Starks