

3C SYSTEMS COMPANY

Design, Development, Analysis, & Regulation of Communications Systems

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6 July 2018

Ms. Marlene H. Dortch
Secretary
Federal Communications Commission
445 12th Street, S.W.
Washington, D.C. 20554

RE: Amendment to License Modification Applications IBFS File Nos. SES-MOD-20151231-00981, SAT-MOD-20151231-00090, and SAT-MOD-20151231-00091, IB Docket No. 11-109

Dear Ms. Dortch:

I have reviewed the DoT GPS ABC Assessment in light of Ligado's May 2018 Modification Applications Amendment. Based on my over 40 years' experience with GPS, review of the Modification Applications Amendment, review of the DoT GPS ABC Assessment, familiarity with the NASCTN report¹, participation in the Roberson and Associates study, and participation in the IWG, my opinion is that operation of the Ligado system in compliance with the Modification Application Amendment will not result in harmful interference to space-based receivers or certified aviation receivers.

Background

I have over 40 years' experience in the design, development, analysis, and application of GPS systems. I graduated from Caltech with a BS in Applied Mathematics in 1977 and hold a graduate degree from USC, I spent the first part of my career at Teledyne and Magnavox. In the early to mid-80's, as Director GPS Development, I led Litton Aero Products GPS efforts leading to development of the LTN-700, LTN-710, and μ NAV GPS Navigation Systems, and the codeless L2 signal-processing technique incorporated in Western Atlas Aero Service's GPS survey set (MINI-MAC). In the late 80's, I joined Litton Guidance and Control Systems. I founded my consulting company, 3C Systems Company, in 1989, with which I have worked on a range of complex GPS matters, and since 2009 I have advised Ligado, and its predecessor companies, on GPS issues.

In addition, I hold thirty US patents in GPS and related fields, nine of which specifically cover GPS technology. I have several additional patents pending. I have presented over 30 technical papers, 21 of which focused on GPS technology. I am a Senior Member of the IEEE, a Senior Member of the American Institute of Aeronautics and Astronautics, and am a member of the Institute of

¹ NASCTN, NIST Technical Note 1952, LTE Impacts on GPS Final Report, February 2017.

Navigation, the Pacific Telecommunications Council, and the Society of Satellite Professionals International. I hold a General Radiotelephone Operator License from the FCC.

Review of DoT GPS ABC Assessment

Having reviewed the DoT GPS ABC Assessment, I am of the opinion that operating the Ligado system in conformance with the Modification Application Amendment will not result in harmful interference to space-based receivers or certified aviation receivers.

To form this conclusion, I reviewed the following documents:

- Amendment to License Modification Applications IBFS File Nos. SES-MOD-20151231-00981, SAT-MOD-20151231-00090, and SAT-MOD-20151231-00091, IB Docket No. 11-109, 31 May 2018.
- United States Department of Transportation Global Positioning System (GPS) Adjacent Band Compatibility Assessment, Final Report, December 2017, including all appendices.

I also developed a simulation program to verify the NASA simulation results reported in Section 4.2 and Appendix K of the assessment.

In the Modification Application Amendment, Ligado proposes to:

1. Limit ATC base stations operating in the Lower Downlink Band to a maximum 9.8 dBW EIRP with a +/- 45-degree cross-polarized base station antenna
2. Prohibit any ATC base station antenna in the Lower Downlink Band from operating at a location less than 250 feet laterally or less than 30 feet below an obstacle clearance surface established by the FAA
3. Comply with the reporting, notification and monitoring obligations set forth in Exhibit 1 to the amendment

The DoT GPS ABC assessment took the approach of determining interference tolerance masks (ITMs) or tolerable interference levels. "The ITM defines, for a given frequency, the maximum power allowed to ensure the tested GPS/GNSS receiver did not experience more than a 1 dB reduction in carrier-to-noise density ratio (CNR) for various categories of GPS/GNSS receivers."² In my opinion this analysis does not address the question the FCC must answer: whether GPS devices will experience harmful interference. Instead, it uses an overly restrictive criteria for determining adjacent band operating levels.³

As a general matter, it is worth noting that statements like "[when the] receiver exceeds a 1 dB signal-to-noise density (C/N0) interference protection criteria ... the behavior of the GPS/GNSS receiver can become unpredictable in its ability to meet the accuracy, availability, and integrity requirements of its intended application and a receiver in a mobile application may not be able to reacquire GPS positioning ..."⁴ and "... the total unwanted N0 + I0 level is now 25% higher which is highly significant to system designers"⁵ are misleading at best. If GPS/GNSS receivers became unpredictable when experiencing a 1 dB drop in C/N0 (or equivalently 25% higher N0 + I0 level),

² Page 18.

³ See Mark A. Sturza, White Paper, "Changes in C/N0 Are Not a Reliable Indicator of KPI Impact" at 3, attached as Attachment B, attached to Reply Comments of Ligado Networks, IB Docket No. 11-109 (June 6, 2016), <https://ecfsapi.fcc.gov/file/60002097963.pdf>.

⁴ Page IV.

⁵ Page 45.

there would be no GPS industry because fluctuations of 1 dB in C/N₀ happen so frequently with GPS devices that they are simply assumed as a given.⁶

Space-Based Receivers

Table ES-2 of the report⁷ shows the maximum tolerable power levels of space-based receivers used for performing scientific measurements. For up to 184,500 ATC macro base stations, an 11 dBW EIRP is tolerable, and for a combination of 102,841 macro and micro base stations, a 12 dBW EIRP is tolerable. This is confirmed by the statement in Section 4.2 that “For the most challenging model (1c), using 184,500 macro cell stations, the tolerable EIRP is 11 dBW.”⁸ It is my understanding that Ligado plans to deploy far fewer than 100,000 ATC base stations, and with the 9.8 dBW EIRP restriction in the amendment, it is clear that **the Ligado network will not cause harmful interference to space-based receivers.**

I performed an analysis of the tolerable number of ATC base stations operating in US cities at 10 dBW EIRP, based on the information contained in the DoT GPS ABC Assessment report. The following table shows the tolerable number of macro base stations operating at the 10 dBW limit that could be deployed in the United States. Four cases are considered, including the unrealistic 0° elevation mask compared to the 5° mask modeling real-world blockage, and 50% of the base stations transmitting simultaneously versus 100%.

Tolerable Number of ATC Base Stations in US Cities Operating at 10 dBW EIRP⁹

	0° Elevation Mask	5° Elevation Mask (real-world blockage)
50% of Base Stations Transmitting Simultaneously	232,272	583,440
100% of Base Stations Transmitting Simultaneously	116,136	291,720

Under any foreseeable deployment scenario, Ligado’s ATC network will not cause harmful interference to NASA’s RO missions.

Certified Aviation Receivers

The report tells us that “These analyses indicate that protection of certified avionics, operating under the assumption of the described 250-foot (76.2-m) radius assessment zone, requires that the Ground Station transmission EIRP not exceed 9.8 dBW (cross-polarized) at 1531 MHz. This limit is obtained from the HTAWS scenario which was found to be the most restrictive of the scenarios examined.”¹⁰ As the amendment limits ATC base station EIRP to 9.8 dBW outside of the 250-foot radius assessment zone, it is clear that **Ligado will not cause harmful interference to certified aviation receivers.**

⁶ Data from both the RAA and NASCTN show that that C/N₀ fluctuates by 3 dB in a “natural state” — meaning even without any wireless signals.

⁷ Page VI.

⁸ Page 116.

⁹ To put this number in context, the two largest wireless carriers, AT&T and Verizon, today have 67,000 and 58,300 respectively.

¹⁰ Page 153.

GLN, HPR, TIM, and CEL

Table ES-1 of the report¹¹, shows the maximum tolerable ATC base station EIRP at 1530 MHz for GLN (general location and navigation), HPR (high-precision receiver), TIM (timing), and CEL (cellular) GPS/GNSS receivers. For cellular receivers, a 11.7 W ATC base station EIRP is tolerable for all cases. As the amendment limits ATC base station EIRP to 9.8 dBW (10 W), it is clear that the Ligado network will not cause harmful interference to cellular devices.

It is possible to protect all categories of receivers. To the extent general location and navigation receivers, high-precision receivers, and timing receiver sensitivities exist, they are the result of poor frontend filtering in the receivers and these devices can therefore be made resilient with appropriate filters. As shown by the cellular devices, this is not a technology limitation, but rather a manufacturer's choice. There is no technical reason for such wide filters in general location and navigation receivers or timing receivers. RAA and NASCTN have shown that operating these devices with appropriate frontend filtering reduces sensitivity to OOB interference to similar levels as the cellular devices tested. Given the industry awareness of the potential for adjacent band ATC operations for at least 7 years, since 2011, it is surprising that general location and navigation or timing devices are still being produced with poor frontend filtering. There is no technical justification for this practice. With regard to high-precision receivers, there is a case for using wider filters. However, with modern DSP, there are likely ways to achieve similar performance with narrower filters.

Sincerely,

/s/ Mark A. Sturza

Mark A. Sturza
President

¹¹ Page V.