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April 12, 2016

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

Re: Boeing Response to CORF Late Filed Reply
Written Ex Parte Notice, GN Docket No.14-177, IB Docket Nos. 15-256 and 97-95; RM-11664; and WT Docket No. 10-112

Dear Ms. Dortch:

The Boeing Company ("Boeing") writes to address the late-filed reply comments submitted by the Committee on Radio Frequencies ("CORF") of the National Academy of Sciences.[1] It appears that CORF's reply comments primarily restate the concerns raised in its initial comments, concerns that were addressed at length in the comments and reply comments by multiple parties including Boeing. Thus, the reply comments of CORF do not fully reflect the substantial and constructive discussion of these matters. For the convenience of Commission staff, Boeing files this letter to briefly summarize CORF's stated concerns and the responses that were presented in the record.

Protection of the Earth Exploration Satellite Service in the 57-59.3 GHz Band

CORF expressed concern that transmissions by WiGig devices aboard aircraft might present a risk of interference to Earth Exploration Satellite Services ("EESS") operating in the 57-59.3 GHz band.[2] Accordingly, CORF urged "great caution" before authorizing aeronautical

[1] Reply Comments of the National Academy of Sciences' Committee on Radio Frequencies, GN Docket No. 14-177, et al. (Filed March 14, 2016) ("*CORF Reply*").

[2] *CORF Reply Comments* at 2; Comments of the National Academy of Sciences' Committee on Radio Frequencies, GN Docket No. 14-177, et al., at 11-16 (Filed Jan. 27, 2016) ("*CORF Comments*").

transmissions in this band, and recommended "further study of real-world transmission scenarios" prior to authorizing unlicensed use of this band.[3]

As an initial matter, Boeing is a world-leader in aviation design and manufacture, and Boeing and its customers rely on EESS satellite data for accurate weather forecasting, which is critical to the safe and efficient operation of aircraft.[4] Thus, Boeing shares CORF's strong interest in ensuring the reliable operation of EESS satellites. CORF's reply comments are incorrect in suggesting that the record "did not address the negative impact on critical EESS operations."[5] Boeing and others have explained that the careful arrangement of in-cabin network connections and the attenuation provided by aircraft interior and fuselage ensures that WiGig technologies used aboard aircraft will have no effect on EESS.

CORF's reply comments contend that Boeing overestimates the attenuation expected to be provided by the aircraft fuselage. To this end, CORF provides an illustration of the output of equations used in Report ITU-R-M.2283. CORF summarizes the result of these equations "show[ing] that little or no attenuation above 10 dB is expected for a relatively large range of angles."[6]

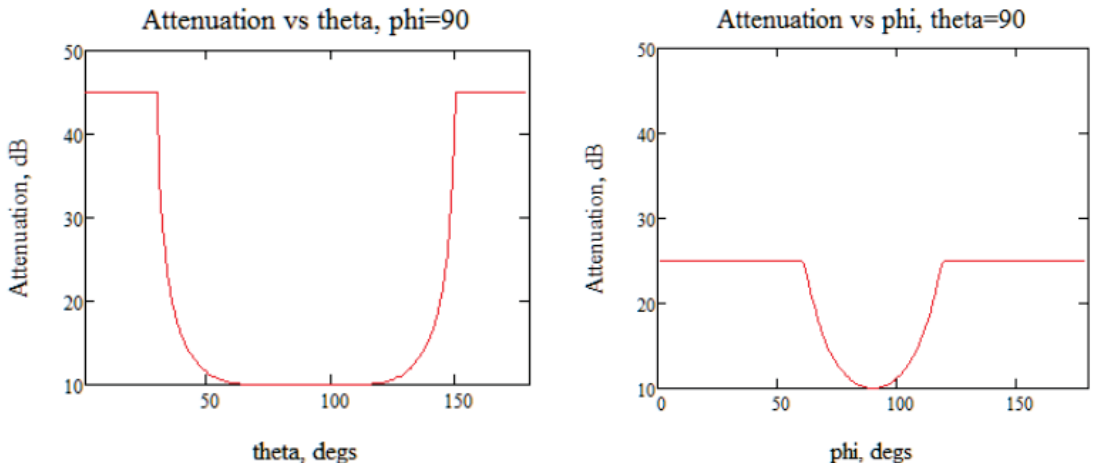


Figure 1. CORF Illustration of Attenuation Equations for Transmitters Installed Within the Aircraft Cabin Body (ITU-R-M.2283 Section A-3.7)

[3] *CORF Reply* at 2.

[4] Reply Comments of The Boeing Company, GN Docket No. 14-177, et al., at 22 (Feb. 26, 2016) ("*Boeing Reply*").

[5] *CORF Reply* at 2.

[6] *Id.* at 4.

CORF is correct that the equations given in ITU-R-M.2283 show low levels of attenuation for emission angles directly perpendicular to passenger windows. This observation, however, does not translate into a risk of interference to EESS for two reasons. First, such emissions would be directed laterally, rather than either upward toward satellites or downward toward terrestrial receivers. As illustrated in Figure 2, for viewing angles greater than 60 degrees, the aircraft structure will indeed provide significant attenuation for transmitters installed within the cabin.

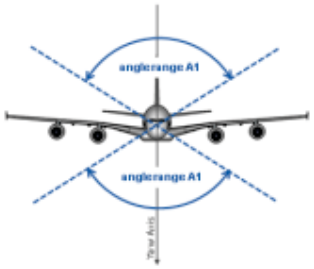
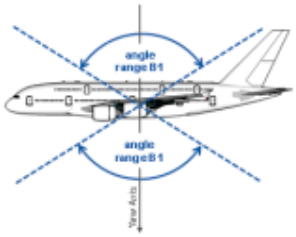
Case	Viewing Angle		Configuration	Attenuation
1	viewed from angel within range A1 (+/–60° relative to yaw axis) 	viewed from angle within range B1 (+/–60° relative to yaw axis) 	a) transmitters installed within cabin	25 dB
			b) transmitters installed in lower lobe of aircraft fuselage	35 dB
			c) transmitters installed in enclosed compartments or in aircraft fitted with shielded windows	35 dB

Figure 2. Detail of Table 5 from Report ITU-R-M.2283[7]

Moreover, the attenuation estimates in ITU-R-M.2283 are based on calculations derived from measurements in the frequency range from 962 MHz to 18 GHz.[8] Because attenuation due to line-of-sight obstruction increases as frequency increases, the attenuation level expected for the emissions in the 60 GHz range should be assumed to be even greater than the estimates provided in ITU-R-M.2283.

Second, it is unlikely that full power WiGig emissions would be directed straight out aircraft windows, *i.e.* in the range of 90 degrees that CORF identifies as providing little attenuation. CORF's concern in this regard seems to be based on an assumption that there are "few direct lines of sight between centrally located access points and user terminals" inside

[7] Technical characteristics and spectrum requirements of Wireless Avionics Intra-Communications systems to support their safe operation, Report ITU-R M.2283-0, Annex 3, A-3.1 (Dec. 2013), available at http://www.itu.int/dms_pub/itur/opb/rep/R-REP-M.2283-2013-PDF-E.pdf

[8] *Id.*

aircraft, which would necessitate access points relying on "scattered and reflected signals" to connect with user devices, ostensibly resulting in emissions directly at – and through – aircraft windows.[9]

Although this analysis may be valid for current Wi-Fi configurations, it is not correct for WiGig deployments. As Boeing, the Wi-Fi Alliance, and Microsoft explained in reply comments, WiGig systems would not rely on omnidirectional antennas "spraying" transmissions throughout the cabin.[10] Instead, WiGig transmissions use beam forming, in which multiple antennas create narrow, discrete, directional (line-of-sight) communications between in-cabin access points and user devices in passengers' hands, laps, or on tray tables.[11] Therefore, as Boeing explained in its reply comments, "the optimal location of WiGig access points on aircraft is within the ceiling, pointing straight down…and directly away from satellites above."[12]

Also unlike WiFi, which relies on only a few access points and thus requires omnidirectional antennas and higher power levels, WiGig-enabled commercial aircraft would be "equipped with multiple (often as many as twenty) low power access points situated just above passenger seats."[13] Each WiGig access point would therefore be highly directional, transmitting at about 10 dBm, with a resulting antenna gain of about 30 dBm eirp.[14] As a result, "neither the transmitter nor the receiver would direct energy towards the aircraft's windows," substantially reducing the primary avenue of potentially interfering emissions.[15] Any incidental energy reaching the windows from transmission sidelobes would be at significantly reduced power levels, 10 dB or more below the main beam.[16] Any reflected or scattered energy reaching the windows would be even further reduced due to the absorption of signals by passengers and materials within the aircraft.[17]

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[9] *CORF Reply* at 5.

[10] Reply Comments of The Wi-Fi Alliance, GN Docket No. 14-177, et al., at 7 (Feb. 26, 2016) ("*Wi-Fi Alliance Reply*"); Reply Comments of Microsoft Corporation, GN Docket No. 17-114 at 8 (Feb. 26, 2016) ("*Microsoft Reply*").

[11] *Wi-Fi Alliance Reply* at 7, *Microsoft Reply* at 8.

[12] *Boeing Reply* at 22.

[13] *Id.* at 23.

[14] *Id.*

[15] *Wi-Fi Alliance Reply* at 7.

[16] *Id.* at 8.

[17] *Id*.

To provide further technical basis for this discussion, the Wi-Fi Alliance prepared an interference analysis summarizing the various factors relevant to the interference potential of airborne WiGig operations on EESS operations, including transmit power, activity factor, fuselage attenuation, free space losses, atmospheric losses, and the aggregate effect of multiple aircraft.[18] The Wi-Fi Alliance analysis shows that even fairly conservative (worst-case) estimates for these factors nonetheless provide adequate protection for EESS operations.[19]

These substantial mitigating factors apply to all WiGig channels, thus, there would be no justification for the Commission to adopt CORF's proposal to prohibit airborne use of WiGig Channel 1 (57.24-59.4 GHz).[20] Similarly, there would be no justification to adopt CORF's proposal to apply "RF-reflective film"[21] to the windows of thousands of in-service commercial aircraft, an undertaking that would be impractical and unfeasibly expensive.

Protection of the Radio Astronomy Service in the 64-71 GHz Band

CORF also expresses concern that WiGig devices operating on board aircraft in the extended 60 GHz band could present a risk of interference to the radio astronomy service ("RAS") in the 111.8-114.25 GHz, 130-134 GHz, 136-148.5 GHz, and 192-213 GHz bands due to second and third harmonics.[22] As discussed above, however, it is unlikely that WiGig devices will generate measurable interference due to the shielding provided by aircraft structure and the highly directional nature of WiGig networking. Further, any potentially interfering emissions in the 60 GHz range that did escape the aircraft would be "considerably weaker" in the second and third harmonic than at the fundamental frequency.[23] Thus, it is unlikely as a practical matter that WiGig operations onboard aircraft would represent a risk of interference to RAS operations.

The Wi-Fi Alliance analysis also addresses the potential for interference with RAS. Even given the subtler signals (and thus much greater sensitivity) involved in RAS observations, the

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[18] *Wi-Fi Alliance Reply*, Attachment 1.

[19] *Id.*, Attachment 1 at 5. (showing a link budget margin of 29.4 dB for EESS satellites after accounting for any WiGig interference)

[20] *CORF Reply* at 2.

[21] *Id* at 5.

[22] *CORF Comments* at 4, *CORF Reply* at 3; *see also* Comments of the National Radio Astronomy Observatory, GN Docket No. 14-177, et al., at 5 (Jan. 22, 2016).

[23] *Microsoft Reply* at 7.

combined effects of physical attenuation and diminished power of harmonics still results in at least a 5 dB margin between the receiver noise floor and the received signal spectral density.[24]

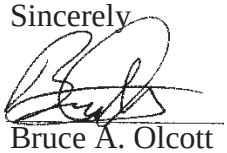
Protection of the Radio Astronomy Service in the 42.5-43.5 GHz Band

The satellite industry, including Boeing, proposed that the 42.0-42.5 GHz be identified for use by FSS because it is contiguous with an existing FSS allocation and because FSS network operators are well prepared to reliably protect adjacent frequency RAS operations through the use of geographic exclusion zones.[25] Although CORF's comments assert that there was "little support" in the record for additional allocations at 42.0-42.5 GHz,[26] the reply comments of SIA explained clearly that the 42.0-42.5 GHz band "is a critical near-term expansion band for FSS."[27] Boeing acknowledges that is will be necessary to develop suitable exclusion zones for the ten sites of the Very Long Baseline Array.[28] FSS operators, however, have substantial experience crafting coverage maps to include, or avoid, geographic areas with high precision. The satellite industry should therefore have no difficulty protecting the sites of the Very Long Baseline Array.

Conclusion

Boeing reiterates its commitment to protecting the important scientific missions of the EESS and RAS networks. In proposing WiGig operations aboard aircraft in the 57-71 GHz band and FSS operations in the 42.0-42.5 band, Boeing has taken EESS and RAS operations into account, and Boeing believes that the discussion presented in the record should alleviate the concerns that CORF has identified. The Commission should therefore proceed with its proposals to permit unlicensed operations in the 57-71 GHz band aboard aircraft and authorize FSS in the 42.0-42.5 GHz band.

Sincerely,



Bruce A. Olcott

[24] *Wi-Fi Alliance Reply*, Attachment 1 at 5.

[25] *Boeing Reply* at 19, Reply Comments of the Satellite Industry Association, GN Docket No. 14-177, et al., at 14 (Jan. 26, 2016) ("*SIA Reply*").

[26] *CORF Reply* at 9.

[27] *SIA Reply* at 6.

[28] *CORF Reply* at 10.