Before the
Federal Communications Commission
Washington, D.C. 20554

In the Matter of	)	
	)	
Expanding Access to Broadband and	)	GN Docket No. 13-114
Encouraging Innovation through Establishment	)	RM-11640
of an Air-Ground Mobile Broadband	)	
Secondary Service for Passengers Aboard	)	
Aircraft in the 14.0-14.5 GHz Band	)	

COMMENTS OF THE SATELLITE INDUSTRY ASSOCIATION

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COMMENTS OF THE SATELLITE INDUSTRY ASSOCIATION

The Satellite Industry Association ("SIA") hereby submits these comments in response to the Notice of Proposed Rulemaking ("NPRM") in the above-referenced proceeding, which seeks to implement a proposal proffered by Qualcomm Incorporated ("Qualcomm") to add a secondary allocation and establish new Federal Communications Commission ("FCC" or "Commission") rules for an Aeronautical Mobile Service ("AMS") in the 14.0-14.5 GHz band to provide air-ground mobile broadband service.[1]

I. INTRODUCTION AND SUMMARY

SIA is a U.S.-based trade association providing worldwide representation of the leading satellite operators, service providers, manufacturers, launch services providers, and ground equipment suppliers. Since its creation more than eighteen years ago, SIA has advocated for the unified voice of the U.S. satellite industry on policy, regulatory, and legislative issues affecting the satellite business.[2]

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[1] *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 (2013) ("NPRM").

[2] SIA Executive Members include: Artel, LLC; The Boeing Company; The DIRECTV

As the primary user of uplink frequencies in the 14.0-14.5 GHz band, the satellite industry has a substantial interest in the proposed introduction of a new secondary service in that band. The 14.0-14.5 GHz segment of the Ku-band is used today for a wide range of fixed-satellite services, including broadband to aircraft, and new technologies such as high-throughput satellites are being developed and deployed.[3] In 2011, the provision of Ku-band satellite services generated more than $1 billion in revenue in North America alone, and revenues are projected to grow by 4.1 percent CAGR over 10 years.[4] It is critical, therefore, for the Commission to proceed with caution in considering Qualcomm's proposal for a secondary AMS allocation in the 14.0-14.5 GHz band.

Before the Commission decides whether to move forward with a new secondary allocation for air-ground mobile broadband in the 14.0-14.5 GHz band, it must address the issues raised below in order to ensure that the new service would truly be secondary to the primary fixed-satellite service ("FSS"). As a secondary service, the AMS must fully protect the primary

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Group; EchoStar Satellite Services LLC; Harris CapRock Communications; Hughes Network Systems, LLC; Intelsat S.A.; Iridium Communications Inc.; Kratos Defense & Security Solutions; LightSquared; Lockheed Martin Corporation.; Northrop Grumman Corporation; Rockwell Collins Government Systems; SES Americom, Inc.; and SSL. SIA Associate Members include: AIS Engineering, Inc.; Astrium Services Government, Inc.; ATK Inc.; Cisco; Cobham SATCOM Land Systems; Comtech EF Data Corp.; DRS Technologies, Inc.; Encompass Government Solutions; Eutelsat, Inc.; Globecomm Systems, Inc.; Glowlink Communications Technology, Inc.; Inmarsat, Inc.; ITT Exelis; Marshall Communications Corporation.; MTN Government Services; NewSat America, Inc.; O3b Networks; Orbital Sciences Corporation; Panasonic Avionics Corporation; Spacecom, Ltd.; Row 44, Inc.; Spacenet Inc.; TeleCommunication Systems, Inc.; Telesat Canada; The SI Organization, Inc.; TrustComm, Inc.; Ultisat, Inc.; ViaSat, Inc., and XTAR, LLC. Additional information about SIA can be found at www.sia.org.

[3] For example, Intelsat has recently announced the development of its high performance, next generation satellite platform, Intelsat Epic^{NG}, which specifically uses the 14.0-14.5 GHz band.

[4] NSR, "Global Assessment of Supply and Demand," 9th Edition, 2012.

FSS in the band and must not constrain existing or future uses. The Technical Annex contains a detailed analysis showing a considerable risk of unacceptable interference to primary FSS from AMS ground stations and aircraft terminals. As shown in the Technical Annex, more stringent power limits than those proposed in the NPRM are required to protect geostationary orbit ("GSO") satellites from unacceptable interference, as well as additional measures for the protection of future primary Ku-band non-geostationary orbit ("NGSO") systems. The technical criteria adopted in any new rules must then be enforced, as it may not be possible to isolate and address individual sources of interference after an AMS system has been deployed.

In light of the measures that would be needed to prevent unacceptable interference to FSS, the Commission should consider carefully whether the public interest would be served by introducing the proposed AMS service in the 14.0-14.5 GHz band instead of in another less constrained band. The record raises questions as to whether secondary AMS can provide quality service in the 14.0-14.5 GHz band while protecting and not constraining the primary FSS in the same band—a factor that the Commission previously has relied upon to reject another proposed secondary allocation in this band.[5] Not only must the secondary AMS observe more stringent power limits than proposed in the NPRM to protect the primary FSS, but as SIA previously has shown, the secondary AMS will have to accept much more interference from existing and future FSS deployments than anticipated by Qualcomm. The combination of both factors will affect the anticipated throughput of the proposed AMS system.

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[5] *Utilities Telecom Council and Winchester Cator, LLC Petition for Rulemaking to Establish Rules Governing Critical Infrastructure Industry Fixed Service Operations in the 14.0-14.5 GHz Band*, Order, 28 FCC Rcd 7051, 7054-55 (¶ 10) (OET, WTB and IB 2013) ("UTC-Winchester Denial").

II. THE INTRODUCTION OF SECONDARY AMS SERVICE IN 14.0-14.5 GHZ MUST NOT BE AT THE EXPENSE OF PRIMARY FIXED-SATELLITE SERVICES IN THE BAND

SIA welcomes the Commission's interest in expanding access to broadband on aircraft. The satellite industry has been a pioneer in aircraft communications. Mobile satellite service ("MSS") operators have been providing satellite-based data communications to aircraft for many years.[6] Over a decade ago, Boeing introduced the first-of-its-kind Connexion by Boeing service—an innovative broadband Internet service for passengers on commercial aircraft using the FSS frequencies, including the 14.0-14.5 GHz band uplink spectrum.[7] In July 2003, Boeing filed a petition for rulemaking that led to the Commission's December 2012 *ESAA Order*, which, for the first time, adopted formal rules for Earth Stations Aboard Aircraft ("ESAA") to provide broadband service to passengers aboard aircraft via FSS.[8] In the interim, several other entities have begun offering broadband connectivity to aircraft via satellite, including SIA members

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[6] Inmarsat's satellite communications network is the backbone for two-way voice, fax and data services for aircraft operating virtually anywhere in the world. *See* https://www.satcomdirect.com/main/aviation/inmarsat-classic-aero-mini-m/.

[7] *See Boeing Company,* Order and Authorization, 16 FCC Rcd 5864 (Int'l Bur. and OET 2001) (blanket license for up to 800 technically identical receive only earth stations aboard aircraft); *Boeing Company,* Order and Authorization, 16 FCC Rcd 22645 (Int'l Bur. and OET 2001 (modifying prior receive only authorization to provide blanket license for up to 800 technically identical earth stations aboard aircraft transmitting in 14.0-14.5 GHz and receiving in 11.7-12.2 GHz.

[8] *See Amendment of Parts 2 and 25 of the Commission's Rules To Allocate Spectrum in the 14-14.5 GHz Band to the Aeronautical Mobile-Satellite Service ("AMSS") and To Adopt Licensing and Service Rules for AMSS Operations in the Ku-Band*, Petition for Rulemaking, RM-10800 (Jul. 21, 2003). *See also Revisions to Parts 2 and 25 of the Commission's Rules to Govern the Use of Earth Stations Aboard Aircraft Communicating with Fixed-Satellite Service Geostationary-Orbit Space Stations Operating in the 10.95-11.2 GHz, 11.45-11.7 GHz, 11.7-12.2 GHz and 14.0-14.5 GHz Frequency Bands, Service Rules and Procedures to Govern the Use of Aeronautical Mobile Satellite Service Earth Stations in Frequency Bands Allocated to the Fixed Satellite Service*, Notice and Proposed Rulemaking and Report and Order, 27 FCC Rcd 16510 (2012) ("ESAA Order and NPRM").

ViaSat,[9] Row 44,[10] and Panasonic.[11] These notable developments were made possible through the application of new technologies, such as tracking phased-array antennas, within the two-degree spacing environment established by the Commission for traditional FSS service.[12] SIA is pleased that the Commission now is on the verge of completing the final rulemaking steps for this innovative service.[13]

Broadband connectivity to aircraft, however, is only the latest innovation among the extensive variety of satellite services offered in the Ku-band. Major media networks, for example, use the Ku-band frequencies to distribute programming to thousands of affiliates and millions of viewers. News organizations use these frequencies for live coverage of breaking news and sporting events around the country. Private enterprises, including the retail and oil and gas industries, use the Ku-band extensively for wide-area network connectivity, including to remote regions of the country. The U.S. government also uses the Ku-band to construct secure satellite networks for U.S. embassies and the military, and to pilot unmanned aerial vehicles in defense of the nation.

To bring these essential services to the public, satellite operators have invested billions of

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9 *See ViaSat, Inc.*, Order and Authorization, 22 FCC Rcd 19964 (Int'l Bur. and OET 2007).

10 *See Row 44, Inc.*, Order and Authorization, 24 FCC Rcd 10223 (Int'l Bur. and OET 2009).

11 *See Panasonic Avionics Corporation*, Order and Authorization, 26 FCC Rcd 12557 (Int'l Bur. and OET 2011).

12 The Commission had previously adopted rules for Earth Stations on Vessels ("ESVs") and Vehicle-Mounted Earth Stations ("VMESs") based on its two-degree spacing policy. *See* 47 C.F.R. §§ 25.222 and 25.226.

13 ESAA Order and NPRM, *supra* note 8. Comments filed in response to the NPRM on May 22, 2013 unanimously endorsed making ESAA subject to the primary allocation in the 14-14.5 GHz uplink band as an application of the FSS. *See* FCC IB Docket No. 12-376.

dollars over many decades to put in orbit hundreds of Ku-band spacecraft. Today, there are no fewer than 28 Ku-band satellites operating in the 14-14.5 GHz band in geostationary orbit ("GSO") providing service to at least 70 percent of the contiguous United States,[14] and many others over the Atlantic and Pacific Ocean regions that provide transoceanic and intercontinental services to the U.S. The satellite industry also continues to invest in new and innovative technologies for the Ku-band to increase throughput and improve spectrum efficiency. Examples include Intelsat's next-generation, multi-spot beam high-throughput EPIC^{NG} satellite,[15] the use of higher-order modulation and coding schemes for increased throughput per MHz, the deployment of smaller antennas to lower end user costs, and increased deployment of tracking antennas for mobility applications.

The proposed introduction of a new secondary service, such as the AMS, in the Ku-band uplink spectrum could threaten these investments and advancements. For the satellite industry to continue investing and innovating in the Ku-band, FSS in the 14.0-14.5 GHz band must be protected from unacceptable interference for both existing and future operations. In addition, FSS innovation and growth must not be constrained by the presence of the proposed secondary service in the 14.0-14.5 GHz band. At a minimum, appropriate technical safeguards are necessary to ensure that satellite stakeholders and their customers are not negatively impacted.

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[14] Technical Annex, Appendix 1.

[15] Intelsat License LLC, Application for Authority to Launch and Operate Intelsat 29e, a Replacement Satellite With New Frequencies, at 50.0º W.L. (310.0º E.L.), File No. SAT-LOA-20130722-00097 (filed Jul. 22, 2013).

III. THE PROPOSED PROTECTIONS FOR FSS ARE NOT SUFFICIENT

SIA agrees with the Commission that "it is essential that [the Commission] protect FSS in the band from harmful interference."[16] The NPRM acknowledges that "[t]he mobility and ubiquity of FSS earth stations in the band necessitate great caution in preventing harmful interference."[17] The NPRM further recognizes that keeping the 14.0-14.5 GHz band free of other services "has allowed the FSS to innovate in an environment free of interference from other services with different operational and technical characteristics."[18] As discussed below, however, the Commission must do more than what is proposed in the NPRM to ensure that existing and future FSS operations are adequately protected from, and not constrained by, the proposed secondary service.

A. The Proposed AMS in the Aggregate Should Not Cause More Than a 0.33 Percent Rise in Thermal Noise.

SIA concurs with Qualcomm and the NPRM that the starting point for analyzing the potential impact on FSS operations posed by the proposed AMS should be Commission adherence to ITU-R Recommendation S.1432, which establishes that the interference from *all* non-primary sources of interference into a primary FSS link should not exceed a one percent rise in thermal noise ("ΔT/T")—*i.e.,* rise in aggregate noise floor.[19] This does not mean, however, that the proposed AMS should be allocated the whole one percent ΔT/T, as suggested by the NPRM, for the simple reason that it is not the only non-primary source of interference.

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16 NPRM at ¶ 27.

17 *Id.*

18 *Id.* at ¶ 14.

19 ITU-R Recommendation S.1432, *available at* http://www.itu.int/rec/R-REC-S.1432-1-200601-I/en.

For instance, the 14.0-14.2 GHz segment is further allocated on a secondary basis to the National Aeronautics and Space Administration ("NASA") Tracking and Data Relay Satellite System ("TDRSS"),[20] and the 14.4-14.5 GHz segment is further allocated to federal fixed ("FS") and mobile services ("MS") on a secondary basis.[21] If the entire one percent ΔT/T that is budgeted for non-primary emissions were to be allotted to the proposed AMS, the total ΔT/T impact into Ku-band satellite receivers necessarily would be greater than one percent due to the presence of these other secondary services.

Moreover, additional secondary or unlicensed services may be introduced in the future, whether in the United States or neighboring countries. The Commission must recognize that satellites with coverage beams that provide service to CONUS often also provide service to other countries through the use of the same beam. Such satellites would be subject to interference from secondary services in the 14.0-14.5 GHz band that may be introduced in those other countries. For example, if the U.S., Canada, and Mexico were each to introduce a secondary AMS in the 14.0-14.5 GHz, and each were to allow the AMS systems in their country to contribute the full one percent of ΔT/T into an FSS uplink, then a Ku-band satellite with a beam that spanned all three countries would suffer an aggregate impact into its receive beam of much more than a one percent ΔT/T (especially when interference from existing secondary services are also taken into account).

For these reasons, and as explained in the Technical Annex, the proposed AMS should be considered in both the GSO and NGSO contexts as one of at least three non-primary sources of interference in the 14.0-14.5 GHz band. Accordingly, the proposed AMS should be limited to

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20 *Id.*

21 *Id.*

creating no more than a 0.33 percent ΔT/T impact into primary FSS uplinks in the same band.[22] This will ensure that when combined with other existing and potential future non-primary interferers in the band, the aggregate rise in thermal noise from all non-primary sources of interference to the primary FSS will not exceed the one percent ΔT/T limit prescribed by ITU Recommendation S.1432.

B. The Commission Should Take Further Steps to Protect GSO FSS

The proposed AMS EIRP density "limits" for AMS base stations, as calculated by Qualcomm (and incorporated in the NPRM), would not be sufficient to protect GSO FSS satellites from unacceptable interference. If the Commission decides to proceed with the AMS proposal, it must adopt more stringent limits.

First, as discussed above, the AMS should be allowed to cause no more than a 0.33 percent increase in ΔT/T, if existing FSS operations are to be adequately protected. Accordingly, Qualcomm's calculation that the aggregate interference from its proposed air-ground mobile broadband system to GSO FSS satellites would be less than 0.5 percent ΔT/T for ground stations is insufficient to protect GSO FSS.[23] The single-entry and aggregate EIRP density limits would have to be recalculated with the lower 0.33 percent threshold in mind.

In addition, Qualcomm's technical analysis (as incorporated in the NPRM) is premised on faulty assumptions about the sensitivity of GSO satellite receivers. For example, both Qualcomm and the NPRM wrongly assume an "average" GSO satellite receive gain-to-noise

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[22] Technical Annex at 7.

[23] *See, e.g.,* Petition for Rulemaking of Qualcomm Incorporated, RM-11640 (filed July 7, 2011) ("Qualcomm Petition") at A-17.

temperature (G/T) of 2.0 dB/K.[24] Appendix 1 of the Technical Annex lists the Ku-band GSO satellites in orbit today that cover at least 70 percent of the contiguous United States and summarizes both their peak G/T and derives their "average" G/T figures. For simplicity, the "average" is calculated as the mid-point between the peak and edge-of-coverage G/T (in dB/K). It shows that for nearly all of the satellites listed, both the peak G/T and the "average" G/T exceeds 2.0 dB/K, sometimes by a considerable margin. As established by the chart in Appendix 1, a better representation of the "average" G/T for Ku-band satellites serving the contiguous United States is 6 dB/K.[25] This is the highest of the "average" G/Ts shown in Appendix 1, and use of this value would better ensure that more of the Ku-band satellites serving the contiguous United States would be protected from unacceptable interference.

With these adjustments to ΔT/T and G/T, the Technical Annex establishes that the single-entry EIRP density limit from an AMS base station should be reduced to -82.4 dBW/Hz. In addition, the aggregate EIRP density limit from AMS base stations should be reduced to -52.4 dBW/Hz.[26]

The Technical Annex also shows a significant risk of more interference into the primary FSS from AMS aircraft terminals than would be contemplated under ITU Recommendation S.1432 from non-primary sources.[27] First, as discussed above, AMS aircraft terminals must be limited to an aggregate impact of no more than 0.33 percent ΔT/T to account for other non-

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[24] *See* NPRM at ¶ 103.

[25] Technical Annex, Appendix 1. The average G/T was assumed to be midway between the beam peak value and the assumed edge of coverage value. *See also* Technical Annex at 4-5.

[26] Technical Annex at 8.

[27] *Id*. at 17-23.

primary sources of interference in the 14.0-14.5 GHz band. In addition, the maximum EIRP density from individual aircraft terminals would need to be reduced to ensure that the aggregate limit is not exceeded.

To compute the interference from aircraft terminals over the CONUS to GSO FSS satellite receivers, Qualcomm divides the CONUS into bins of width of 5º in longitude and 2.5º in latitude, resulting in 89 bins over the CONUS.[28] The contributions from aircraft in these bins are added together to compute the overall rise over thermal. As explained in the Technical Annex, this analysis is questionable for many reasons. First, Qualcomm does not consider certain interference geometries that produce additional interference into GSO satellites.[29] Second, Qualcomm assumes a G/T performance of only 2 dB/K for GSO satellite receive systems.[30] As explained above, a G/T value of 6 dB/K is more appropriate. Third, in order to properly project the worst-case interference, instances where there is a non-uniform, high-concentration of aircraft require quantitative consideration. Even Qualcomm admits this, but has provided no quantitative insight as to the extent of this increase.[31]

When all of the above are taken into account, the analysis in the Technical Annex shows that the overall interference from aircraft AMS terminals into the GSO arc would be approximately 12 dB worse than Qualcomm's calculations, assuming a 5º aircraft roll angle (for a 600 aircraft scenario).[32] As a result, the Commission would need to reduce the maximum EIRP

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28 *See* Qualcomm Petition at Appendix A, Section 3.3.1.2.

29 Technical Annex at 19-21.

30 *Id.* at 21.

31 *Id.* at 22.

32 *Id.* SIA would also note that it will be necessary to take into account all aspects of

density per aircraft terminal from the proposed 3 dBW/2 MHz to -9 dBW/2 MHz for the 600 aircraft scenario, and to -11 dBW/2 MHz for the 1000 aircraft scenario, in order to adequately protect GSO satellite receivers.[33]

C. The Commission Should Take Further Steps to Protect NGSO FSS

Because of its faulty assumptions about NGSO networks and short-sighted reliance on the current state of the NGSO industry, Qualcomm's AMS proposal also seriously underrepresents the potential for interference to future NGSO FSS operations in the Ku-band. When the wide range of possible NGSO geometries is properly considered, the resultant rise over thermal could result in interference to NGSO FSS satellite receivers from AMS operations that greatly exceed the 1 percent $\Delta T/T$ threshold that could be expected from all non-primary interferers (not just the proposed AMS). The only apparent preventative mechanisms for this interference would be significantly lower EIRP limits on AMS base stations or robust coordination and power-down obligations. For aircraft stations, it is not clear whether any mitigation mechanism will be effective.

Managing interference to NGSO networks presents unique difficulties. GSO systems have uniform orbital and elevation characteristics that make interference mitigation based on spatial separation more feasible (even though, as discussed above, Qualcomm also seriously underestimates the potential for unacceptable interference to GSO systems posed by the AMS proposal). In contrast, NGSO systems have varied orbits that, combined with lower mission

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aircraft orientation (i.e., pitch and roll) when deriving EIRP density limits, and not just the roll of the aircraft. Compare NPRM at Appendix B, proposed § 22.1120 ("When deriving the aggregate EIRP density toward the GSO arc, the aircraft cruise level roll angle of ±5° in elevation must be taken into account.").

[33] *Id.* at 22-23.

altitudes, can create a wide variety of conceivable interference scenarios with respect to a particular AMS base station or flight path. Most obviously, GSO FSS space stations are positioned over the equator, so a U.S. earth station communicating with the spacecraft will always be pointed southward. An NGSO satellite serving the United States, on the other hand, could be located to the north of a U.S. earth station communicating with the satellite. As a result, an AMS transmitter oriented toward the north could be directly within the NGSO satellite's receive beam, greatly increasing the potential for unacceptable interference.

As explained in more detail in the Technical Annex, Qualcomm's underestimation of the potential for interference into NGSO FSS satellites posed by AMS stems from dubious assumptions about NGSO orbits and operational parameters. Qualcomm's interference analysis is flawed in that it analyzes only one particular geometry, while ignoring other possible scenarios and variations in technical parameters.

Moreover, Qualcomm begins from the fundamentally wrong assertion that NGSO satellite systems should be required to tolerate a six percent $\Delta T/T$, citing to Table 5-1 of Appendix 5 of the ITU Radio Regulations.[34] However, Table 5-1 does not apply to the situation contemplated here, regarding potential interference caused by a secondary service to primary NGSO FSS operations. Instead, the appropriate guideline is ITU-R Recommendation S.1432, which, as discussed above, sets a clear one percent $\Delta T/T$ limit on allowable interference to FSS from all non-primary sources. This in turn sets a ceiling of 0.33 percent increase in $\Delta T/T$ from the proposed AMS into NGSO FSS systems, for the same reasons set forth above. Based on this understanding, and using more representative operational and technical assumptions, the real interference risk posed to NGSO FSS operations from AMS base stations and aircraft stations is

[34] Qualcomm Petition at A-11.

actually much greater than suggested by Qualcomm.

The Commission should take all necessary steps to protect NGSO FSS in the Ku-band. Qualcomm's proposal seeks to minimize the seriousness of this risk by pointing out that there currently are no licensed or planned NGSO FSS operations. However, the fact remains that NGSO FSS is a primary service in the 14.0-14.5 GHz band, and various regulatory, technical, and market developments have coalesced to create favorable conditions for future development in this sector. Introducing the level of interference risk represented by the AMS proposal could substantially inhibit the development of this fledgling sector at a critical moment, even if the AMS system were to be nominally secondary.

1. The Proposed AMS Ground Stations Will Cause Too Much Interference Into NGSO Satellite Receivers

As demonstrated in the Technical Annex, by making best-case scenario assumptions about a single theoretical Ku-band NGSO FSS system, Qualcomm misrepresents the potential for interference from AMS ground stations. Qualcomm assumes an NGSO system in which satellites at 1000 km altitude receive from their earth stations at elevation angles of 15° or greater based on the assertion that lower angles would be subject to blockage. However, this assumption ignores real-world NGSO systems that operate both at lower altitudes and lower elevation angles. These variables would materially affect interference calculations, and were not accounted for in Qualcomm's analysis.

More significantly, Qualcomm's assumptions about the position of the NGSO satellite with respect to the AMS ground station result in a serious underestimate of the potential for unacceptable interference. Qualcomm's NGSO interference conclusions rely heavily on the effect of its isoflux antenna design, which reduces EIRP significantly at 15° as compared to 1° elevation angles. However, this is only sufficient where the NGSO satellite has a 15° look angle

at the AMS station. Qualcomm ignores that an NGSO satellite at an altitude of 1000 km receiving from an FSS earth station at 15° would have significant antenna gain towards the horizon. As illustrated in the Technical Annex, an AMS station could have a significantly lower elevation angle to the NGSO satellite.[35] The benefits of Qualcomm's isoflux antenna design would not be relevant, for example, to an AMS station with a 1° angle to the NGSO satellite. Adjusting for additional path loss due to increased separation distance, such a satellite would receive approximately 13.5 dB more interference than Qualcomm calculated.[36] Depending on the placement of the beam peak, an NGSO satellite serving an earth station with a 15° elevation angle could find an AMS ground station at a 1°elevation inside a -3 dB, or even a -0.3 dB, interference contour.[37]

Qualcomm also makes biased assumptions regarding the likely NGSO satellite G/T performance level. Qualcomm assumes a -7 dB G/T value in its interference calculations, but a future NGSO system conceivably could be designed to serve lower powered terminals requiring higher satellite receive gain. If a future 30 dBi gain antenna is assumed, beam peak G/T performance levels could reach +3 dB/K, approximately 10 dB higher than Qualcomm's arbitrary assumptions.[38]

Taking into account the variables discussed above, and as further described in the Technical Annex, it becomes clear that Qualcomm seriously underestimated the potential interference to NGSO FSS satellites posed by AMS ground stations. Indeed, using reasonable assumptions, the resulting ΔT/T can range from 13.5 to 215 percent depending on the positioning

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35 Technical Annex at 10-14.

36 *Id*. at 13.

37 *Id*. at 11-13.

38 *Id*. at 14.

and gain of the satellite receive antenna.[39] This is far more than the 0.81 percent Qualcomm reports, and greatly beyond the 0.33 percent ΔT/T that the Commission should expect primary NGSO services to receive from an additional secondary terrestrial service based on ITU-R Recommendation S.1432.

The only way to prevent this interference is through EIRP density reductions for the proposed AMS stations. If the Commission moves forward with the AMS proposal, it should adopt a strict EIRP density versus elevation mask to protect NGSO operations. As shown in the Technical Annex, the single-entry EIRP density limit would need to be -8.2 dBW/2MHz.[40] In order to protect the development of the NGSO sector, this requirement should apply regardless of whether the operator is providing service in the U.S. or is currently operational. Moreover, the Commission should make it clear that, consistent with their secondary status, AMS licensees may be required to adjust their operations in the future to adequately protect, and not constrain, Ku-band NGSO systems.

2. Interference from Multiple Aircraft Stations May Not Be Preventable

Qualcomm's analysis of interference from AMS aircraft stations to NGSO satellites is flawed in the same ways as its analysis of the base station interference scenario. Qualcomm again ignores that NGSO satellites will be susceptible to interference from aircraft at lower elevation angles because of the gain of the satellite receive beam toward the horizon, it ignores that NGSO systems might intentionally operate at elevations less than 15°, and it ignores the possibility of higher gain spot beams. Although interference from a single aircraft might be manageable under some conditions, it is not clear whether any mitigation mechanism can prevent

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39 *Id.* at 14-15.

40 *Id.* at 26.

unacceptable interference from multiple operational aircraft.

Assuming a zero elevation angle to the NGSO satellite and an aircraft banking at 5°, the Technical Annex presents calculations based on realistic assumptions that demonstrate possible $\Delta T/T$ ranging from 0.06 to 0.94 percent for a single aircraft.[41] However, because of the large geographic range potentially covered by an NGSO FSS satellite receive beam, a single satellite could potentially receive interference from multiple AMS cells. With each AMS cell supporting up to four co-frequency aircraft transmitters simultaneously, the aggregate interference to NGSO FSS satellites could be unmanageable. More problematically, unlike the case of the AMS ground stations, where the narrower azimuthal beam width potentially could be turned off for period of time when in-line interference occurs, the wide azimuthal beam width of proposed AMS aircraft terminals may prevent this mitigation technique from being effective.[42]

D. Effective Monitoring and Enforcement Are Essential

Before moving forward with adding a new secondary allocation in the 14.0-14.5 GHz band for air-ground mobile broadband, the Commission must satisfy itself that its proposed rules for the protection of FSS can and will be observed in practice. Accordingly, the technical criteria for the protection of FSS, including EIRP density limits, must be made mandatory rather than permissive. Technical criteria also must be capable of effective monitoring and enforcement, as it likely will not be possible to isolate and address individual sources of interference. The NPRM, however, raises a number of important questions that cast doubt on the Commission's ability effectively to monitor and enforce the proposed rules.

Much of the NPRM's interference analysis is based on Qualcomm's representations of its

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41 *Id.*

42 *Id*.

future plans and its proposed use of the AMS. These plans could, of course, change, and other entrants may have different plans. For example, the NPRM notes that "[a]ccording to Qualcomm, air-ground mobile broadband base stations close to the southern U.S. border or coastline would reduce emission power to ensure that signal levels are not high enough to cause harmful interference to GSO FSS satellites."[43] The NPRM appears to be satisfied with Qualcomm's promise—it concludes that "[r]educing emission power would reduce the likelihood of interference"[44]—but it does not codify Qualcomm's commitment as a requirement in the proposed rules for all potential AMS providers. Given this absence of a specific regulatory obligation, it is not clear how the Commission or Qualcomm would define the geographic area in which the power reductions are necessary. Nor is it clear at what elevation angle the proposed power reduction becomes necessary. Similarly, neither the NPRM nor Qualcomm quantifies the actual power reduction or explains how compliance with these power limits should be monitored or enforced.

At a minimum, the Commission should adopt Qualcomm's commitment to reduce the power of its ground stations near the southern border of the United States as a requirement. In addition, the Commission should take steps to ensure effective monitoring and enforcement by crafting clear and specific rules regarding the proposed power reduction and considering record-keeping requirements for the interference levels of these ground stations.

In addition, certain of the NPRM's proposals are impractical or unlikely to be effective from an enforcement standpoint. For example, the NPRM proposes to "allow air-ground mobile

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43 NPRM at ¶ 110.

44 *Id.*

broadband base stations to increase power up to six dB to compensate for 'rain fade.'"[45] The NPRM then asks whether, in compensation for the increase in power, the Commission should require air-ground mobile broadband base stations to "reduce the number of beams they emit in order to protect FSS operations."[46] Presumably, the Commission is referring to a reduction in the number of co-frequency beams from a given base station so that the aggregate EIRP density limit in any given frequency is not exceeded, but it could also mean reducing power at other base stations. It is not clear how this could be managed by the licensee or enforced by the Commission.

Qualcomm also bases its air-ground mobile broadband system on certain antenna performance assumptions, such as certain antenna gain roll-off in the direction of the GSO arc for both its base stations and aircraft terminals in order to calculate the protection criteria for FSS spacecraft. While the various protection criteria need to be revised for the reasons explained above and in the Technical Annex, it is just as important to ensure that the antenna performance assumptions on which those criteria were based are true. The Commission must ensure that the antennas deployed by an AMS licensee will in fact perform as well as is assumed in the protection criteria. Accordingly, at a minimum, the Commission should specify antenna performance requirements and certification processes for AMS base station and aircraft antennas.

IV. THE PROPOSED AMS SYSTEM MUST ACCEPT ALL INTERFERENCE FROM EXISTING AND FUTURE FSS OPERATIONS

As a secondary service, the proposed AMS must accept all interference from the primary FSS. SIA is therefore pleased that the Commission has made it clear that:

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45 *Id.* at ¶ 115.

46 *Id.*

> [s]econdary status is appropriate for air-ground mobile broadband because of the need to protect FSS in the band. . . we propose a secondary allocation here, and do not contemplate any way to entertain a future request to elevate the status to primary, because co-primary status for air-ground mobile broadband would likely constrain the ability to blanket license FSS earth stations, and, for example, could prohibit satellite newsgathering trucks from changing locations to cover news events without prior coordination with neighboring co-primary air-ground mobile broadband base stations.[47]

As detailed in the Technical Annex and as SIA has previously shown, the amount of interference that the proposed AMS system would receive from primary FSS satellites operating in the band is likely to be much greater than Qualcomm first thought. In an August 31, 2012 analysis, SIA demonstrated that the proposed AMS service is unlikely to be able to provide quality, uninterrupted service to customers given the interference potential from incumbent FSS operators using the 14.0-14.5 GHz band.[48] Specifically, routinely operated VSATs have a high probability of causing interference to both the AMS return link and forward link, or at a minimum, the throughput for these links will be reduced from the levels suggested by Qualcomm.[49] Moreover, the AMS return and forward links can also be disrupted or experience long-term interference from ESAA terminals onboard aircraft.[50] Although Qualcomm has disputed this analysis,[51] SIA repeatedly has provided additional technical analyses reiterating its

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47 *Id*. at ¶ 27.

48 *Ex Parte* Presentation of the Satellite Industry Association, RM-11640 (filed Aug. 31, 2012) ("August 2012 SIA *Ex Parte*").

49 *Id.*, Technical Analysis at 2-7, 9.

50 *Id.*, Technical Analysis at 7-10 (because this analysis predated the Commission's coining of the term "ESAA," it refers instead to "AMSS equipped aircraft").

51 *See, e.g.*, *Ex Parte* Presentation of Qualcomm Incorporated, RM-11640 (filed Sept. 11, 2012); *Ex Parte* Presentation of Qualcomm Incorporated, RM-11640 (filed Oct. 30, 2012); *Ex*

belief that the information provided by Qualcomm is not sufficient to demonstrate that the AMS could operate successfully given interference from licensed FSS terminals in the 14.0-14.5 GHz band, in particular because of its faulty assumptions about the nature and extent of potential VSAT interference.[52]

Moreover, the scenarios used by SIA and Qualcomm in the studies provided to the FCC do not account for certain real-world situations that likely will further increase the potential interference into AMS operations. First, as the Commission continues to approve VSAT authorizations, the number of VSATs deployed will increase, expanding the interference potential for AMS operations. Second, when planning an AMS system, Qualcomm cannot assume that VSATs will be evenly distributed across the country. For example, when a major news story occurs, dozens of satellite news gathering ("SNG") trucks may be deployed to a single area, creating a high concentration of VSATs in a small geographic area, with a concomitant increase in potential interference to AMS operations.

While Qualcomm has responded to each SIA showing by indicating that its system can accept increasingly large amounts of interference, it has not indicated what this additional interference means for its system performance. Nor is it clear what impact power reductions necessary to protect the FSS would have on its system performance, when combined with increased interference.

Given this, the Commission should carefully consider whether the public interest is

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Parte Presentation of Qualcomm Incorporated, RM-11640 (filed Dec. 19, 2012).

[52] *See, e.g.*, *Ex Parte* Presentation of the Satellite Industry Association, RM-11640 (filed Oct. 22, 2012); *Ex Parte* Presentation of the Satellite Industry Association, RM-11640 (filed Dec. 11, 2012); *Ex Parte* Presentation of the Satellite Industry Association, RM-11640 (filed Feb. 22, 2013); *Ex Parte* Presentation of the Satellite Industry Association, RM-11640 (filed May 2, 2013).

served by authorizing a secondary service that may not be able to provide quality service to customers. This is a factor that the Commission considered important in rejecting a different secondary allocation in the 14.0-14.5 GHz band proposed by the Utilities Telecom Council and Winchester Cator, LLC ("UTC-Winchester") for "smart grid" critical infrastructure applications. In that proceeding, the Commission found that UTC-Winchester had not provided evidence that it could provide quality service given the interference potential from primary users in the band.[53]

In light of the significant constraints that being a secondary service in a primary FSS band would impose, the Commission should weigh whether it is in the public interest to allocate Ku-band spectrum for the proposed AMS even on a secondary basis. Instead, the Commission should consider whether the public would be better served by finding other spectrum for the proposed service that would place fewer constraints on the AMS and perhaps enable a better quality of service for AMS consumers.

V. THE PROPOSED AMS SYSTEM MUST PROTECT IRREGULAR FSS OPERATIONS

In addition to the potential interference to primary FSS operations in the 14.0-14.5 GHz band, the Commission should consider how a secondary allocation could interfere with or otherwise constrain a number of routine, but irregular, FSS operations typically authorized by the Commission on a non-harmful interference basis relative to regular FSS operations. These include Special Temporary Authorizations ("STAs") issued for launch and early orbit phase ("LEOP") operations, satellite relocations, and use-prior-to-grant, as well as the experimental authorizations that have been critical for continuing innovation in satellite technology. Although these operations are not protected as primary operations in the band, any unacceptable

[53] *See* UTC-Winchester Denial, 28 FCC Rcd at 7054-55 (¶ 10).

interference into any of these necessary operations from the AMS, and any requirement to protect the AMS from interference from such operations, could impair the ability of satellite operators to safely and efficiently provide primary FSS operations in the band.

Critical LEOP and transfer orbit operations could be particularly vulnerable to secondary AMS transmissions. As explained in the Technical Annex, in the early part of LEOP, the satellite is in a non-geostationary orbit and therefore would be subject to the same interference threats discussed above with respect to NGSO satellites.[54] LEOP transmissions in the 14.0-14.5 GHz band are used for ranging and telecommanding of the satellite, both of which are critical to ensure that the satellite can be placed safely into orbit. Moreover, with the new all-electric propulsion satellites that are now becoming available, satellite operators will increasingly be launching satellites that have longer mission lives, but which require as long as six months to reach geostationary orbit. These longer LEOP missions mean extended exposure to AMS interference.

Secondary AMS operations should be subordinated to these irregular FSS operations—*i.e.,* the proposed AMS operations should not be allowed to cause interference into such operations and cannot claim protection from interference from such operations. Without such status, the continued growth and development of primary FSS systems in the 14.0-14.5 GHz band would be curtailed by the presence of the new secondary service.

VI. CONCLUSION

In evaluating Qualcomm's proposal to establish a new air-ground mobile broadband service in the 14.0-14.5 GHz band, the Commission must consider the existing interference environment in that band, as well as the complex interference scenarios that would be created by

[54] Technical Annex at 10.

the introduction of the proposed AMS. The band already is used intensively by primary FSS operations for a wide range of commercial, government, and military applications, as well as for other important U.S. government operations. As shown herein, the proposals in the NPRM do not adequately protect the primary FSS, and it is not clear whether the public interest would be served by introducing a constrained AMS in the 14.0-14.5 GHz band. If the Commission decides to proceed with introducing a secondary AMS in this band, it is critical that any new rules ensure that the proposed AMS is secondary to the primary FSS and include sufficient technical criteria to protect existing and future FSS operations. The Commission must also be satisfied that its new rules can be adequately monitored and enforced prior to proceeding with the new service.

Respectfully submitted,

The Satellite Industry Association

By: _____

Patricia A. Cooper
President

August 26, 2013

Technical Annex

Interference Issues between the Proposed Air-Ground Mobile Broadband Service and the Fixed-Satellite Service

A.1 Introduction

This technical annex addresses several of the technical issues raised in the FCC's NPRM concerning interference between a proposed new, secondary air-ground mobile broadband service (Aeronautical Mobile Service or "AMS") in the 14.0-14.5 GHz band, and the primary Fixed Satellite Service ("FSS") already operating in that band.[1] Qualcomm Incorporated originally proposed the AMS allocation in a petition for rulemaking submitted on July 7, 2011.

The proposed new secondary AMS would operate on a Time-Division Duplex ("TDD") basis in the 14.0-14.5 GHz band, which is one of the most heavily used frequency bands in North America and worldwide by the primary FSS. As shown in this annex, the proposed TDD transmissions from both the AMS ground stations and the AMS aircraft terminals create considerable risk of unacceptable interference into the primary FSS.

A.2 Interference from the AMS Ground Stations

In the NPRM the Commission specifically asks for comments on the interference caused by the proposed new AMS ground stations.[2] These stations are proposed to be scattered across CONUS, numbering as many as 250 from a single AMS licensee. Each AMS ground station will transmit up to four co-frequency carriers, each on an independently steerable beam using a phased array antenna. Although generally pointing in a northerly direction, the steerable beams

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[1] See FCC Notice of Proposed Rulemaking in the matter of "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," ET Docket No. 13-114, 9 May 2013.

[2] See paragraphs 103 and 105 of the NPRM.

operate over a wide range of azimuths in order for each AMS ground station to serve the aircraft within its designated cell.

There are several potential interference issues arising from the transmissions from these AMS ground stations. This study focuses on the direct path interference from the transmitting AMS ground station into the FSS satellite receivers due to sidelobe or backlobe radiation from the phased array antenna of the AMS ground station, as illustrated in Figure A.2-1. This is addressed in detail in Section A.2.1.1 for GSO satellites and Section A.2.1.2 for NGSO satellites.

Other interference effects require more study. For example, Qualcomm has not addressed interference caused by rain scatter and possibly troposcatter effects from the main beam radiation of the AMS ground station into the FSS satellite receivers. These effects are well known for high-power, low-elevation transmission paths, such as the AMS transmissions contemplated here.[3] Analysis of these real-world interference mechanisms is needed before the Commission can consider licensing a potentially interference-causing new service.

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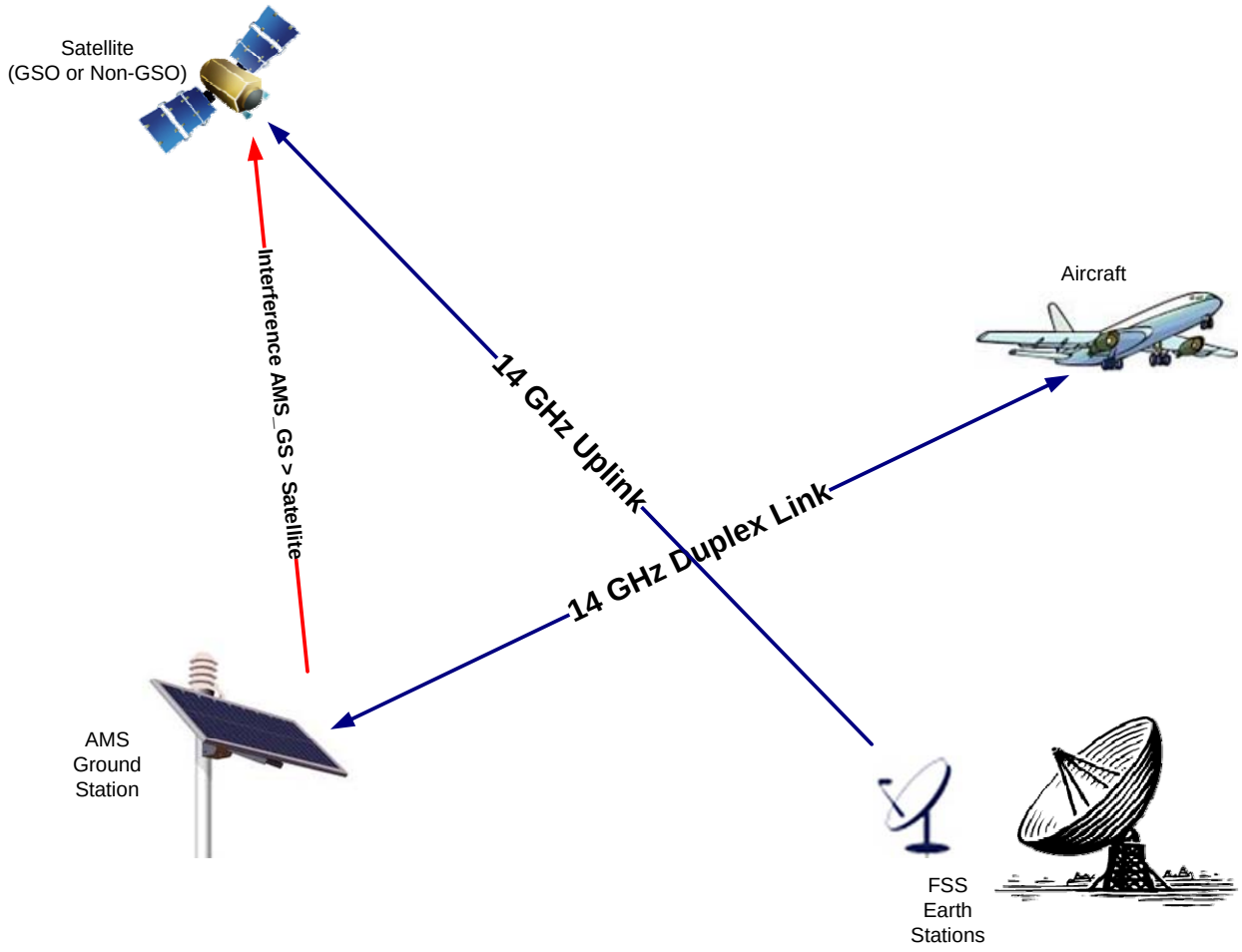
[3] See, for example, "Rainfall scatter interference between terrestrial and satellite radio-links", Annals of Telecommunications, January-February 1981, Volume 36, Issue 1-2, pp 166-170.

Figure A.2-1: Direct path interference from the AMS ground station transmissions



A.2.1 Direct Path Interference from AMS Ground Stations to FSS Satellite Receivers

The FSS satellites that must be protected from this interference include those operating in both geostationary orbits ("GSO") and non-geostationary orbits ("NGSO"). These two cases are dealt with separately below.

A.2.1.1 Interference from AMS Ground Stations into GSO FSS Satellite Receivers

The Commission is considering adopting the mechanism proposed by Qualcomm to protect GSO satellite receivers, which is to limit the single-entry and aggregate EIRP density towards the GSO orbit from the AMS ground stations to values that will not cause more than a specified overall increase in ΔT/T at the GSO satellite receiver. It is not clear whether this is a practical

approach, given that the ΔT/T experienced by a satellite receiver will depend on the receiver's sensitivity, which in turn will vary depending on the satellite and the receive gain pattern on the Earth's surface. But in principle, at least, this is a possible method of limiting the interference, for the direct signal path, provided that:

a) The EIRP density limits imposed must be sufficient to adequately protect current <u>and future</u> GSO satellite receivers operating in this band;
b) The EIRP density limits imposed must be able to be measured and verified with a high degree of certainty by the AMS system operator, and be capable of effective monitoring and enforcement;
c) The aggregate EIRP density limits imposed must be met regardless of the number of AMS licensees and AMS related transmitters that might ultimately be licensed in the same part of the 14.0-14.5 GHz band, and (again) be capable of effective monitoring and enforcement; and
d) The EIRP density limits must apply to all visible parts of the GSO orbit and not be limited to only the 45°W to 150°W orbit range proposed by the Commission.[4]

Regarding (a) above, Appendix 1 contains a summary of the G/T performance of a subset of the Ku-band satellites serving the United States. Only those satellites having non-steerable beams in the 14-14.5 GHz band that provide approximately 70% or greater coverage of CONUS are listed to illustrate those satellites most likely to be impacted and the sensitivity of their receivers. Appendix 1 shows that peak G/T values vary between 0 dB/K and greater than +9 dB/K. The "average" G/T value over the main service area of these satellite receive beams (which include most of CONUS) was then assumed (for simplicity) to be the G/T value that is halfway between the beam's peak and the beam edge of coverage G/T values. The "average" G/T value determined in this way is as high as +6 dB/K for SES-2, a satellite serving all of CONUS. Moreover, for nearly all of the Appendix 1 satellites, the average is more than the +2 dB/K suggested by Qualcomm for use in calculating the EIRP density limits necessary to protect primary FSS satellites. Thus, use of an average +2 dB/K G/T to calculate such limits would

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[4] See Section 7 on page 36 of the NPRM.

significantly underestimate the amount of interference that will be received by nearly all FSS satellites serving the United States. Instead, SIA recommends that the EIRP density limits necessary to protect the primary FSS be calculated based on an "average" G/T value for Ku-band satellites of at least +6 dB/K to more accurately represent the range of G/Ts for Ku-band satellites serving the United States.

Regarding (b) above, Qualcomm has attempted to measure the backlobe radiation of its phased array AMS ground station.[5] However, Qualcomm's conclusions from these measurements are not reliable because Qualcomm: (a) only measured the radiation towards two discrete GSO orbital positions, (b) only performed the measurement with a single fixed pointing direction of the intended forward pointing beam, and (c) only performed the test at one frequency in the band.[6] It is therefore an act of faith to infer that the same level of performance can be maintained towards all of the GSO, for all main-beam pointing directions, and across the entire 500 MHz band. As the sidelobe and backlobe radiation of the AMS ground station antenna is so crucial to Qualcomm's claims of non-interference, verification of these characteristics is essential. Accordingly, the FCC must establish a thorough measurement procedure to be followed by the AMS licensee to ensure compliance with the required EIRP density towards the GSO. Additionally, as the aggregate EIRP density must be maintained at a compliant level, it is also essential that the FCC establish thorough procedures for monitoring and ensuring the aggregate EIRP density into any GSO satellite from the proposed 250 transmitting AMS base stations is compliant, providing the GSO operator with a means of validating such levels. The procedure must acknowledge that the environment is not static, consistent with Qualcomm's described operational practices, with the base station levels varying in a statistically complex manner adjusting to weather conditions (uplink power control), interference avoidance hopping, and traffic demands. Certain minimum antenna performance standards and/or pointing restrictions for AMS licensees would also be warranted in this regard.

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[5] See Attachment B to Qualcomm's *ex parte* dated September 11, 2012.

[6] Furthermore, the AMS ground station antenna used for the tests was a prototype design that does not appear to be the same design nor have the same performance characteristics as Qualcomm is proposing for an operational system.

Regarding (c) above, the Commission should determine that no more than one AMS license will be granted for each portion of the 14.0-14.5 GHz band, and both the single-entry and aggregate EIRP density limits towards the GSO must be met by each AMS operator. If the Commission were to issue more than one AMS license for any portion of the 14.0-14.5 GHz band then it would be very difficult to determine how to apply and enforce the aggregate EIRP density limits to the combined transmissions from the ground stations of multiple operators. Even for a single AMS licensee, there is considerable uncertainty as to how the licensee (let alone the Commission or FSS operators) will be able to monitor and ensure compliance with aggregate EIRP density limits, especially given the flexibility requested by Qualcomm. For instance, Qualcomm proposes to use automatic power control to compensate for rain fade in a particular cell, and to reduce power in the same frequency in other cells in order not to exceed the EIRP density in the direction of the GSO. Similarly, Qualcomm proposes to reduce power for its cell sites close to the U.S. border when elevation angles are too high and/or azimuths deviate too far from true north. This raises some serious questions. How would an AMS licensee make these dynamic adjustments to ensure continued compliance with aggregate EIRP density limits? How would the Commission and/or the affected FSS operators monitor compliance?

Regarding (d) above, there is no technical basis for protecting only a portion of the GSO arc. As a secondary service, the proposed AMS must protect the entire GSO arc that is visible from the base station location. While the satellites that provide service over large portions of the U.S. tend to be within a more limited arc, this does not mean that AMS base stations should be unconstrained and allowed to transmit at any power whatsoever to other parts of the GSO arc.

Assuming the above conditions (a), (b), (c) and (d) are met or adequately addressed then the issue is one of determining the appropriate single-entry and aggregate EIRP density limits towards the GSO orbit. This is considered in the analysis that follows.

The first analysis below addresses the protection of typical Ku-band satellites deployed today which tend to use large CONUS or partial-CONUS beam coverage. Table A.2-1 shows the interference analysis for this case using the following assumptions:

- Victim GSO satellite G/T is +6 dB/K, averaged over the service area of the AMS ground stations. The rationale for using this value for these satellites is given in Section A.2.1 above.
- Permissible aggregate interference level is set at 0.33% ΔT/T by allocating to the proposed AMS one-third of the total 1% ΔT/T (or "Rise over Thermal") interference from all non-primary sources.
    - The 1% ΔT/T budget for interference from all non-primary sources into the primary FSS is derived from ITU-R Recommendation S.1432, and is the relevant standard proposed by Qualcomm and in the NPRM to protect the FSS.
    - The AMS should be considered one of three non-primary sources of interference in the 14.0-14.5 GHz band. Allocating the entire 1% ΔT/T to the AMS would be inappropriate because: (a) there are already other secondary allocations in various parts of the 14.0-14.5 GHz band, such as the Federal space research service in the 14.0-14.2 GHz band (used for TDRSS) and the Federal fixed and mobile services in the 14.4-14.5 GHz band; and (b) good engineering practice dictates that allowance should be made for additional secondary service in the future, whether in the United States or neighboring countries, including the possible introduction of AMS in other countries within the receive beams of the Ku-band satellites serving the United States. The 1% ΔT/T budget for non-primary sources of interference into primary FSS uplinks would definitely be exceeded if the entire 1% were to be allocated to the proposed AMS in the United States alone, especially when the additional interference from the other secondary Federal services and the possible expansion of AMS in other countries are taken into account. Accordingly, Qualcomm's proposed system should not increase the ΔT/T of the receiving satellite by more than 0.33%.

Table A.2-1: Interference analysis from AMS ground station to GSO satellite receiver (Current Ku-band Satellites)

Row #	Parameter	Units	Values
1	Single-entry EIRP density of interferor (per 50MHz) towards the GSO	dBW/50MHz	-5.4
2	Single-entry EIRP density of interferor (per Hz) towards the GSO	dBW/Hz	-82.4
3	Number of AMS_GS terminals within GSO beam	#	250
4	Number of simultaneous co-frequency transmissions from each AMS_GS terminal	#	4
5	Number of interferors	#	1,000
6	Aggregate EIRP density of interferors (per Hz) towards the GSO	dBW/Hz	-52.4
7	Frequency	GHz	14.50
8	Space Loss to GSO orbit	dB	207.03
9	Rx interfering signal power density at GSO satellite	dBW/Hz	-225.64
10	Noise power density at GSO satellite	dBW/Hz	-200.82
11	Victim satellite G/T (average across service area of AMS ground stations)	dB/K	6.00
12	Resulting ΔT/T at GSO satellite receiver	%	0.33%

The key result from this calculation of interference is given in row 6, where the aggregate EIRP density of all the AMS ground station transmitters in the direction of the GSO orbit must not exceed -52.4 dBW/Hz. Note that this value is 5.7 dB lower than the value of -46.7 dBW/Hz mentioned by the Commission in the NPRM.[7] This difference can be almost entirely accounted for by a combination of: (a) the higher GSO satellite G/T performance assumed here (+6 dB/K versus +2 dB/K used by Qualcomm); and (b) the difference in the target ΔT/T interference level (0.33% versus 0.5% used by Qualcomm).[8] The proposed aggregate limit of -52.4 dBW/Hz towards the GSO should apply regardless of the number of AMS ground stations deployed, as it represents the aggregate interference resulting from all of them.[9]

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[7] See discussion in paragraph 112 of the NPRM and proposed rule §22.1120 (a) in the NPRM.

[8] The remaining small difference is accounted for by the difference in the exact frequency used for the calculation and the assumed average location of the AMS ground stations which affects the assumed range to the GSO satellite (and hence the space loss).

[9] We therefore do not believe it is necessary to adopt formula (2) included by the Commission in its proposed rule §22.1120 (a) in the NPRM, which relates to the way the aggregate limit should be made a function of the number of AMS ground stations.

The additional result in row 2 is the single-entry EIRP density towards the GSO for each carrier from each AMS ground station, under the assumption that there are 250 such ground stations across CONUS and that each ground station re-uses the spectrum four times. For the case of interference into today's Ku-band satellites, which use larger area coverage beams, the single entry interference is not a key factor – the aggregate is all that matters. However, the satellite industry has been moving towards the use of smaller spot beams on Ku-band satellites for certain applications.[10] In order to protect these types of applications the Commission should also ensure that the single-entry EIRP density level towards the GSO, given in row 2 of Table A.2-1 above, is not exceeded. This single-entry limit should apply to all situations, including when uplink power control is used, or when the AMS ground stations are located on or close to the southern U.S. border with Mexico.

A.2.1.2 Interference from AMS Ground Stations into NGSO FSS Satellite Receivers

The ITU and the FCC have established sound principles for sharing between NGSO and GSO satellite systems in the Ku-band, thereby enabling the future development of NGSO systems in this band. Over the past ten years or so several things have worked in favor of a fledgling but fast-growing NGSO industry. First, launch costs for smaller LEO and MEO satellites have decreased rapidly due to new entrants such as SpaceX and other innovative launcher technologies. Second, component costs have also dropped for smaller satellites that are part of a fleet of many identical spacecraft. This has resulted in the launch of many new smallsats and cubesats providing important science and communications functions, and the prospects of further commercialization of this industry in the future. The Ku-band is one of the few parts of commercially accessible spectrum that could be used to support these NGSO systems. Therefore the Commission must do everything necessary to ensure that new uses of the Ku-band spectrum, such as the proposed AMS, do not prevent the introduction of innovative NGSO satellite systems that already have a primary allocation in this band.

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[10] For example, Intelsat has recently announced the development of its high performance, next generation satellite platform, Intelsat Epic^{NG}, which uses the 14.0-14.5 GHz band. See Intelsat License LLC, Application for Authority to Launch and Operate Intelsat 29e, a Replacement Satellite With New Frequencies, at 50.0º W.L. (310.0º E.L.), File No. SAT-LOA-20130722-00097 (filed Jul. 22, 2013).

The 14.0-14.5 GHz uplink spectrum is also used during the Launch and Early Operations Phase (LEOP) for many commercial satellites. During the early part of LEOP the satellite is in a non-geostationary orbit and therefore would not be adequately protected by any limits on the AMS transmissions (from the AMS ground stations or aircraft terminals) towards the GSO arc. During LEOP the uplink transmissions in the 14.0-14.5 GHz band are used for ranging and telecommanding of the satellite, both of which are critical to the safety of the mission and must be protected from interference. Such LEOP missions will take place for much longer periods of time (*e.g.*, six months) with the new electric propulsion systems that are now becoming available, and which provide considerable mass efficiencies for the mission. Therefore the period of vulnerability to AMS interference will be longer.

Qualcomm's analysis of interference from its proposed AMS ground stations into NGSO satellite receivers is flawed as it makes dubious assumptions and only analyzes one particular geometry situation while ignoring others that will occur and which will result in significantly higher levels of interference into the NGSO satellite receivers. The various shortfalls of the Qualcomm analysis are addressed in detail below.

First, Qualcomm ignores the fact that an NGSO satellite serving a user at 15° elevation will inevitably have significant gain towards the Earth's horizon, as viewed from the NGSO satellite. This situation is depicted in Figure A.2-3 below which shows that the finite beamwidth of the NGSO satellite receive beam will make it vulnerable to low elevation interference (down to 0° elevation) from the transmitting AMS ground station (which is located to the left of the NGSO earth station shown in Figure A.2-3).

Figure A.2-3: Illustrative diagram showing the potential low elevation interference mechanism from the transmitting AMS ground station into the NGSO satellite receiver

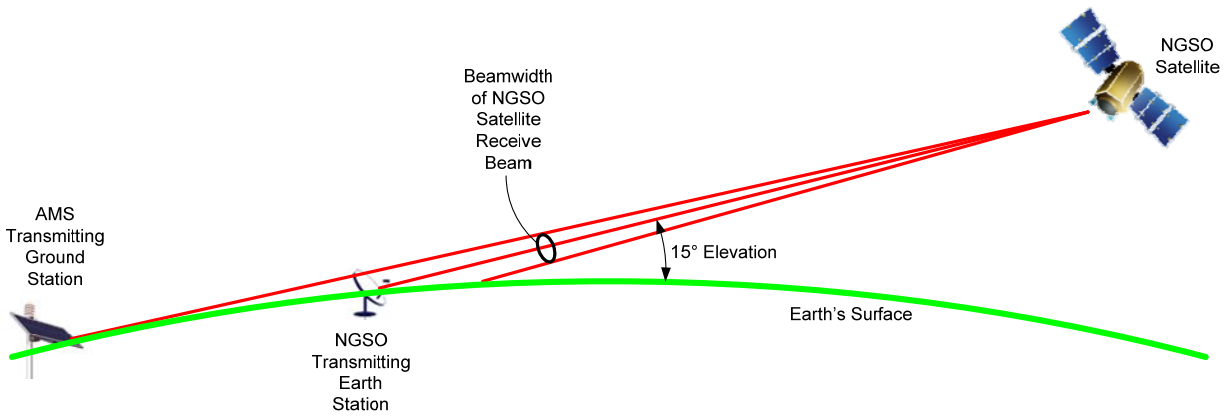
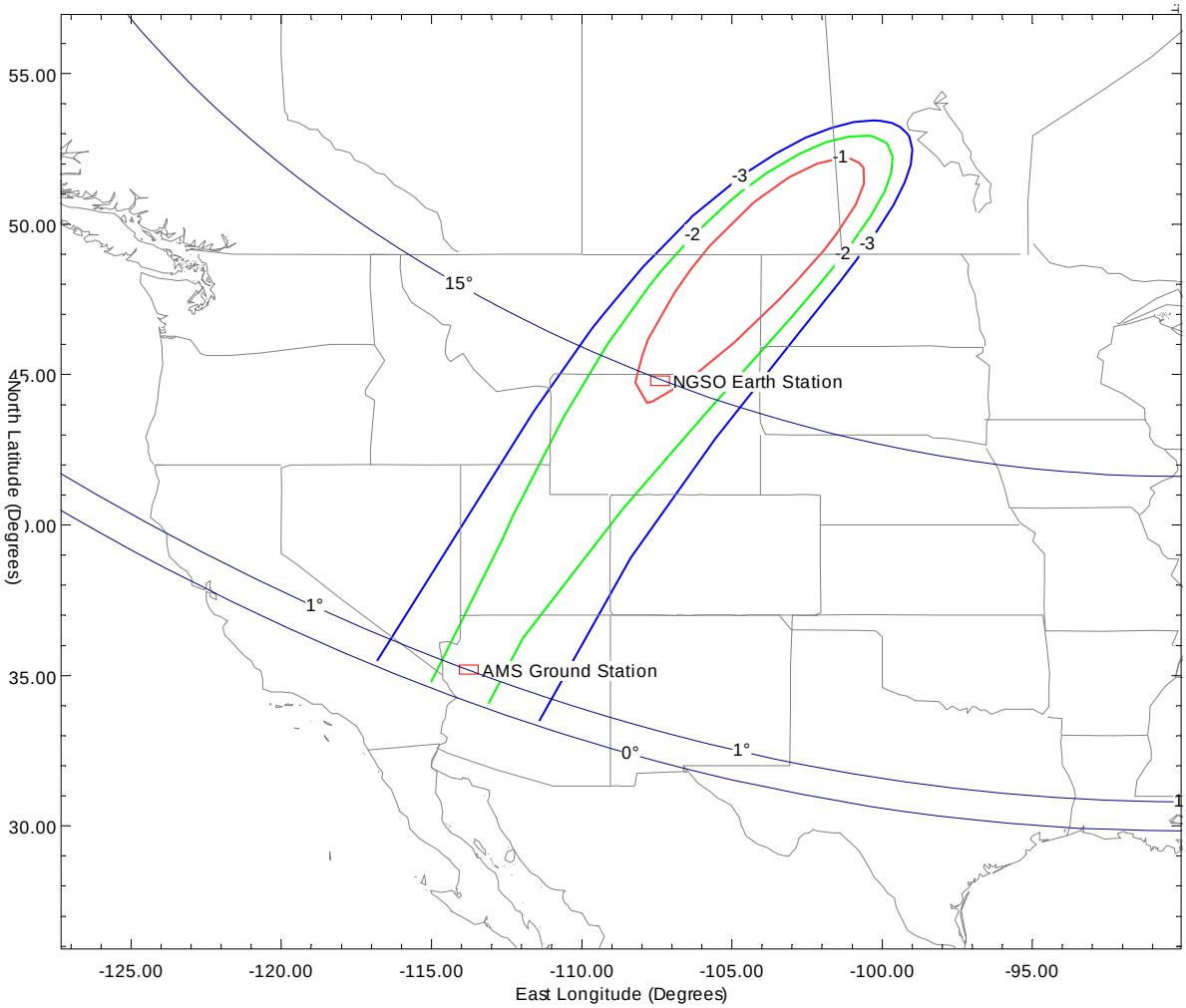


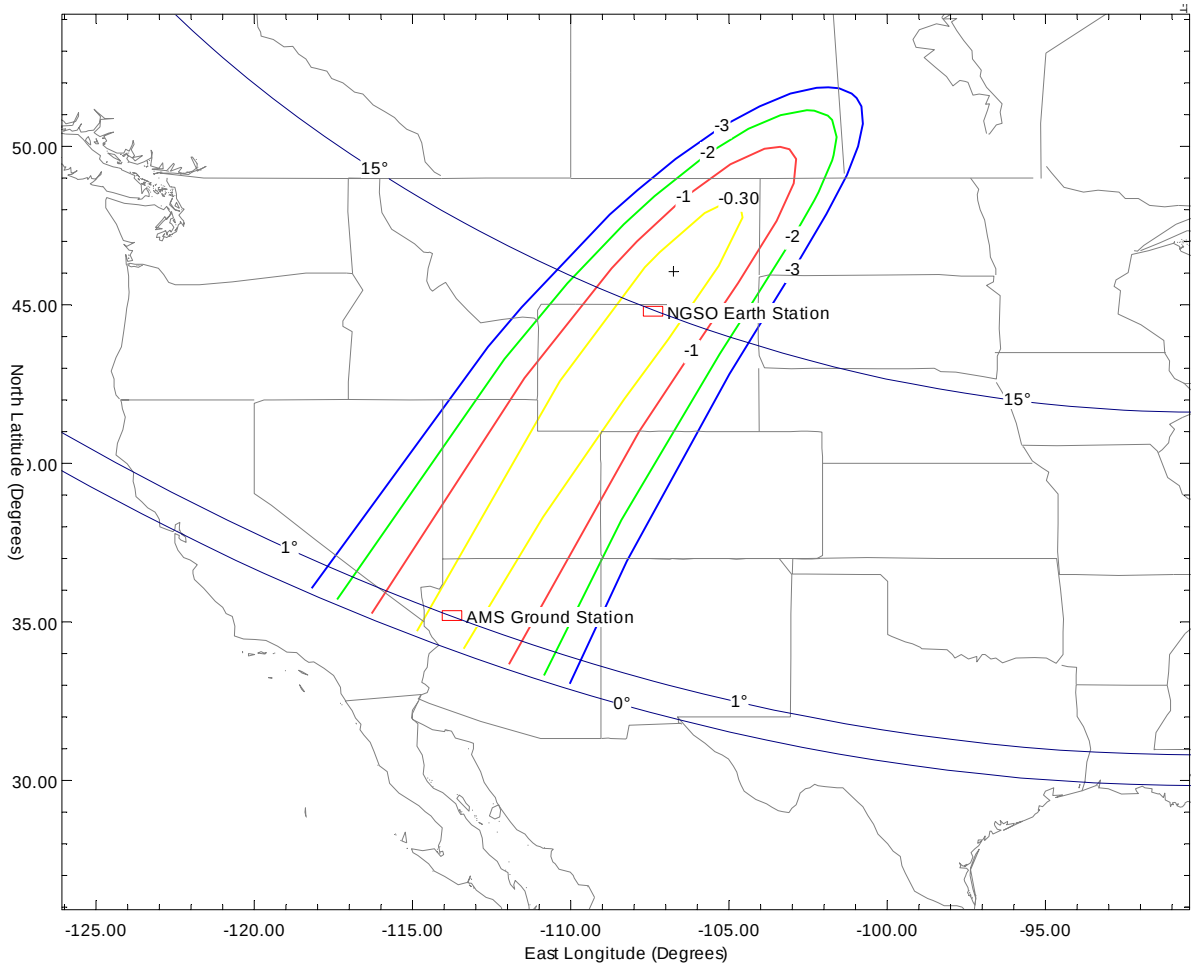
Figure A.2-4 shows the same situation from a different perspective, where a 1,000 km altitude NGSO satellite receive beam with a 21 dBi peak gain is accurately modeled with a Gaussian roll-off and the -1, -2 and -3 dB relative gain contours are shown. From this it is clear that even when the -2 dB relative gain contour is pointed to serve the NGSO earth station, the -3 dB contour inevitably points towards the 1° elevation contour where the high EIRP interfering AMS ground station would appear.

Figure A.2-4: Accurate beam representation of the potential low elevation interference mechanism from the transmitting AMS ground station into the NGSO satellite receiver (-2 dB contour towards NGSO earth station)



If the beam peak of the NGSO satellite, rather than the -2 dB contour, were pointed more towards the NGSO earth station, the interference from the AMS ground station would be significantly worse, as shown in Figure A.2-5 below. In this case the interfering AMS ground station appears on the -0.3 dB relative gain contour of the NGSO satellite receive beam, resulting in interference almost 3 dB worse than would be the case for Figure A.2-4 above.

Figure A.2-5: Accurate beam representation of the potential low elevation interference mechanism from the transmitting AMS ground station into the NGSO satellite receiver (Peak gain towards NGSO earth station)



Qualcomm has explained that its AMS ground station will be transmitting 17 dB more EIRP at an elevation angle of 1° than it would be transmitting at an elevation angle of 15°, by virtue of its isoflux antenna design. Yet the increased path loss from the NGSO satellite to the interfering ground station at 1° elevation compared to the situation at 15° elevation is only 3.5 dB (in PFD terms, based on the square of the distance). Therefore, the NGSO satellite will receive approximately 13.5 dB more interference than Qualcomm has calculated (*i.e.*, 17 – 3.5).

Qualcomm's assumption that 15° is the minimum elevation angle at which an NGSO system would intentionally operate is also very questionable. Other existing NGSO satellite systems

operate to elevation angles below 10°.[11] The real-world use of lower minimum elevation angles than 15° further invalidates the Qualcomm interference analysis.

Qualcomm's assumption concerning the likely NGSO satellite G/T performance level is also biased in Qualcomm's favor. Future NGSO satellite systems may well be designed to serve small and low-powered user terminals, and as such may require relatively high satellite receive gain. Alternatively, another type of NGSO system may not be aiming to provide ubiquitous geographic coverage but may instead use higher gain steerable spot beams that are directed towards only the geographic locations where service is to be provided to support very high data rates.[12] It is therefore quite feasible that a future NGSO satellite system would have a beam with a peak gain as high as 30 dBi, and a noise temperature of around 500K, resulting in a beam peak G/T performance level of +3 dB/K. This is approximately 10 dB higher than the -7 dB G/T value that Qualcomm has arbitrarily assumed in its interference analysis.

Table A.2-2 below provides the uplink interference analysis under the conditions described above. Several cases are shown, and they all assume the minimum elevation angle that the NGSO system is intended to serve is 15°. Case A uses the same assumptions as Qualcomm used concerning the G/T of the NGSO satellite towards the intended NGSO earth station. Case B is a minor adjustment of Case A, where the peak of the NGSO beam is assumed to be pointed at the NGSO earth station. Case C assumes a higher NGSO peak antenna gain (30 dBi instead of 20 dBi). Note that the interference levels range from a $\Delta T/T$ of 13% to more than 200% for the various cases considered, considerably more than the 0.81% stated by Qualcomm.

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[11] For example, Iridium operates down to 8° elevation and Globalstar down to 10° elevation.

[12] An example of this is the recently launched O3b Ka-band satellite system that has relatively high gain spot beams which achieve a G/T level of +4 dB/K (based on Schedule S information filed with the FCC).

Table A.2-2: Interference analysis from AMS ground station to NGSO satellite receiver (using Qualcomm proposed EIRP for AMS ground station)

			Case A	Case B	Case C
Row #	Parameter	Units	Values	Values	Values
1	Single-entry (max) EIRP density of AMS_GS interferor (per 50MHz)	dBW/50MHz	39.5	39.5	39.5
2	Single-entry (max) EIRP density of AMS_GS interferor (per Hz)	dBW/Hz	-37.49	-37.49	-37.49
3	Frequency	GHz	14.50	14.50	14.50
4	NGSO orbit altitude	km	1,000	1,000	1,000
5	Elevation angle from AMS_GS to NGSO satellite	°	1	1	1
6	Range from AMS_GS to NGSO satellite	km	3,600	3,600	3,600
7	Space Loss from AMS_GS to NGSO satellite	dB	186.80	186.80	186.80
8	Polarization discrimination (AMS linear, NGSO circular)	dB	3.0	3.0	3.0
9	NGSO satellite receive peak gain	dBi	20.0	20.0	30.0
10	NGSO satellite receive system noise temperature	K	500	500	500
11	Rx interfering signal power density at NGSO satellite	dBW/Hz	-207.28	-207.28	-197.28
12	Noise power density at NGSO satellite	dBW/Hz	-201.61	-201.61	-201.61
13	NGSO satellite G/T at beam peak	dB/K	-7.0	-7.0	3.0
14	NGSO beam roll-off in direction of AMS_GS	dB	-3.0	-0.3	-1.0
15	NGSO satellite G/T in direction of AMS_GS	dB/K	-10.0	-7.3	2.0
16	Resulting $\Delta T/T$ at NGSO satellite receiver	%	13.57%	25.27%	215.05%

Not only did Qualcomm ignore the low elevation interference into NGSO satellite receivers as addressed above – it also has glossed over the situation for elevation angles between 15° and 90° by concentrating exclusively on the 15° elevation case. For elevation angles greater than 15° it is not clear whether, or to what extent, the isoflux performance of the AMS ground station antenna is maintained. In order to not cause any more interference to NGSO satellites at zenith than is caused at 15° elevation, the AMS ground station antenna gain would have to reduce in keeping with the reduced path loss to the higher elevation NGSO satellite. The range to an NGSO satellite in a 1,000 km altitude orbit at 15° elevation is 2,411 km. Therefore the path loss reduction at zenith (90° elevation) is 20*log(2411/1000) = 7.6 dB compared to the 15° elevation case.

Finally, Qualcomm has proposed that NGSO FSS satellite systems should accept up to 6% increase in their system noise temperature as a result of the interference from the proposed new secondary AMS.[13] Qualcomm asserts that this is consistent with Table 5-1 of Appendix 5 of the

[13] See Table A.3 in Section 3.1.1 of the Qualcomm Petition for Rulemaking, 7 July 2011. Note that Qualcomm incorrectly states here that the 6% interference allowance is based on Appendix 5 of the ITU Radio Regulations.

ITU Radio Regulations, but this is not so. Appendix 5 does not refer to the allowable interference from a non-allocated (or secondary) terrestrial service into a primary satellite service, such as the NGSO FSS. In fact, for the same reasons explained in the context of the interference to the GSO FSS in Section A.2.1.1 above, the aggregate interference of such non-allocated services should be well below 1%, and a figure of 0.33% is proposed.

In order to reduce the uplink interference from AMS ground stations into NGSO satellite receivers to a ΔT/T level of 0.33% the maximum EIRP density of the AMS ground stations must be reduced to the levels shown in Table A.2-3 below. These EIRP density levels are lower than those proposed by Qualcomm by 16.1 dB, 18.8 dB and 28.1 dB, respectively, for the three cases considered in this analysis.

Table A.2-3: Interference analysis from AMS ground station to NGSO satellite receiver (to not exceed a ΔT/T of 0.33%)

			Case A	Case B	Case C
Row #	Parameter	Units	Values	Values	Values
1	Single-entry (max) EIRP density of AMS_GS interferor (per 50MHz)	dBW/50MHz	23.4	20.7	11.4
2	Single-entry (max) EIRP density of AMS_GS interferor (per Hz)	dBW/Hz	-53.59	-56.29	-65.59
3	Frequency	GHz	14.50	14.50	14.50
4	NGSO orbit altitude	km	1,000	1,000	1,000
5	Elevation angle from AMS_GS to NGSO satellite	°	1	1	1
6	Range from AMS_GS to NGSO satellite	km	3,600	3,600	3,600
7	Space Loss from AMS_GS to NGSO satellite	dB	186.80	186.80	186.80
8	Polarization discrimination (AMS linear, NGSO circular)	dB	3.0	3.0	3.0
9	NGSO satellite receive peak gain	dBi	20.0	20.0	30.0
10	NGSO satellite receive system noise temperature	K	500	500	500
11	Rx interfering signal power density at NGSO satellite	dBW/Hz	-223.38	-226.08	-225.38
12	Noise power density at NGSO satellite	dBW/Hz	-201.61	-201.61	-201.61
13	NGSO satellite G/T at beam peak	dB/K	-7.0	-7.0	3.0
14	NGSO beam roll-off in direction of AMS_GS	dB	-3.0	-0.3	-1.0
15	NGSO satellite G/T in direction of AMS_GS	dB/K	-10.0	-7.3	2.0
16	Resulting ΔT/T at NGSO satellite receiver	%	0.33%	0.33%	0.33%

Based on the above it is clear that Qualcomm's assertion that there will be no interference to NGSO FSS systems from the proposed AMS ground stations is not accurate. There will be direct in-line interference events that cause a ΔT/T of greater than 13% as a minimum, in excess of 25% for NGSO satellites that point their beams to lower elevation angles and in excess of 200% for higher gain NGSO satellites, and any of these will be unacceptable to the NGSO

operations. There appears to be no way to prevent such interference events other than by lowering the EIRP density levels of the transmitting AMS ground stations by a significant amount or by shutting off the AMS ground station transmissions altogether when they are within a certain angular alignment with an NGSO satellite. Although Qualcomm suggests that it might be prepared to perform such interference mitigation when an NGSO FSS system becomes operational, it is unlikely that this would be viable without severely impacting the quality of service of the AMS system.

The Commission should adopt clear rules to govern these situations which will likely arise if the AMS is actually licensed. Such rules should provide an EIRP density versus elevation mask (for all elevation angles) that protects all scenarios of interference from the AMS ground station into NGSO satellite receivers. In addition, the Commission should make it clear that, as a secondary service, the AMS licensee will be expected to adjust its system in the future to protect primary Ku-band NGSO systems that may be launched to ensure adequate protection of such future systems, and that the AMS licensee cannot expect to be protected from interference from such future systems.

A.3 Interference from the AMS Aircraft Terminals

The NPRM also asks for comments on the interference caused by the proposed new AMS aircraft terminals.[14] These terminals are assumed to be operating across CONUS and numbering as many as 1,000 on the same frequency, but with no more than four co-frequency terminals per AMS cell. The aircraft terminals generally point in a southerly direction, thereby potentially interfering directly into FSS satellite receivers. This interference mechanism is illustrated in Figure A.3-1 below.

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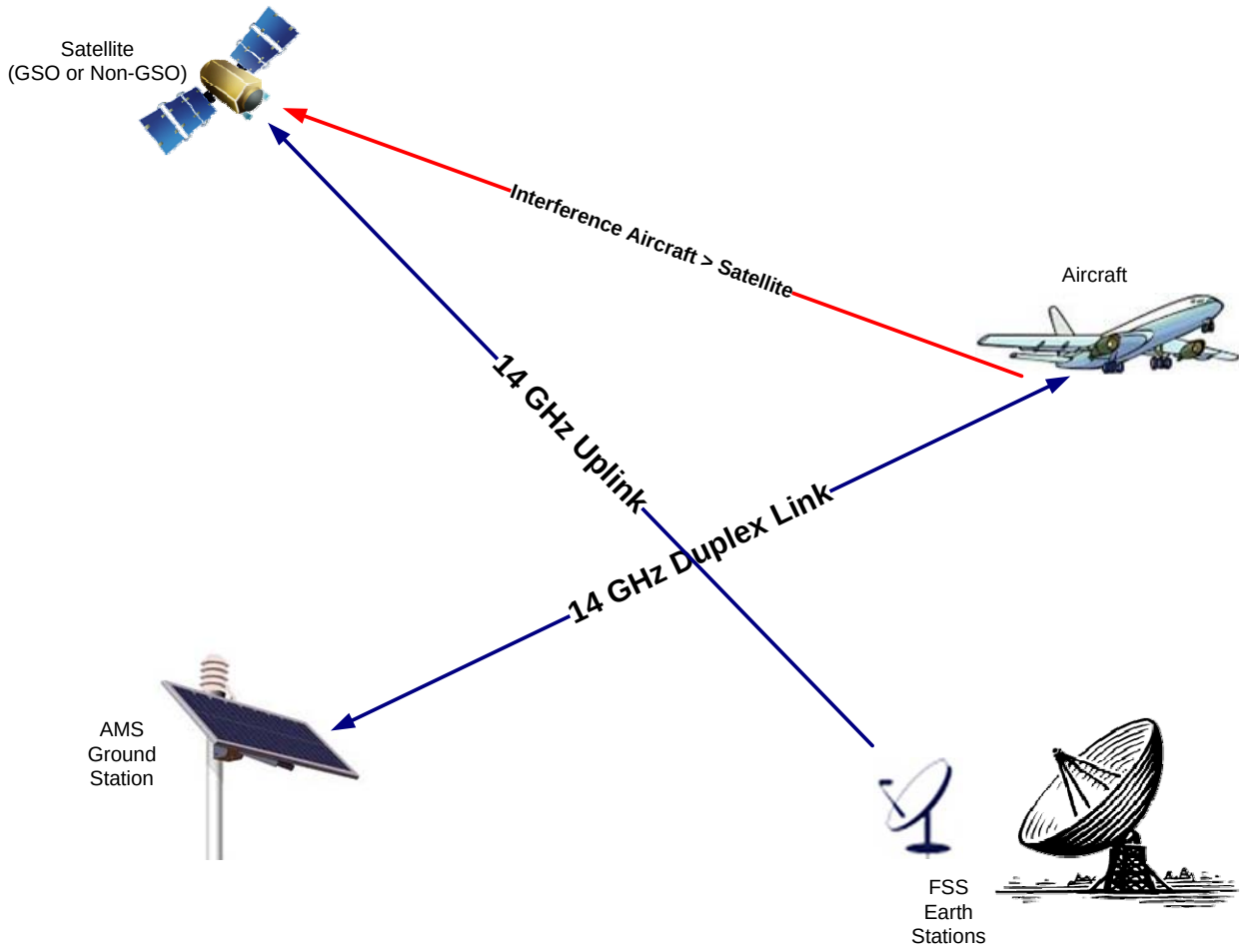
[14] See paragraphs 104 and 105 of the NPRM.

Figure A.3-1: Potential interference mechanism resulting from the AMS aircraft terminal transmissions



Both GSO and NGSO FSS satellites must be protected from this interference. These two cases are dealt with separately below.

A.3.1.1 Interference from AMS Aircraft Terminals into GSO FSS Satellite Receivers

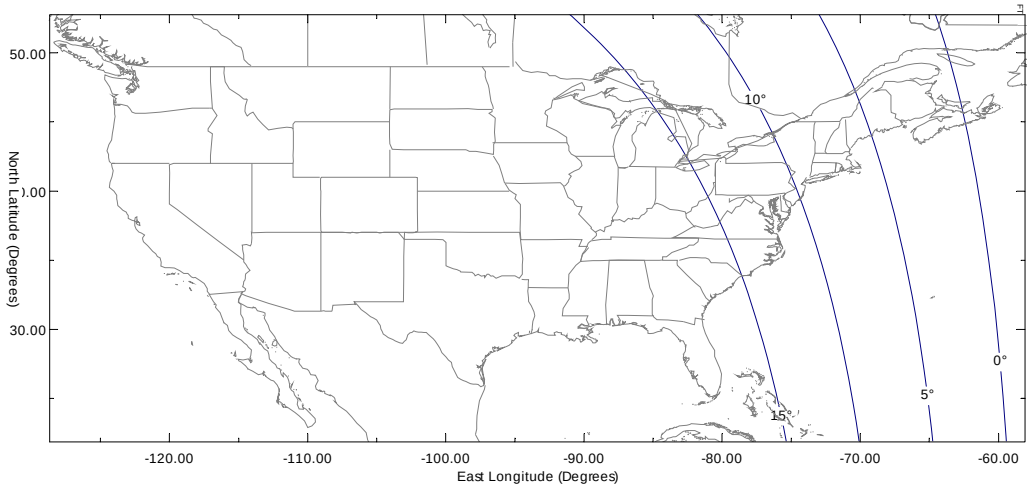
The rationale explained in Section A.2.1 above for the case of aggregate interference from AMS ground stations supports the use of 0.33% ΔT/T as the protection criterion for the GSO FSS relating to interference from AMS aircraft terminals.

Qualcomm's analysis of this interference effect, which concludes that the aggregate ΔT/T would be less than 0.21% based on 600 aircraft communicating with 150 base stations, appears at first

blush to demonstrate compliance with this criterion,[15] but upon further scrutiny this is not the case. The complex Qualcomm methodology uses a statistical combination of elevation and azimuth pointing directions to any GSO orbital position to arrive at its optimistic conclusion. This analysis is suspect for several reasons, as follows:

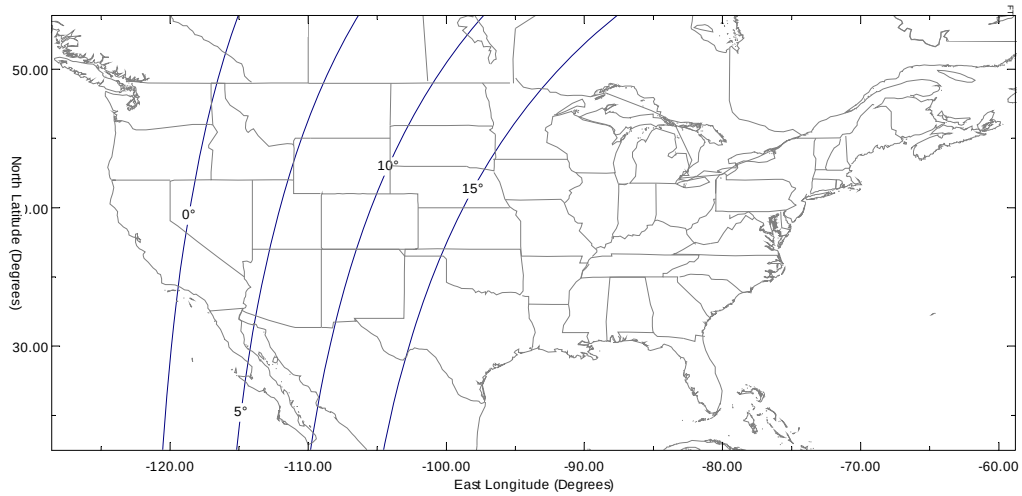
a) The Qualcomm analysis does not consider some interference geometries that produce more interference into GSO satellites. Qualcomm rightly recognizes that the interference into the GSO is worse for GSO satellites located to the east or to the west of CONUS where the elevation angles from CONUS are lower than for mid-CONUS orbital positions. However, Qualcomm chose to analyze only a carefully selected mid-Pacific GSO orbital position rather than a mid-Atlantic one, and the latter gives rise to more aircraft terminals operating at low elevation angles and hence more interference. The contrast between these two cases is illustrated below.

   Qualcomm chose the 140°W orbital position that provides the following low elevation angle contours (15°, 10°, 5° and 0°) from CONUS. Note the small geographic area covered by these low elevation contours, and the fact that Qualcomm's analysis is totally dependent on the geographic area covered by these low elevation contours:



[15] See Section 3.3.1.2 of the Qualcomm Petition for Rulemaking, 7 July 2011.

By contrast, a mid-Atlantic orbital position of 40°W provides the following low elevation angle contours from CONUS:



Note how a much larger geographic area is covered by the low elevation angle contours in this case.

This effect is quantified by comparing the elevation angles for the various "bins" in the two tables given in Tables A.3-1 and A.3-2 below. Table A.3-1 has been copied from Table A.11 of the Qualcomm Petition for Rulemaking and gives the elevation angles for the various latitude and longitude bins across CONUS to the 140°W GSO orbital position. Table A.3-2 gives the corresponding elevation angles for the same bins but to the 40°W GSO orbital position.

Table A.3-1: Elevation angles over CONUS to a GSO satellite at 140°W longitude

	125	120	115	110	105	100	95	90	85	80	75	70
50.0	30.93	29.60	27.95	26.01	23.82	21.40	18.80					
47.5	33.49	32.04	30.25	28.14	25.77	23.17	20.38	17.44	14.37			4.69
45.0	36.06	34.48	32.53	30.25	27.70	24.91	21.93	18.80	15.55		8.79	5.33
42.5	38.62	36.91	34.79	32.34	29.59	26.62	23.44	20.12	16.69	13.16	9.58	5.95
40.0	41.19	39.32	37.03	34.39	31.45	28.28	24.91	21.40	17.78	14.08	10.33	
37.5		41.72	39.25	36.41	33.27	29.89	26.33	22.64	18.84	14.97	11.05	
35.0		44.10	41.42	38.38	35.03	31.45	27.70	23.82	19.84	15.81		
32.5			43.56	40.29	36.74	32.95	29.01	24.95	20.80	16.61		
30.0					38.38	34.39	30.25	26.01	21.71	17.36		
27.5						35.75	31.43			18.06		
25.0						37.03				18.71		

Table A.3-2: Elevation angles over CONUS to a GSO satellite at 40°W longitude

		Longitude											
		-125	-120	-115	-110	-105	-100	-95	-90	-85	-80	-75	-70
Latitude	50.0			0.88	4.02	7.13	10.18	13.16					
	47.5			1.37	4.69	7.97	11.21	14.37	17.44	20.38			28.14
	45.0			1.85	5.33	8.79	12.20	15.55	18.80	21.93		27.70	30.25
	42.5			2.31	5.95	9.58	13.16	16.69	20.12	23.44	26.61	29.59	32.34
	40.0			2.75	6.55	10.33	14.08	17.78	21.40	24.91	28.28	31.45	
	37.5			3.16	7.11	11.05	14.97	18.84	22.64	26.33	29.89	33.27	
	35.0			3.56	7.65	11.74	15.81	19.84	23.82	27.70	31.45		
	32.5			3.93	8.15	12.38	16.61	20.80	24.94	29.01	32.95		
	30.0					12.99	17.36	21.70	26.01	30.25	34.39		
	27.5						18.06	22.55			35.75		
	25.0						18.71				37.03		

For the Qualcomm example there are only five bins with elevation angles between 4.7° and 10°, and six bins with elevation angles between 10° and 15°. For the case of the 40°W GSO orbital position there are not only much lower elevation angles, but many more bins with low elevation angles. From Table A.3-2 it can be seen that, for the 40°W GSO orbital position, there are three bins with elevation angles less than 2°, seven bins with elevation angles between 2° and 5°, ten bins with elevation angles between 5° and 10° and 13 bins with elevation angles between 10° and 15°. In total there are 33 bins with elevation angles less than 15° compared to only 11 bins in the Qualcomm analysis.

Based on this data, and using the 3D antenna gain data provided by Qualcomm,[16] the overall interference was found to be approximately 8 dB worse than Qualcomm calculated, assuming a 5° aircraft roll angle. This applies to the case of 600 aircraft terminals.

b) The Qualcomm analysis assumes the GSO satellite receive system G/T performance is only +2 dB/K whereas a value of +6 dB/K is more appropriate (as explained in Section A.2.1 above). This results in an interference level that is 4 dB worse than Qualcomm calculated.

[16] See Qualcomm *ex parte* dated September 2, 2011.

c) Qualcomm makes brief mention of the fact that a non-uniform distribution of aircraft and AMS ground stations across CONUS would result in higher levels of interference to GSO satellites from the aircraft terminals.[17] However, Qualcomm fails to quantify this effect.

Based on the above three factors it is prudent to reduce the maximum aircraft terminal EIRP density by at least the amounts stated in (a) and (b) above (*i.e.*, 8 dB + 4 dB = 12 dB). This would require that the maximum aircraft EIRP is reduced from +3 dBW/2MHz to -9 dBW/2MHz in order to adequately protect GSO satellite receivers, for the case of 600 aircraft terminals.

In addition, a 3D antenna gain mask must be imposed on the aircraft terminals that is at least as tight as the masks already proposed by Qualcomm.

The rule tentatively proposed by the Commission to control the aggregate interference from AMS aircraft terminals into GSO satellites is unlikely to be enforceable as it cannot be measured or actively controlled in practice.[18] In particular, the location and bank angle of the individual aircraft cannot be controlled by the AMS operator. This is different from the case of the emissions from the AMS ground stations, which are static emitters in fixed locations, and which therefore can be rigorously analyzed. Furthermore, the EIRP density mentioned in this proposed rule (-47 dBW/Hz) should be set to be the same as that proposed for the AMS ground stations, as addressed in Section A.2.1 above, which was -52.4 dBW/Hz. To overcome the shortcomings of the aggregate EIRP density rule, it would be useful to also impose a limitation on the number of simultaneously active aircraft terminals on the same portion of the Ku-band spectrum, which could be related to the single-entry EIRP density limit per aircraft terminal. For a limit of -9 dBW/2MHz, as proposed above, the limit on the number of simultaneously active aircraft terminals on the same portion of the Ku-band spectrum should be 600, which was the basis of the original Qualcomm interference analysis. If this were expanded to 1000 aircraft terminals

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[17] See third paragraph on page A-22 of the Qualcomm Petition for Rulemaking, 7 July 2011, which reads as follows: "If for some reason most of the planes are concentrated on the east or west coast it may be necessary to increase the number of GSs in areas with heavy traffic. In this case, the GS service area and the GS-aircraft distance will be reduced along with their maximum transmit EIRP."

[18] See proposed rule §22.1120 (b) in the NPRM, which reads as follows: "Furthermore, the aggregate EIRP from all air-ground mobile broadband aircraft stations toward the GSO arc must not exceed -47 dBW/Hz."

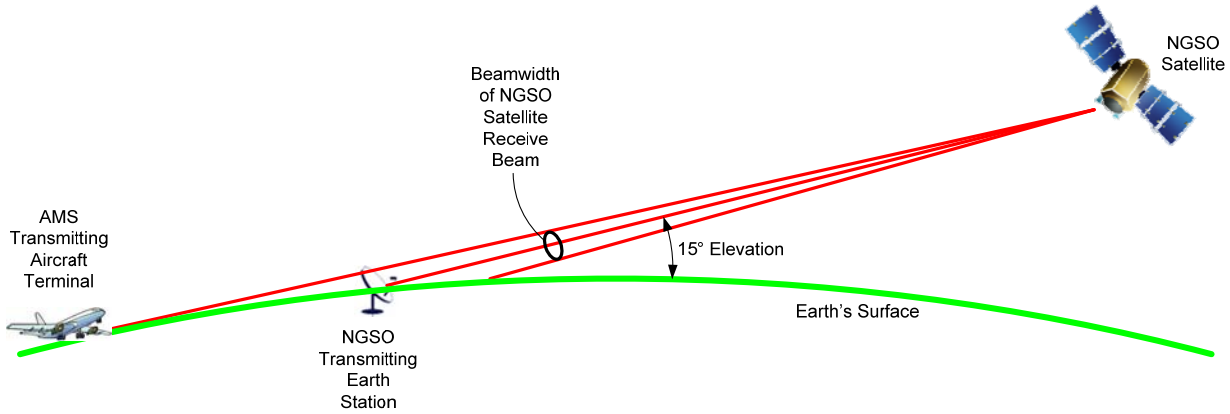
communicating simultaneously with 250 base stations, this limit would need to be scaled appropriately to -11.2 dBW/2MHz (-9 dBW/2MHz - 10log(1000/600)).

A.3.1.2 Interference from AMS Aircraft Terminals into NGSO FSS Satellite Receivers

Qualcomm's analysis of the interference from its proposed AMS aircraft terminals into NGSO FSS satellite receivers is flawed for the same reasons explained in Section A.2.1 above for the case of the interference from the AMS ground stations into NGSO FSS satellite receivers. It ignores the fact that the NGSO satellite receive beam will be vulnerable to interfering sources at elevation angles less than 15° because of the finite roll-off of the NGSO satellite receive beam toward the Earth's horizon. It also ignores the fact that an NGSO system may intentionally need to provide a viable communications link at elevation angles below 15°, as explained in Section A.2.1 above. Furthermore it ignores the possibility of an NGSO satellite system using higher gain spot beams.

Figure A.3-2 below shows the interference mechanism from the aircraft terminals into an NGSO satellite receiver. In the case of an aircraft flying at an altitude of 10 km, it is even possible for a direct line-of sight path to exist between the aircraft and the NGSO satellite at a slightly negative elevation angle. This has not been considered in the analysis below, where the minimum elevation angle is assumed to be zero.

Figure A.3-2: Illustrative diagram showing the potential low elevation interference mechanism from the transmitting AMS aircraft terminal into the NGSO satellite receiver



In the case of the interference from the AMS aircraft terminals into NGSO satellite receivers, only a relatively small number of aircraft terminals are needed to cause high levels of interference. The analysis presented in Table A.3-3 below assumes a single AMS aircraft terminal transmitting at the EIRP density proposed by Qualcomm (+3 dBW/2MHz). The elevation angle from the aircraft to the NGSO satellite is assumed to be zero and the aircraft is banking at 5°. This results in an antenna discrimination, based on the 3D antenna pattern data provided by Qualcomm for the aircraft terminal, of only 0.8 dB.[19] The assumptions concerning the NGSO satellite receive antenna and receiver sensitivity are the same as explained in Section A.2.1 above. The resulting interference levels would be acceptable for a single aircraft for cases A and B, with $\Delta T/T$ levels of 0.07% and 0.11%, respectively. Case C, with a $\Delta T/T$ level of close to 1% would be unacceptable even for a single AMS aircraft terminal. There would in fact be multiple aircraft simultaneously transmitting on the same frequency within the main beam of the NGSO satellite, and then all three cases considered in the analysis below become unacceptable. For cases A and B, where the NGSO satellite beam gain is only 20 dB, the diameter of the beam across the Earth's surface (orthogonal to the line from the Earth to the satellite) at the range corresponding to zero elevation is approximately 850 km, so the NGSO satellite beam will potentially see a large geographic area and therefore receive interference from a significant number of AMS cells. Figure A.3-3 below shows the -3 dB contour that was shown previously in Figure A.2-5 demonstrating that it covers the full north-south extent of CONUS and in so doing would receive interference from approximately ten AMS cells. Each cell would have four co-frequency aircraft transmitters, making a total of forty potential interferers. This factor will significantly increase the aggregate interference to the NGSO satellite receiver above the single-entry levels given in Table A.3-3 below.

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[19] See Qualcomm *ex parte* dated September 2, 2011.

Figure A.3-3: Large geographic footprint of a 21 dBi NGSO satellite receive beam at low elevation angles

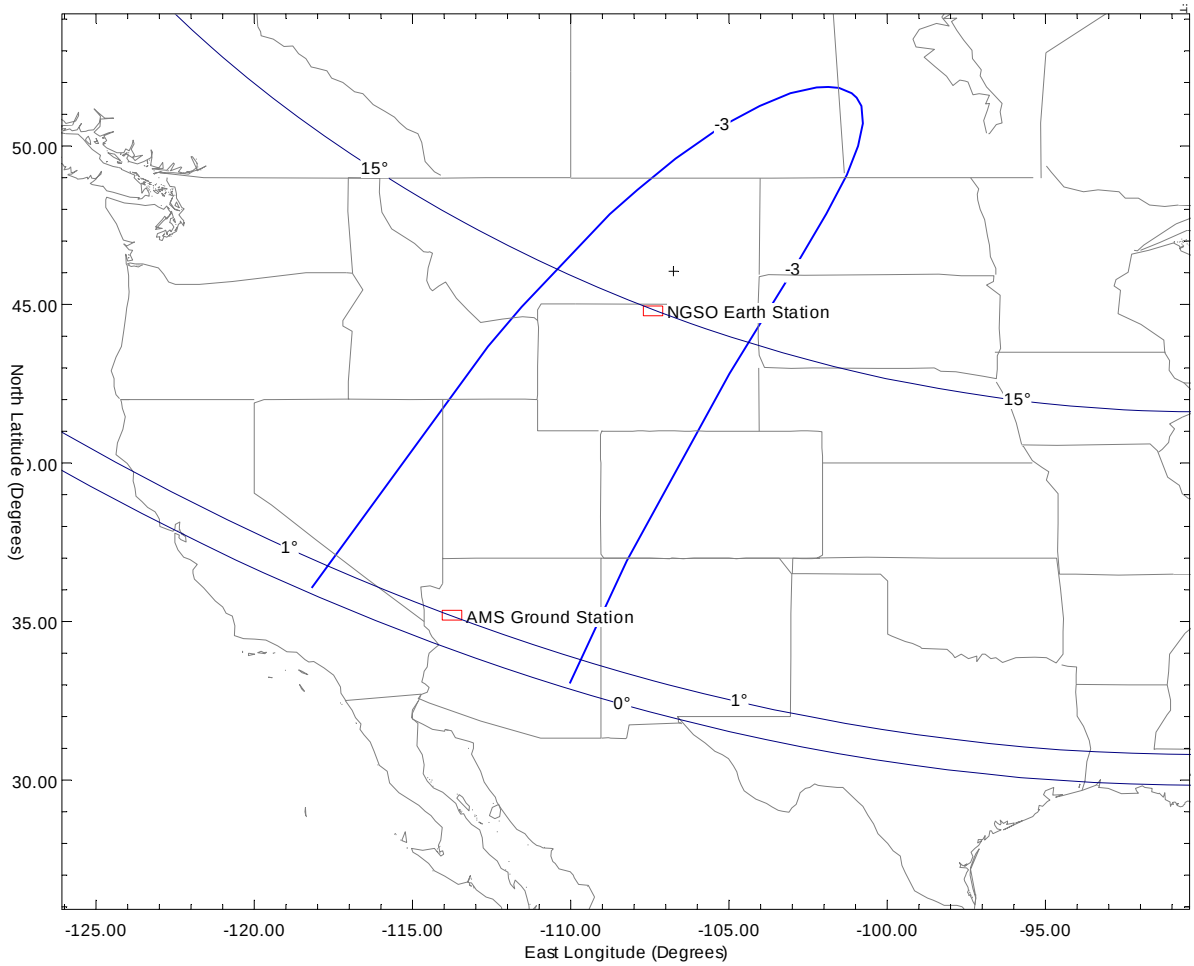

Table A.3-3: Interference analysis from AMS aircraft terminals to NGSO satellite receiver (single-entry)

Row #	Parameter	Units	Case A Values	Case B Values	Case C Values
1	Single-entry (max) EIRP density of AMS_Airplane interferor (per 2MHz)	dBW/2MHz	3	3	3
2	Single-entry (max) EIRP density of AMS_Airplane interferor (per Hz)	dBW/Hz	-60.0	-60.0	-60.0
3	Frequency	GHz	14.50	14.50	14.50
4	NGSO orbit altitude	km	1,000	1,000	1,000
5	Elevation angle from AMS_Airplane to NGSO satellite	°	0	0	0
6	Range from AMS_Airplane to NGSO satellite	km	3,709	3,709	3,709
7	Gain discrimininating towards the NGSO	dB	0.8	0.8	0.8
8	Space Loss from AMS_Airplane to NGSO satellite	dB	187.1	187.1	187.1
9	Polarization discrimination (AMS linear, NGSO circular)	dB	3.0	3.0	3.0
10	NGSO satellite receive peak gain	dBi	20.0	20.0	30.0
11	NGSO satellite receive system noise temperature	K	500	500	500
12	Rx interfering signal power density at NGSO satellite	dBW/Hz	-230.9	-230.9	-220.9
13	Noise power density at NGSO satellite	dBW/Hz	-201.6	-201.6	-201.6
14	NGSO satellite G/T at beam peak	dB/K	-7.0	-7.0	3.0
15	NGSO beam roll-off in direction of AMS_Airplane	dB	-3.0	-0.3	-1.0
16	NGSO satellite G/T in direction of AMS_Airplane	dB/K	-10.0	-7.3	2.0
17	Resulting ΔT/T at NGSO satellite receiver	%	0.06%	0.11%	0.94%

There appear to be no operational mitigation techniques that the AMS operator could employ to overcome these high levels of interference, unlike the case of the interfering AMS ground station which had a narrower antenna beamwidth in azimuth and which could therefore turn off for short periods of time when in-line interference situations occurred. The wide azimuthal beamwidth of the proposed AMS aircraft terminals prevents this technique from being used effectively.

In the absence of an operational mitigation technique it would be necessary to reduce the AMS aircraft terminal EIRP density to a significantly lower level than is proposed by Qualcomm. Using the analysis results presented above (Case B), assuming that a worst case ΔT/T of 0.33% was acceptable, and that up to forty aircraft could be interfering into a single NGSO satellite beam (with a gain of 21 dBi), the EIRP density per aircraft would need to be reduced by approximately 11.2 dB. This would require that the maximum EIRP density of each AMS aircraft terminal must not exceed -8.2. dBW/2MHz. In addition, an antenna gain mask for all elevation angles must be defined, taking account of a 5° aircraft bank angle.

A.4 Summary of the Limits to be Imposed on AMS Ground Stations and Aircraft Terminals

Table A.4-1 below summarizes the constraints that must be imposed if the AMS were to operate in the 14.0-14.5 GHz primary FSS frequency band in order to protect the primary FSS services, both GSO and NGSO, in that band.

Table A.4-1: Summary of necessary constraints on the proposed AMS in order to protect Primary FSS in the 14.0-14.5 GHz band

	To protect GSO FSS	To protect NGSO FSS
AMS Ground Station Transmissions	1. Aggregate EIRP density towards the GSO orbit < -52.4 dBW/Hz. 2. Single-entry (per GS) EIRP density towards the GSO orbit < -82.4 dBW/Hz (under all conditions).	**1.** Single-entry (per GS) EIRP density versus elevation angle mask for all elevation angles and any azimuth direction (Between 16.1-28.1 dB lower at zero elevation than currently proposed by Qualcomm).
AMS Aircraft Terminal Transmissions	1. Peak EIRP density per AMS aircraft terminal < -11.2 dBW/2MHz. 2. Aircraft antenna gain mask defined for all elevation angles and azimuth directions and assuming a 5° aircraft bank angle. 3. Aggregate EIRP density towards the GSO orbit < -52.4 dBW/Hz. 4. Maximum number of simultaneously active co-frequency aircraft terminals < 1000 (can be related to item 1 above).	1. Peak EIRP density per AMS aircraft terminal < -8.2 dBW/2MHz. 2. Aircraft antenna gain mask defined for all elevation angles and azimuth directions and assuming a 5° aircraft bank angle.

A.5 Interference into the AMS Ground Stations and AMS Aircraft Terminals

The record in this proceeding clearly shows that there are severe interference issues from the incumbent services into the proposed new AMS.[20] In some situations the interference will completely prevent the AMS link from operating, while in others it will significantly reduce the C/(N+I) levels on the AMS links. One of Qualcomm's important responses to this fundamental problem is to argue that Qualcomm can tolerate the cases of reduced C/(N+I) levels by reducing the throughput on the AMS links. Such an approach may not, however, be viable when the AMS has to operate at the reduced power levels proposed in the preceding sections of this technical annex.

[20] See SIA *ex-parte* presentations dated August 31, 2012 and October 22, 2012.

APPENDIX 1: G/T Performance of Ku-Band Satellites Serving at least 70% of the Continental U.S.

Satellite	Nominal Orbital Location (° WL)	Beam Peak G/T (dB/K)	Approximate Edge of Coverage Relative Gain Contour Below Beam Peak (dB)	Assumed Average Relative Gain Contour Below Beam Peak (dB)	Assumed Average G/T (dB/K)
Horizons 1	127	5.3	4.0	2.0	3.3
AMC-21	125	8.2	6.0	3.0	5.2
Galaxy 18	123	8.3	8.0	4.0	4.3
Echostar 9	121	7.0	6.0	3.0	4.0
Anik F3	118.7	9.3	8	4	5.3
Satmex 8	116.8	6.0	4	2	4.0
Satmex 5	114.9	6.5	4.0	2.0	4.5
Satmex 6	113	6.0	6.0	3.0	3.0
Anik F2	111.1	8.6	10.0	5.0	3.6
Anik F1R	107.3	8.9	9.0	4.5	4.4
Anik F1	107.3	Unknown	-	-	-
AMC-15	105.05	5.4	4.0	2.0	3.4
SES-3	103	Unknown	-	-	-
AMC-1	103	6.7	9.7	4.8	1.9
SES-1	101	7.0	5.0	2.5	4.5
Galaxy 16	99	6.1	5.0	2.5	3.6
Galaxy 19	97	4.5	2.0	1.0	3.5
Galaxy 3C	95.05	5.3	4.0	2.0	2.5
Galaxy 25	93.1	2.7	2.0	1.0	1.7
Galaxy 17	91	7.1	4.0	2.0	5.1
Galaxy 28	89	4.0	4.0	2.0	2.0
SES-2	87	8.0	4.0	2.0	6.0
AMC-16	85	5.6	4.0	2.0	3.6
AMC-9	83	4.8	3.0	1.5	3.3
AMC-5	81	7.7	4.0	2.0	5.7
AMC-6	72	6.0	4.0	2.0	4.0
Telstar 14R	63	5.9	2.0	1.0	4.9
Amazonas-2	61	6.7	3.0	1.5	5.2
Amazonas-3	61	Unknown	-	-	-
Intelsat 9	58	0.0	2.0	1.0	-1.0

Notes:

1) List of satellites obtained from www.lyngsat.com.
2) Only those satellites having non-steerable beams in the 14 – 14.5 GHz band that provided approximately 70% or greater coverage of CONUS are listed. Specifically, if the edge of coverage contour of the satellite covered at least 70% of CONUS, it was included in the table of Appendix 1.
3) Beam peak G/T and SFD values obtained from FCC filings of the spacecraft unless otherwise noted.

CERTIFICATION OF PERSON RESPONSIBLE FOR PREPARING ENGINEERING INFORMATION

I hereby certify that I am the technically qualified person responsible for preparation of the engineering information contained in this supplement, that I am familiar with the Commission's rules, that I have either prepared or reviewed the engineering information submitted in this supplement and that it is complete and accurate to the best of my knowledge and belief.

_____/s/_____

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