Before the
FEDERAL COMMUNICATIONS COMMISSION
Washington, DC 20554

In the Matter of Amendment Of The Commission's Rules To Establish A Next-Generation Air-Ground Communications Service On A Secondary Licensed Basis In The 14.0 to 14.5 GHz Band	RM-11640

REPLY COMMENTS OF QUALCOMM INCORPORATED

Dean R. Brenner
Vice President, Government Affairs

John W. Kuzin
Senior Director, Regulatory

1730 Pennsylvania Avenue, NW
Suite 850
Washington, DC 20006
(202) 263-0020

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SUMMARY

The FCC has a very solid record upon which to issue a Notice of Proposed Rulemaking ("NPRM") proposing to establish the Next Generation Air-Ground ("Next-Gen AG") Communications Service on a Secondary Licensed Basis in the 14.0-14.5 GHz band. The technical papers that Qualcomm filed earlier this year in response to eight questions from the FCC's International Bureau on the interference analysis in Qualcomm's Petition for Rulemaking ("Petition") conclusively demonstrate that the Next-Gen AG service can operate successfully in the presence of – and while fully protecting – all incumbent operations in the band.

The latest comments from the Satellite Industry Association ("SIA") and Row 44, Inc. ("Row 44"), largely rehash arguments made last year to which Qualcomm previously provided full responses. To the limited extent they raise new concerns, Qualcomm easily addresses them herein. Also, Qualcomm agrees with the National Radio Astronomy Observatory and National Academy of Sciences that coordinating the proposed service with radio astronomy operations at 14.47 to 14.5 GHz presents new challenges; nonetheless, future Next-Gen AG licensees will protect radio astronomy sites. In sum, after yet another round of filings, the record shows that there is no valid technical obstacle preventing the Commission from issuing an NPRM.

It is important to reiterate that Qualcomm's detailed technical analysis is based on very conservative operational assumptions, which ensure that all incumbent users will be protected by a substantial margin. Qualcomm assumed, for example, that the Next-Gen AG system was operating at maximum loading and with maximum transmit power levels. In actual operation, however, the system would operate at a 75% load in order to support a consistent system-wide quality of service. In addition, transmit power levels from the aircraft and the serving Ground Station ("GS") would only be as high as needed to maintain a reliable communications connection. Also, Qualcomm did not account for any of the additional losses that are inherently

introduced by antenna polarization mismatches between the Next-Gen AG system and a potential victim receiver. In total, Qualcomm's calculations, which conclusively demonstrated that the proposed service would comply with Rise-over-Thermal ("RoT") levels well below the 1% level the Satellite Industry Association ("SIA") has cited in prior FCC filings, over-estimated potential interference to incumbent operations by at least 8 dB.

Qualcomm looks forward to continuing to work with the FCC and all interested parties towards concluding a rulemaking proceeding. Favorable Commission action will help spur further technological innovation in the wireless industry and recoup value for the public through the auction of the right to use up to 500 MHz of spectrum on a secondary licensed basis.

There can be no serious question of the need for a high-data-rate air-ground network to maintain high-speed in-flight connectivity such as that proposed in the Next-Gen AG Petition. Major U.S. airlines and leading air-ground communications service provider Gogo have told the Commission that mobile broadband demand on-board aircraft is exploding. They are seeing increasing numbers of customers that want to use multiple Wi-Fi-enabled devices while in flight. Accordingly, Qualcomm respectfully requests that the FCC issue an NPRM proposing to establish the Next-Gen AG service as proposed in the Petition as soon as possible.

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QUALCOMM Incorporated ("Qualcomm") hereby replies to the comments filed on its technical response to the International Bureau's questions on Qualcomm's Petition for Rulemaking to establish a Next-Generation Air-Ground ("Next-Gen AG") communications service at 14.0 to 14.5 GHz.[1] As explained herein, the full record before the Commission supports the prompt issuance of an NPRM.

DISCUSSION

I. The Proposed Next-Generation Air-Ground Communications Service Can Successfully Operate On A Secondary Licensed Basis At 14.0-14.5 GHz

Qualcomm previously explained in detail how the proposed Next-Gen AG mobile broadband communications system will operate in the Ku band at 14.0 to 14.5 GHz on a secondary licensed basis to geosynchronous ("GSO") satellite systems, future non-geosynchronous ("NGSO") satellite systems, NASA's Tracking and Data Relay Satellite System

[1] *See* FCC Public Notice, International Bureau Seeks Further Comment On Qualcomm Petition For Rulemaking, DA 12-767 (May 15, 2012) (seeking comment on technical papers Qualcomm filed on January 30, March 29, and April 6, 2012, in response to FCC staff questions posed to Qualcomm via letter dated January 19, 2012 and in follow-on meetings with staff). These Reply Comments are timely filed in accordance with the International Bureau's Letter to Patricia Cooper of SIA, DA 12-835 (May 25, 2012).

("TDRSS"), and radio astronomy users. In the Next-Gen AG Petition for Rulemaking, in Comments and Reply Comments filed in the fall of 2011, and in several focused technical filings submitted earlier this year, Qualcomm has provided extensive documentation showing that the proposed service will fully protect all incumbent users of the band while providing much-needed broadband connectivity to hundreds of aircraft flying above the Continental United States ("CONUS").

As the Commission well knows, Qualcomm has a vested interest in protecting incumbent operations at 14.0 to 14.5 GHz, for the company has used this band since 1988 for its own successful GSO satellite-based OmniTRACS mobile communications and information service. This successful business has given Qualcomm a deep understanding of the operating environment in the band, which has been integrated into its analysis.

SIA alleges that while Qualcomm is proposing a secondary allocation, a future Next-Gen AG licensee will seek additional protection (*e.g.*, by requesting primary status) at some point in the future.[2] While SIA's own members have taken that approach[3] and Qualcomm cannot control what other future licensees might do, Qualcomm does not see any need for primary status in this case. Qualcomm has shown that the Next-Gen AG service can operate successfully on a secondary basis, taking into account all other users and operations within the 14.0-14.5 GHz band.

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[2] *See* SIA Comments (filed July 16, 2012) at 16. SIA's claim that Next-Gen AG system operators will seek relief from the FCC rather than relocate multiple Ground Stations ("GSs") as FSS VSAT deployments increase would be directly at odds with the nature of the secondary allocation that Qualcomm has proposed.

[3] *See, e.g.,* Panasonic September 29, 2011, Comments at 6 (citing Boeing Request for Elevation to Primary Status, IB Docket No.5-20 (April 20, 2010). *See also* Boeing September 29, 2011, Comments at 4-6; Row 44 September 29, 2011, Comments at 3.

A. The Proposed Regulatory Framework Will Enable Ongoing Innovation And Competition In The Next-Gen Air-Ground Communications Ecosystem

As Qualcomm's technical submissions explain, the proposed system will provide millions of airplane travelers with high-data-rate in-flight broadband connectivity and fully protect primary users and successfully coexist with other secondary users of the 14.0 to 14.5 GHz band. The Next-Gen AG system will use advanced RF equipment and antenna designs, tightly-focused GS communications beams that point away from GSO satellites, low transmit power from aircraft, and seamless hand-offs to successive GSs that track the flight path and enable continued use of low-transmit power levels and interference avoidance.

Qualcomm's Technical Submissions Are Based On Very Conservative Assumptions. Qualcomm's calculations, which demonstrate that the proposed Next-Gen AG service will comply with Rise-over-Thermal ("RoT") levels well below the 1% level SIA has cited in prior FCC filings, over-estimated potential interference to incumbent operations by at least 8 to 11 dB.[4] For example, Qualcomm's interference analysis assumed that the Next-Gen AG system would operate at maximum loading and at maximum transmit power levels. In actual operation, however, the system would operate at no greater than 75% load to be able to support a consistent system-wide quality of service. Also, transmit power levels from the aircraft and the serving GS would only be as high as needed to maintain a reliable communications connection. In addition, Qualcomm did not account for any of the losses due to antenna polarization mismatches that would exist between the Next-Gen AG system and a potential victim receiver. Moreover, had Qualcomm separately calculated the sidelobe area in the geo-arc from the aircraft antenna, the transmit power toward the geo-arc would be at least 5 dB less than the values used in the Appendix to the Petition. Furthermore, Qualcomm's calculations did not account for

[4] *See* Qualcomm March 29, 2012 filing at 16-18.

atmospheric losses from Next-Gen AG aircraft and GSs to satellites at very low elevation angles nor did it incorporate the lower G/T that these satellites would have over these regions. Taking these factors into account would provide at least an additional 8 to 11 dB of margin.

In other words, Qualcomm's previous filings have shown that in addition to the RoT from Next-Gen AG system being well below the 1% threshold, there is an additional margin of at least 8 to 11 dB. And, as discussed below, measurements from a prototype Next-Gen AG GS antenna show that the antenna's backlobe has at least 5 dB *additional* margin than was previously observed in simulations.

Qualcomm Is Asking The Commission To Implement Performance-Based Rules. Despite the clear explanation in Qualcomm's October 2011 Reply Comments, SIA and Row 44 again contend that Qualcomm's detailed technical proposal would lock in potential Next-Gen AG providers to a single approach and thus be inconsistent with FCC policies against favoring specific technical implementations.[5] Qualcomm explained that it is in no way advocating a technology-specific service or regulatory regime.[6] It is asking the Commission to propose and adopt a set of performance-based regulations that – like nearly all of the agency's other rules – can be met with any technology. Qualcomm once again invites other technology developers to work on improving the proposed system design and in no way intends for the FCC to adopt rules that would limit competitive opportunities.

B. The Interference Issues Raised by SIA and Row 44 Have Already Been Addressed Or Can Readily Be Addressed

Each of the technical concerns that SIA and Row 44 raise in their latest comments has already been addressed in Qualcomm's filings or is readily addressed, as explained below.

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5 *See* SIA Comments at 3-4.

6 *See* Qualcomm October 2011 Reply Comments at iii, 14-15.

The Impact of The Next-Gen AG Service On Primary FSS Operations Will Remain The Same If Additional Next-Gen AG GSs Are Added. SIA contends that interference will exceed the available 1% RoT because Qualcomm assumes a fixed EIRP and front-to-back ratio in its calculation even though the Next-Gen AG GS antenna beam will track the aircraft in flight and the Next-Gen AG system may implement 250 base stations with 1000 total beams (instead of 150 base stations and 600 total beams).[7] SIA apparently overlooked Qualcomm's previous detailed analysis and responses that refuted this claim. As Qualcomm previously explained, if the Next-Gen AG system uses more base stations than the number used in its initial interference calculations, the system will operate with lower power levels and thus not exceed the allowable RoT.[8] With regard to the use of a fixed EIRP and front-to-back ratio, Qualcomm's interference calculations consider a maximum EIRP per beam and minimum front to back ratio. Specifically, Qualcomm used the maximum EIRP needed for an aircraft at the farthest distance from a serving GS at the edge of the cell site. In actual operation, the EIRP is reduced at distances closer to the GS and at other azimuthal and elevation angles to the GS. And, as noted, the EIRP will depend on the number of GS sites and will be reduced when GS cells are split.

1. Qualcomm Has Designed A Next-Gen AG System That Can Operate In The Presence Of GSO and NGSO FSS Operations

SIA claims that Qualcomm's technical analysis is based on several unsupported assumptions. The first set of issues raised by SIA relates to alleged interference from primary FSS operations into Next-Gen AG equipped aircraft.

Very Small Aperture Terminal ("VSAT") Roof-top Installations Do Not Materially Impact The Next-Gen AG Service. In showing how the Next-Gen AG system will withstand

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7 *See* SIA Comments at 5.

8 *See* Qualcomm March 29, 2012 filing, Att. at 1-6

interference from VSATs, Qualcomm divided the VSATs within a 300 km radius of Next-Gen AG equipped aircraft into one group located north of the aircraft and another group located to the south of the aircraft. SIA claims that Qualcomm provides inadequate support for its assumption that only 25% of the VSATs on the south side of the plane will have an unobstructed view of the aircraft.[9] SIA claims that many VSATs are mounted on roofs of buildings in urban, suburban and rural settings that would have unobstructed views of aircraft at flying altitude.[10]

Qualcomm agrees that there are different types of deployments of VSAT antennas and that some of these antennas may be on roof-tops. But, many roof-top installations are on short buildings, such as gas stations. Since the elevation angle between a roof-top VSAT antenna and the aircraft is only a few degrees, one would expect that at such low elevation angles, there would be some obstructions such as trees and other taller buildings between the VSAT antenna on short buildings and the aircraft. Therefore, the assumption that effectively 25% of the VSAT terminals on the south-side of the aircraft have no attenuation towards the aircraft is likely to be conservative. Qualcomm explained in Section 3.3.3 of the Appendix to the Petition that the $C/(I_{VSAT}+N)$ of the aircraft receiver is 9.4 dB assuming uniform distribution of VSAT terminals and that 25% of the VSAT terminals south of the aircraft are unblocked toward the aircraft. However, even if one assumes that 100% of the south-side VSAT antennas are unblocked towards the aircraft, then repeating the Section 3.3.3 computation for $C/(I_{VSAT}+N)$ of the aircraft signal results in 9 dB, a decrease of only 0.4 dB, which has practically no impact; in any case, the 25% assumption is actually not material. This is because the south-side VSAT terminals

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9 *See* SIA Comments at 6-7.

10 *See id*. at 7.

have their antenna backlobe towards the aircraft, resulting in negligible interference toward the aircraft even if there is no other blockage between the aircraft and the VSAT terminals.[11]

SIA claims that the interference analysis with regard to VSATs on the north side of the plane is unclear. SIA claims that subtracting an additional 15 dB of front-to-back ratio in light of Qualcomm's Monte Carlo simulation approach makes the interference calculations inaccurate.[12] The Monte Carlo simulation that Qualcomm used only averages the VSAT off-boresight antenna gain with respect to the line connecting the VSAT and aircraft. It does not include the -15 dB front-to-back ratio of the aircraft antenna gain pattern which is accounted for separately. Even without a Monte Carlo simulation, it is still possible to accurately estimate the roll-off of the VSAT antenna gain toward the aircraft. Because the boresight of VSAT antennas is pointed toward the satellite at high elevations angles of 40° in most of the CONUS, the angle between the boresight of the VSAT antenna toward the satellite and the line connecting the VSAT antenna to the aircraft is larger than 30° in most of the 300 km area around the aircraft. This is because the elevation angle of the aircraft to the VSAT terminal is much smaller than the elevation angle of the VSAT terminals to the satellite. The roll-off of antenna type B (which was used for VSATs in Table A.7 of Appendix A of the Petition) exceeds 32 dB for angles larger than 30°. Thus, even without a detailed simulation, the 32 dB value mentioned only accounts for the roll-off of the VSAT antenna gain toward the aircraft and does not include the 15 dB of front-to-back ratio of the antenna.

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[11] Qualcomm also has explained that Next-Gen AG system may leverage 3G/4G cellular air interfaces that allow for data rates to be adapted depending on C/I variations. Thus, even in low-probability cases where signal conditions cause C/I to drop significantly, the Next-Gen AG system will continue to operate at a lower data rate.

[12] *See* SIA Comments at 7.

Qualcomm's Calculations Are Based Upon The Number of Simultaneously Transmitting VSATs. SIA next claims that there are 60,000 VSATs operating within a 50 MHz segment and that Qualcomm's estimate of 5,500 is too low. SIA says that accounting for this would lead the C/I_{VSAT} ratio at the receiving satellite to be 6.9 dB, which reduces the C/(N+I) from 10.21 to 5.2 dB and is only 1.2 dB above the 4 dB minimum requirement.[13] According to SIA, if the VSAT deployment density is two times greater due to non-uniformity of VSAT distribution across the CONUS, the carrier-to-interference ("C/I") ratio falls below the required minimum. In Section 3.3.3 of Appendix A of the Petition, Qualcomm computed the number of *simultaneous* VSAT terminals whose aggregate power would saturate the satellite transponder. That is, the 5,500 VSAT terminals used in the calculation is the number of VSAT terminals that are *simultaneously* transmitting at a given point in time, whereas the 60,000 VSAT terminals mentioned in SIA comments is the total number of VSAT terminals that are operating but not necessarily transmitting at a given point in time. Assuming the VSAT terminals transmit data about 10% of the time,[14] the effective total number of VSAT terminals in operation (not necessarily those transmitting s*imultaneously*, from which the 5,500 number was derived) is close to the number suggested in SIA comments.

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[13] *See* SIA Comments at 7-8.

[14] VSAT terminals typically use slotted Aloha multiple access protocol. Slotted Aloha's maximum theoretical throughput is 36%, but in order to avoid large delays, the system is usually run at traffic loading of 70% or less, resulting in an effective maximum throughput of 25% per VSAT terminal. However, the actual offered traffic from a VSAT terminal on average is likely much lower than the 25% limit per terminal and 10% average VSAT utilization may even be on the high side. In any case, there is plenty of margin in the *C/(I+N)* received at the aircraft for the proposed Next-Gen AG system parameters, and variations in VSAT traffic loading only slightly reduces the available margin and has no impact on Next-Gen AG system performance.

SIA goes on to say that the situation only worsens when Qualcomm lowers transmit power levels to accommodate greater levels of Next-Gen AG system traffic.[15] However, as Qualcomm has explained in its prior filings, the Next-Gen AG system will service high-traffic areas by increasing the density of GSs and using lower power levels.[16] As Qualcomm reiterated above, as the number and density of GSs increase, the serving *radius* and necessary EIRP of each affected GS is reduced. Despite the reduced EIRP and smaller path loss from each affected GS to the aircraft, the aircraft receives the same signal power and approximately the same C/I as that of a system with a smaller number of GSs that use a greater EIRP.

SIA next lists several issues associated with interference from primary FSS operations into Next-Gen AG GSs.

The Next-Gen AG System Can Gracefully Handle Interference From FSS Operations. SIA claims that according to the air-to-ground link budget contained in Table A.2 of the Qualcomm Petition, FSS earth station transmissions with a C/I ratio of 5.8 dB would disrupt a Next-Gen AG link by causing the link's carrier-to-noise ratio to be at the minimum required level of 4.0 dB.[17] The likelihood that the GSs will receive any significant interference from FSS terminals is very small. Even where there is interference from FSS terminals and the received C/I at the GS falls below 4 dB, Next-Gen AG service will continue but at lower data rate. 4 dB is the C/I requirement for the highest supported data rate and not the threshold where the link

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[15] *See* SIA Comments at 8.

[16] *See* Qualcomm January 30, 2012, filing, Att. at 1; Qualcomm March 29, 2012, filing, Att. at 1-6.

[17] *See* SIA Comments at 9-10.

does not function. Qualcomm has explained that the Next-Gen AG system will use a rate adaptive air interface that automatically adjusts its rate according to the received C/I.[18]

SIA's Minimum Separation Distance Calculations Are Not Accurate. SIA next calculates the minimum separation distance between the Next-Gen AG system and a transmitting FSS earth station located within the main lobe (826.6 km) or the 3 dB bandwidth of the receiving antenna (585.2 km).[19] There are a number of assumptions in the SIA calculations that differ from the actual Next-Gen AG system parameters. Below, Qualcomm calculates of the distance between the FSS earth station and the Next-Gen AG GS where the link between the aircraft and the GS is still maintained.

The GS antenna will be on a tower or a tall building, at least 30 meters above ground and VSAT terminals are most likely on shorter structures. Therefore, the elevation angle of the GS antenna with respect to VMSE/ESV or VSAT terminals will most likely be a few degrees below the horizon. Standard techniques can be used to suppress the sidelobe for the GS antenna below the horizon by 20 dB or more. In addition, there will be some polarization mismatch between the GS antenna and the FSS antenna. Based on the above parameters, Table 1 shows the distance from the FSS site to the GS where the GS receives a C/(I+N) of at least -9 dB. As mentioned, the Next-Gen AG system will use an appropriately modified 4G (or similar) air interface that employs rate adaptation to mitigate C/(I+N) changes due to fading or interference from other GS sites. The C/(I+N) requirement of 4 dB used in the link budgets in the Petition correspond to the highest rate that the Next-Gen AG system is designed to provide. The air

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18 *See* Qualcomm October 2011 Reply Comments at A-3. Rate adaptability is an integral part of 3G and 4G cellular systems.

19 *See* SIA Comments at 9.

interface, however, has lower data rates and may operate at C/(I+N) of -9 dB but at lower data rate.

	Path loss exponent of 2.5	Units
Distance of FSS interferer to GS	0.55	km
FSS off axis transmit power	3.0	dBW
GS antenna attenuation at angles below horizon	-20	dB
Path loss from FSS to GS	-137.7	dB
Atmospheric loss	0.0	dB, .01 dB/km
Polarization mismatch between FSS and GS antennas	-1.5	dB
G/T of GS receiver	8.0	dB/°K
Distance of FSS interferer to GS	-63.0	dB Hz
FSS off axis transmit power	228.6	dBW/°K-Hz
I/N of FSS interferer at the GS	17.4	dB
C/N of aircraft signal at the GS	8.7	dB
C/I, aircraft signal to FSS interferer at the GS receiver	-8.7	dB
Net C/(I+N) at the GS	-8.8	dB

Table 1. Distance between FSS and GS to avoid interference when FSS, aircraft and GS are aligned

Thus, the Next-Gen AG system can tolerate the occasional interference posed by a nearby FSS station; in the worst case, the data rate will be temporarily reduced. The results in Table 1 demonstrate that the FSS must, in realistic propagation environments, get very close to the GS site before the aircraft to GS link may get degraded. The distance may be much less than 1 km. Note that the impact is only to the small piece of the spectrum on which the FSS terminal is

transmitting. Moreover, there are a number of other mitigation techniques such as assigning the aircraft to a different piece of spectrum or handing off the aircraft to another GS site. In addition, Qualcomm expects that GS site installations typically will be in remote locations to reduce the likelihood of nearby FSS deployments. Moreover, in many cases there will be obstructions between the GS antenna and the FSS location, such as when the GS antenna is on top of a building and the interfering FSS source happens to be on a shorter building. The system operator will conduct surveys at every GS site location to assess the local environment. If, in the end, an FSS earth station is deployed nearby and the noted interference reduction techniques do not work, the Next-Gen AG provider will need to relocate the site.

NGSO Operations Will Be Protected. Next, SIA claims that the assumptions Qualcomm used to determine the compatibility of the Next-Gen AG service with NGSO satellite operations could be drastically different from a potential future deployment and lead to different conclusions that those presented by Qualcomm. The NGSO satellite system analyzed by Qualcomm is based on the NGSO systems that have been designed and deployed in the past and as such is the most reasonable construct. Notwithstanding, Qualcomm fully understands that the proposed Next-Gen AG system would need to protect any and all future primary NGSO operations in the 14.0-14.5 GHz band.

Finally, SIA claims NGSO FSS Earth Stations with tracking antennas could significantly disrupt Next-Gen AG-equipped airplanes and GSs. Qualcomm disagrees. The interference statistics of NGSO earth stations are the same whether the earth station antennas are fixed or tracking. In other words, Qualcomm's interference analysis applies equally to tracking earth station antennas.

2. Qualcomm Has Provided Sufficient Antenna Data With Which To Assess Next-Gen AG Service Compatibility With Incumbent Operations

Three concerns were raised regarding the antenna data provided by Qualcomm. *First*, SIA claims that Qualcomm has not provided the transmit or receive antenna pattern of its phased array GS antenna or its blade-type aircraft antenna.[20] However, in its filings, Qualcomm has provided both detailed analysis and data on the antenna mask. Qualcomm described the aircraft elevation gain and aircraft azimuth gain profiles in Section 1.1 of Appendix A to the Petition and provided graphical depictions in its September 2, 2011, filing with the FCC. Qualcomm also explained on page A-5 of the Petition that the peak antenna gain for the GS antenna looking directly north is 37 dBi, and the GS antenna gain toward the Geostationary arc, *i.e.*, for angles greater than ± 95° from true north, is 0 dBi.[21]

A Qualcomm-specific antenna pattern for the GS and the aircraft antennas is not needed to perform interference calculations. In fact, providing antenna masks for the purpose of interference calculations and FCC rule making is in keeping with the Commission's practice. In line with its previous request that the FCC implement performance-based regulations to permit any equipment designs that provide the necessary level of protection to incumbent primary operations, there is no need to ask the Commission to adopt or even consider a specific or proprietary antenna design.

Notwithstanding the foregoing, Qualcomm performed an antenna pattern analysis and had an independent antenna test lab specializing in millimeter-wave antenna measurements for the defense industry conduct pattern measurements of Qualcomm's initial prototype antenna,

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[20] *See* SIA Comments at 11; *see id*. at 6-7. Row 44 goes one step further, asking for three-dimensional antenna measurement data and a complete set of azimuth and elevation antenna patterns. *See* Row 44 Comments (filed July 16, 2012) at 7 fn.8 & at 8.

[21] *See* Qualcomm September 2, 2011, filing.

which uses a phased array structure. The test lab found Qualcomm's specified 37dB minimum front-to-back ratio to be extremely conservative. Elevation and azimuth beam cuts of the antenna are shown in Figures 1 and 2 below. Both antenna beam cuts were taken through the peak of the beam pointing north. These pattern cuts come from the 3D pattern measurement data. Figures 1 and 2, which were taken through the peak of the beam, show that, at this beam pointing angle, there is at least 20 dB of margin over Qualcomm's specified level of -37 dB. The margin will be less over other beam pointing angles. Over all azimuthal beam pointing angles of ± 60° from true north, there will be at least 10 dB of margin for the peak of the front to back ratio compared to the value of -37 dB. Note that the results of Figures 1 and 2 are for the first prototype antenna and the design will be improved further. For example, greater sidelobe suppression will be added to further attenuate the sidelobes.

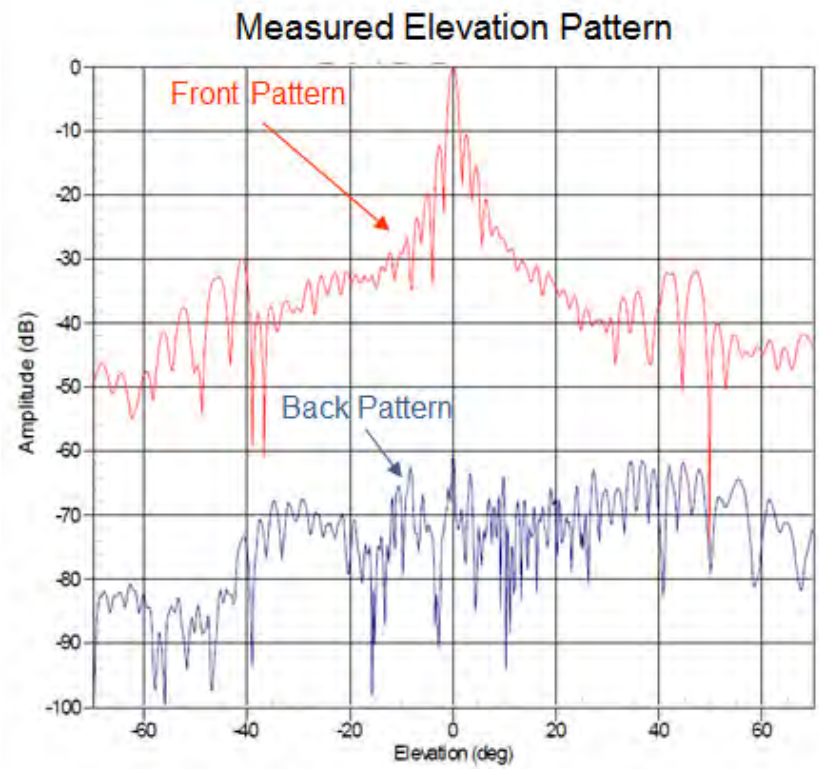

Figure 1. Elevation GS beam cut, beam pointing to north, cut at beam peak direction

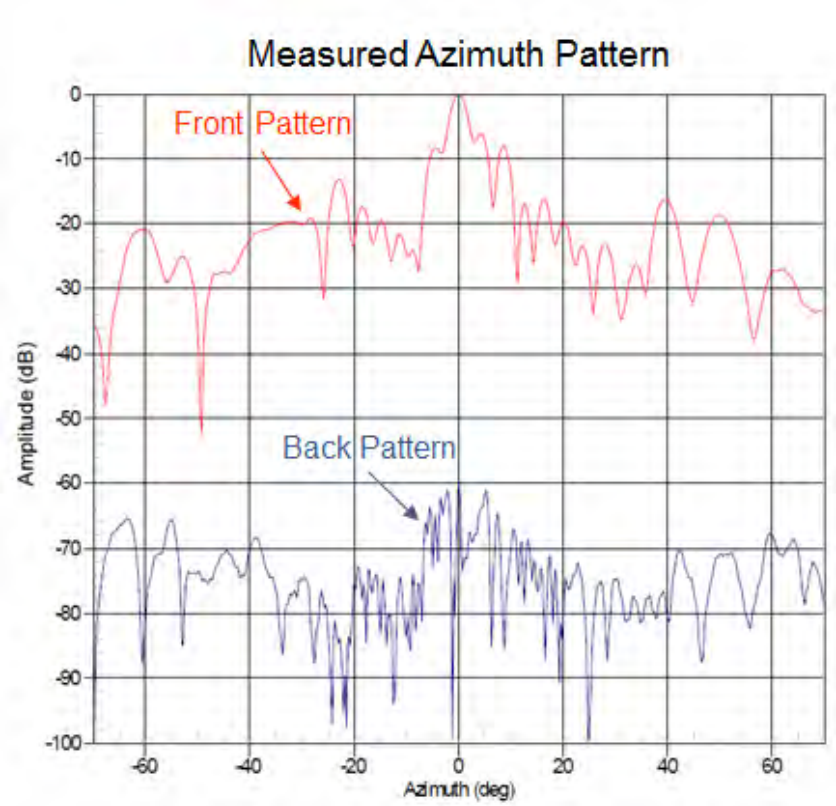

Figure 2. Azimuth GS beam cut, beam pointing to north, cut at beam peak direction

These measurements demonstrate that it is possible to design an antenna that performs in accordance with the calculations made in Appendix A of the Petition. In fact, the measurements show antenna performance with substantial additional margin beyond the numbers used in Qualcomm's calculations.

Second, SIA claims that Qualcomm has provided inconsistent data regarding the aircraft antenna.[22] In fact, there is no inconsistency in the aircraft antenna data provided. The beamwidth of the aircraft antenna without accounting for the aircraft fuselage was simulated to be 12°, as stated in Section 1.1 of Appendix A of the Petition. When the antenna was simulated on a ground plane to model the fuselage and tilted 5° below the horizon, it showed a roll-off of

[22] *See* SIA Comments at 12 (claiming that for the Qualcomm used 3 dB beamwidth in elevation of both 10° and 12° for the aircraft antenna).

approximately 3 dB due to the fuselage effect, *i.e.*, a slightly higher roll-off due to the fuselage. The interference calculation used the roll off with the fuselage effect, *i.e.*, 3 dB roll-off at horizon. But this specific value does not factor materially into the elevation angles towards the geo-arc, which typically are many degrees above horizon.

Third, SIA claims that Qualcomm has made assumptions regarding the orientation of the aircraft antenna that make it difficult to ascertain whether the antenna roll-off gain assumptions used in the calculations apply.[23] According to SIA, in Section 3.3.1.2 of Appendix A of the Petition, Qualcomm states that the aircraft antenna roll-off in elevation is at least 20 dB for angles $\geq 15°$ above the horizon, while in Section 1.1 in that Appendix, Qualcomm states that the roll-off gain in elevation is 20 dB at angles of $\geq 20°$ above horizon. The aircraft antenna mask described in Section 1.1, *i.e.*, antenna roll-offs of, 10, 15 and 20 dB at angles of 5°, 10°, and $> 20°$ above horizon, is what was used in the interference computations. This antenna specification also was provided in Qualcomm's September 1, 2011 filing. The elevation angle of $\geq 15°$ in Section 3.3.1.2. of the Appendix, however, is a typographical error and should instead read $\geq 20°$. However, this typo has no effect on the rest of the computations in that paragraph. Since the elevation angles in nearly all of the bins for Table A.9 are above 25°, after correcting for the worst case aircraft roll of 5° during normal flight operations, all bins have elevation angles greater that 20° whose corresponding antenna roll-off is greater than the 20 dB level that was used in the interference calculation.

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[23] *See id.*

3. Any Remaining Interference Concerns Can Be Readily Addressed

SIA states that Qualcomm does not explain how it would locate a temporary interfering earth station in order to position the null of its beam in the direction of an interfering station.[24] As Qualcomm has explained in prior filings, this level of detail is implementation specific and would depend on the system design. By way of example, since the elevation angle of the GS toward the aircraft is at least 1° above horizon even at the cell edge, then the peak gain of the GS antenna will be placed at least 1° above horizon. As discussed in relation to Table 1 above, a fixed attenuation of 20 dB or more may be included in the antenna design in angles below the horizon where interfering signal sources may reside. In other words, some attenuation to mitigate interference from FSS earth stations may be built into the antenna design because the location of the interfering source is below the horizon with respect to the GS.

Next-Gen AG System Assignment To Clear Spectrum. According to SIA, Qualcomm does not explain how it would dynamically account for variations in frequency usage by mobile and temporary fixed VSAT operations in switching to a different frequency to avoid interference from the primary users.[25] Qualcomm previously addressed this issue.[26] Specifically, if the interference measured at the GS in a specific frequency channel is higher than the established threshold, the system may choose to assign a different frequency channel to the beam communicating with the aircraft.

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[24] *See* SIA Comments at 13.

[25] *See* SIA Comments at 14.

[26] *See* Next-Gen AG Petition at A-35 ("The aircraft sends the SINR estimates of the FL connections to the GS, and the GS will reassign the aircraft to a different piece of spectrum on the FL if the SINR falls below a certain threshold, e.g., 0 dB."); *see also id.* at A-36; Qualcomm October 2011 Reply Comments at A-3, A-4.

SIA also claims that Qualcomm does not explain how many of its GSs can be shut down on a temporary basis to avoid interference and still provide a viable service.[27] As explained in Qualcomm's January 30, 2012, filing, the probability that a Next-Gen AG GS, aircraft, and VMES/EVS station align in such a way that would cause excessive interference to the Next-Gen AG GS is very small and will be short-lived should it occur. Nonetheless, as noted above, should interference occur, only a small part of the spectrum would be impacted and the GS-to-aircraft link can be assigned to an alternative non-interfering portion of the spectrum. A total GS shutdown is highly unlikely under normal operating conditions, as only a small portion of the spectrum in a certain direction will be affected, leading only to a partial capacity loss at worst.

Next-Gen AG GSs Can Be Relocated. SIA goes on to question the practicality of Qualcomm's proposal to relocate GSs if a permanent FSS earth station is installed nearby.[28] The GS antenna that has been prototyped is about 6 feet tall and 1.5 feet wide, while an alternative antenna configuration would have an area of 3 feet by 3 feet. Thus, either antenna can be readily installed in many locations, including on roof-tops and towers.

Next-Gen AG Geographical Deployment. Row 44 claims that Qualcomm has not presented any geographic coverage data demonstrating the viability of its network solution to avoid interference to incumbent users of the 14.0 to 14.5 GHz band are false.[29] In its January 30 and March 29 filings, Qualcomm showed how it would use cell splitting technology to provide increased capacity in certain high traffic regions of the U.S. while not adding any cognizable amount of noise within the band.[30] Qualcomm also demonstrated that the total interference form

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27 *See* SIA Comments at 14.

28 *See id*. at 14-15.

29 *See* Row 44 Comments at 3-4.

30 *See* Qualcomm January 30, 2012 and March 29, 2012 filings.

the Next-Gen AG system is well below the 1% RoT threshold provisioned for the secondary systems by ITU.

The Rise-over-Thermal ("RoT") Level. Row 44 claims that even small decreases in uplink C/N ratio due to the presence of noise from the Next-Gen AG System will significantly affect Row 44's established coverage and communications performance.[31] The total interference caused from the Next-Gen AG system falls well below the 1% RoT threshold allocation for secondary systems. All existing systems can easily coexist within this limit. In fact, Section 3 of Qualcomm's March 29, 2012, filing showed that the interference computation in the Next-Gen AG Petition was conservative by 8 to 11 dB, depending on the size of the satellite beam. And, as previously noted, Qualcomm's GS antenna pattern measurements demonstrated that the interference computation is actually much more conservative than the 8 to 11 dB previously estimated based on simulations of the antenna pattern.

Gaussian Noise Model. Next, Row 44 claims that Qualcomm has not adequately proven its assumptions that the transmitted signal envelope will be of Gaussian nature, and Row 44 states that a peak-to-average ratio of 3 dB should be used.[32] Qualcomm's March 29, 2012, filing explained in lengthy technical detail that the peak-to-average of the Next-Gen AG OFDM signal need not be considered because the OFDM signals appear as Gaussian noise.[33] Qualcomm provided extensive simulation results of the GS OFDM signals showing that signal statistics are

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[31] *See* Row 44 Comments at 4 (decreases in C/N could be caused by inaccurate off-boresight antenna gain roll-off, uncharacterized peak power from Orthogonal Frequency-Division Multiplexing ("OFDM") transmit signals, aircraft banking as well as aircraft mispointing and misalignment").

[32] *See* Row 44 Comments at 9-11.

[33] *See* Qualcomm March 29, 2012, filing at 7-16. *See also* Qualcomm April 6, 2012, filing (providing an IEEE reference to support claim that an OFDM signal can be approximated as a Gaussian random process).

accurately modeled by a Gaussian distribution.[34] Qualcomm subsequently provided a reference paper in the IEEE Transactions on Information Theory, one of the most prestigious refereed journals in the communications field, showing that the statistics of the OFDM signal is, in fact, Gaussian.[35] Thus, Qualcomm has provided a more than ample basis for the FCC to issue a NPRM based on the fact that the total interference is well approximated as a Gaussian random process and that the effect of the interference on a given satellite channel is to raise the thermal noise floor by the average interference power.

Thermal Noise Temperature. While it is true that the thermal noise temperature ("G/T") of CONUS beams in some portions of the beam may be larger than 2 dB/K,[36] it is essentially the average G/T over the satellite beam that determines the received interference at the satellite uplink as was discussed in Appendix A of the Petition and will be expanded upon below. Therefore, it is acceptable to use the average G/T of the beam in the interference computations. Qualcomm's examination of certain CONUS beams showed that an average of 2 dB/K for G/T is a reasonable number.

In place of using an average G/T of the satellite beam in interference computations, one could instead use a trapezoidal approximation of the G/T and numerically integrate the interference over a beam by multiplying the G/T of the beam over each region where G/T is fixed by the EIRP in that region and then perform a summation over all regions as was presented in equation (5) of Section 3.3.1.2 of Appendix A to the Petition. But in doing so, as was discussed in Section 3.3.1.2 following equation (5) leading to equation (6), it suffices to instead use the average G/T of the beam multiplied by the EIRP over the coverage area of the beam.

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34 *See* Qualcomm March 29, 2012, filing.

35 *See* Qualcomm April 6, 2012, filing.

36 *See* Row 44 Comments at 5.

This is because there is little difference between a numerical integration (of the trapezoidal approximation of G/T) and using the average G/T. Therefore, use of average G/T of 2 dB/K is reasonably accurate for the interference calculations, as Qualcomm explained in Section 3.3.2.1 of Appendix A of the Petition.

Front to Backlobe of the GS Antenna. Row 44 states that the front to backlobe of the GS antenna may be 7 dB worse than the 37 dB assumed by Qualcomm. This claim is not correct. As the measurements made on the GS antenna prototype presented above demonstrate, the front to backlobe of the GS antenna is at least 10 dB better than the assumed 37 dB.

* * *

Accordingly, Qualcomm has demonstrated through its detailed interference calculations, through prototyping of the GS antenna and independent lab measurement of the antenna pattern, and through reference to well-respected technical publications, that the assumptions used in the interference computations in the Petition are either reasonably accurate or grossly conservative as in the case of the front-to-back ratio of the GS antenna.

4. Qualcomm Has Proposed A Technically Sound Means Of Identifying Interference From Next-Gen AG Systems

SIA and Row 44 claim that Qualcomm's proposed approach to identifying the Next-Gen AG service as the source of interference to GSO FSS operations is not practical.[37] Qualcomm disagrees with these claims. For the Commission's benefit, Qualcomm expands upon its previously proposed procedure for determining whether the Next-Gen AG service is causing interference to GSO FSS operations in the Appendix to these Reply Comments.

Row 44 claims that atmospheric conditions, such as rain, snow, and ice crystals, can cause omnidirectional reradiation of significant amounts of energy from the Next-Gen AG

[37] *See* SIA Comments at 17-18; Row 44 Comments at 11-12.

service and interfere with AMSS services.[38] This claim is also misplaced. In the Appendix to these Reply Comments, Qualcomm explains that the amount of such reradiation is negligible.

5. SIA's Proposed Regulatory Framework Would Be Acceptable to Qualcomm

Qualcomm has reviewed the regulatory proposals in SIA's Comments and suggests that the Commission seek comment on them in the NPRM.[39] Qualcomm agrees with SIA that the Next-Gen AG regulatory framework should include rules governing maximum EIRP density limits in the direction of the GSO arc applicable to each GS and to each aircraft transceiver. Qualcomm believes, however, that it is preferable to specify power flux density mask in off-axis rather than specifying a gain mask. This would make the system design choice less technology dependent. Also, instead of specifying a cross-polarization isolation, FCC rules should specify the allowable RoT in the geo-arc in each polarization.

6. TDRSS and Radio Astronomy Sites Will Be Protected

Next-Gen AG GS sites near TDRSS sites will be chosen in coordination with NTIA. In case a Next-Gen AG GS is within 125 km of a newly built TDRSS site, the Next-Gen AG operator may identify sites 125 km away from the new TDRSS site and move the impacted site to these sites in order to avoid any impact to the service. In any case, the 14.0-14.5 GHz spectrum may be divided between two Next-Gen AG operators so that each operator will have at least 100 MHz in the 14.2-14.5 GHz band so that even during build out of new TDRSS sites,

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[38] *See* Row 44 Comments at 5, 9.

[39] *See* SIA Comments at 19-20. The antenna pointing rules requested on page 6 of Row 44's comments for airborne transmitters, such as provisions for sufficient pointing accuracy to "prevent satellite interference" and for transmission shut down "within 100 milliseconds of exceeding 0.5 degrees of pointing error" apply to AMSS terminals communicating with GSO satellites and not Next-Gen AG aircraft transceivers. These rules are needed for AMSS to protect adjacent satellites from harm because AMSS terminal antennas point at a specific satellite placed 2° apart in the geo-arc and operate with very high EIRP. Next-Gen AG aircraft transmitters, in contrast, will point toward the ground and away from the geo-arc.

each operator always has access to some spectrum outside of 14.0-14.2 in all sites even within 125 km of new TDRSS sites.

With regard to the comments from the National Academy of Sciences' Committee on Radio Frequencies and the National Radio Astronomy Observatory,[40] Qualcomm agrees that coordination of Next-Gen AG services with radio astronomy operations at 14.47 to 14.5 GHz is more challenging than sharing with AMSS operations. Nonetheless, such coordination is possible and Qualcomm expects that future Next-Gen AG licensees can coordinate their operations so that radio astronomy sites are appropriately protected. This includes avoiding use of this spectrum band within an agreed upon distance from radio astronomy receive sites.

II. The Commission Has A More Than Ample Record On Which To Move Forward

Given Qualcomm's detailed technical presentation, the overall structure of which remains unchallenged, and Qualcomm's detailed responses to the questions posed by the Commission, the FCC should issue a Notice of Proposed Rulemaking proposing to establish the Next-Gen AG service. Despite SIA's repeat request to delay action on this matter and first complete the AMSS proceeding, there is absolutely no reason for the FCC to tie the Next-Gen AG rulemaking to other matters before the agency.[41]

Indeed, the proposed Next-Gen AG service is needed now. Americans are continuing to purchase and use mobile broadband devices, applications and services at exponentially-increasing rates. An increasing number of American air travelers are demanding 24/7 broadband

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[40] *See* Comments of National Radio Astronomy Observatory, filed May 29, 2012; Comments of National Academy of Sciences' Committee on Radio Frequencies, filed July 13, 2012.

[41] Qualcomm has already addressed AMSS parties' demands that the FCC complete the AMSS docket before it moves forward in this proceeding, explaining that the two services involve completely different technologies (*i.e.*, satellite vs. terrestrial) and are not mutually exclusive. *See* Qualcomm October 14, 2011, Reply Comments at 19-21.

connectivity for they have fully integrated into their everyday lives smartphones, tablets, and laptops, and their highly useful applications, such as e-mail, social networking, music, entertainment, news/weather, banking, healthcare/fitness, and home management tools.[42] These trends are continuing unabated.

At the same time, the amount of business travel spending and the number of commercial air travelers are increasing. The National Business Travelers Association estimates that global travel spending by businesses will rise to US $ 1.2 trillion by 2014, from US $896 billion in 2010.[43] The FAA projects that, in 2022, U.S. commercial air carriers will transport more than 1 billion passengers, up from approximately 780 million passengers this year.[44] The deployment of Next-Gen AG broadband services is the next step towards supporting these travelers' growing communications needs and enabling business growth and productivity.

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[42] *See* Next-Gen AG Petition at 3-13.

[43] *See* Odyssey eMagazine, Covering the Business of Business Travel at 3 *available at* http://www.odysseymediagroup.com/i/eodyssey/ody081610.pdf.

[44] *See* Federal Aviation Administration ("FAA") Aerospace Forecast Fiscal Years 2011–2031 at 34 *available at* http://www.faa.gov/about/office_org/headquarters_offices/apl/aviation_forecasts/aerospace_forecasts/2011-2031/media/FAA%20Aerospace%20Forecasts%20FY%202011-2031.pdf.

CONCLUSION

Qualcomm respectfully requests that the FCC promptly issue an NPRM proposing to establish the Next-Generation Air-Ground communications service at 14.0 to 14.5 GHz. The company has responded in detail to all of the questions raised regarding the proposed service, explaining that it can operate in successful coexistence with existing operations in the band. Qualcomm looks forward to working with the FCC and all interested stakeholders during the next stage of this proceeding.

Respectfully submitted,

QUALCOMM INCORPORATED

By: _____

Dean R. Brenner
Vice President, Government Affairs

John W. Kuzin
Senior Director, Regulatory

1730 Pennsylvania Avenue, NW
Suite 850
Washington, DC 20006
(202) 263-0020

Attorneys for QUALCOMM Incorporated

Dated: July 31, 2012

CERTIFICATE OF SERVICE

I, John W. Kuzin, certify that on July 31, 2012, a copy of the foregoing REPLY COMMENTS OF QUALCOMM INCORPORATED was sent to the following parties as indicated below:

Howard Griboff
Deputy Chief, Policy Division
International Bureau
445 12th Street, S.W., Room 7-A662,
Washington, D.C. 20554
Via email: howard.griboff@fcc.gov

Paul Locke
Assistant Chief, Engineering
Policy Division, International Bureau
445 12th Street, S.W., Room 7-A666,
Washington, D.C. 20554
Via email: paul.locke@fcc.gov

Kathleen Collins
Attorney-Advisor, Policy Division,
International Bureau
445 12th Street, S.W., Room 7-A515,
Washington, D.C. 20554
Via e-mail: kathleen.collins@fcc.gov

Best Copy and Printing, Inc.
445 12th Street, S.W., Room CY-B402
Washington, D.C. 20554
www.bcpiweb.com
Via First Class mail

David S. Keir
Lerman Senter PLLC
2000 K Street, N.W., Suite 600
Washington, D.C. 20006-1809
Counsel to Row 44, Inc.
Via First Class mail

Patricia A. Cooper
President
Satellite Industry Association
1200 18th Street, N.W., Suite 1001
Washington, D.C. 20036
Via First Class mail

/s/ John W. Kuzin
John W. Kuzin

Appendix

Test Procedure For Tracing Interference From The Next-Gen AG Service

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Determining The Effect Of Rain, Snow And Ice Crystals On AMSS Operations

I. Test Procedure For Tracing Interference From The Next-Gen AG Service

The following procedure can be used to identify and measure the interference caused by Next-Gen AG GS transmissions to GSO FSS stations. As described in Qualcomm's January 31, 2012, filing, each Next-Gen AG GS will be capable of transmitting a unique, periodic, pseudo-noise (PN) sequence that can be used to identify it as the source of interference to a GSO satellite system. Verifying that the interference power from each individual GS is negligible allows one to ensure that the aggregate level of interference from all GSs is also negligible. The link budget in Table A1 below (derived from Table A.8 in the original Petition for Rulemaking) determines the coherent signal integration time required to detect the signal received at the satellite uplink.

	Nom. Signal at Sat	**Weak Signal at Sat**	**Units**
Single GS Peak EIRP per beam	39.50	39.50	dBW
Number of GS simultaneous beams	6.02	6.02	dB
GS Antenna Front to Back Ratio	-37.00	-45.00	dB
Atmospheric Loss at KU band	0.00	-3.00	dB
GEO Satellite G/T over CONUS	2.00	0.00	dB/K
Test Signal BW	1000.00	1000.00	kHz
1/BW	-60.00	-60.00	-dB-Hz
1/Boltzmann	228.60	228.60	-dB/K-Hz
Path Loss to Geo Arc (at 14 GHz)	-207.00	-207.00	dB
Polarization Discrimination (GEO Satellite/GS Linear)	0.00	0.00	dB
I/N at Satellite Rx	-27.88	-40.88	dB
I/N at Satellite Rx (Desired, Post Coherent Integration)	2.00	2.00	dB
Required Coherent Processing Gain [dB]	29.88	42.88	dB
Required Coherent Processing Gain [chips]	973	19406	chips
Required Coherent Integration Time [msec]	0.97	19.41	msec

Table A1: Link Budget for Interference from Next-Gen AG GSs to GSO uplinks

Each GS will be pre-assigned a distinct PN sequence (*i.e.*, "test signal") with a chip-rate of 1 MHz and bandwidth of 2 MHz and a time slot during which the "test signal" is transmitted. Each GS will be capable of transmitting this test signal at any frequency between 14.0-14.5 GHz.

This flexibility ensures that the test signal can be transmitted anywhere in any GSO satellite's transponder bandwidth. The same 2 MHz frequency band may be assigned to multiple GSs to act as a "test signal" by assigning different time slots to different GSs. When transmitting this test signal, the GS will use an EIRP that is equivalent to transmitting four simultaneous beams on its forward link (for a total EIRP of 45.5 dBW). Assuming the GS array antenna's average front-to-back ratio is -37 dB, and the GSO satellite's average G/T is 2 dB, the link budget shows that the test signal will be received at a level of -27.9 dB below thermal noise in its designated 2 MHz band. To ensure the ability to detect the test signal in a more challenging case, assume further that:

1. The GS array antenna's backlobe gain in the direction of the GSO satellite is 8 dB worse than the average front-to-back ratio of -37 dB, i.e., -45 dB;
2. The GSO satellite G/T looking towards the GS is 2 dB worse than is typical, *i.e.*, only 0 dB; and
3. Additional atmospheric losses of -3 dB at Ku-band towards the satellite.

Under these "weaker signal" assumptions, the test signal will be received at a level of -40.9 dB below the thermal noise in its designated 2 MHz band.

Measurement Procedure

The test signal can be detected and processed using, for example, an Agilent PXA Vector Signal Analyzer (*e.g.*, Agilent N9030A VSA) running MATLAB software for data analysis. For best accuracy, the test can be performed one GS at a time and when the transponder is not being used to avoid swamping the weak test signal. The Agilent VSA is connected directly to an analog intermediate-frequency (IF) test port of the GSO satellite gateway, and tuned to the designated center frequency of the GS test signal. The VSA is then used to capture and digitize the transponder IF signal output over the 2 MHz bandwidth of the test signal for a duration of several seconds. The digitized I/Q signal captures can be processed using MATLAB software running on the VSA, or on a computer connected to the VSA, in semi real-time fashion. The MATLAB application searches for the test signal in the captured samples, and measures its level relative to the thermal noise. The latter step is explained next.

Data Processing

Since the test signal PN sequence is received at levels well below the thermal noise, it cannot be detected by conventional spectrum analysis. The main approach to detecting it is to cross-correlate the digitized complex samples from the VSA with time-delayed and frequency-shifted replicas of the PN sequence. This procedure is well known as "coarse acquisition" or "synchronization" in direct sequence spread-spectrum communications.[45] It relies on the fact that since a PN sequence is "noise like," the received test signal has low cross-correlation with time- and frequency-shifts of the PN sequence, except when both shifts closely match those of the received test signal. This principle is widely exploited in CDMA spread spectrum communications where the cross-correlation operation is performed in a module known as a PN signal "searcher."[46] Specifically, the digitized complex samples are cross-correlated with a suitably time- and frequency-shifted replica PN sequence, and coherently summed over a duration known as the "coherent integration time." Multiple successive cross-correlation outputs are squared and summed in a process known as "non-coherent integration" to yield an energy output statistic. With a properly chosen "coherent integration time," the energy output statistic will display a large "peak" when the PN replica's time- and frequency-shifts closely match those of the test signal. The MATLAB software application performs this PN search procedure on the captured I/Q samples to detect the test signal, and it further refines the detection and demodulates the test signal. The complete process allows accurate estimation of the test signal's power level with respect to the background noise.

Required Coherent Integration Times

In order to detect the test signal, the coherent integration time needs to be sufficiently large to provide enough "coherent processing gain". A rule of thumb is that the test signal I/N after coherent integration should be at least 2 dB for subsequent non-coherent integration to be effective in detecting the test signal. The required coherent processing gains and integration

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[45] *See* Scholtz, R. A. "The Spread Spectrum Concept," *IEEE Transactions on Communications,* vol. COM-25, pp. 748-755, August 1977; or Pickholtz, R. L., Schilling, D. L., and Milstein, L. B. "Theory of Spread Spectrum Communications – A Tutorial," *IEEE Transactions on Communications,* vol. COM-30, pp. 855-884, May 1982.

[46] *See* "Chapter 3: Synchronization of Pseudorandom Sequences" in Viterbi, A. J. CDMA: Principles of Spread Spectrum Communication. Addison-Wesley, New York, 1995.

times are shown in Table A1 for the nominal and weaker signal cases. A coherent integration time of 20 ms allows for a test procedure that is sensitive enough to detect individual GS test signals under "weaker signal" assumptions, *i.e.*, when the test signal from a single GS is at a level of -41 dB below thermal noise in the transponder.

Effect of Adjacent Satellite Interference on Test Signal Detectability

SIA claims that adjacent satellite interference would dilute the accuracy of the test signal measurement.[47] The relative strength of this interference with respect to thermal noise in the transponder may be assessed by looking at the allowed EIRP limits off-axis from earth stations to GSO satellites. FCC Rules Section 25.218(e) & (f) specifies off-axis EIRP envelopes for conventional Ku-band analog and digital earth station operations, respectively. Specifically, the allowed EIRP density in [dBW/4kHz] for analog earth stations (Section 25.218(e)) is no more than:

1. $[21 - 25*\log_{10}(\Theta)]$ dBW/4kHz for $1.5° \leq \Theta \leq 7°$;
2. 0 dBW/4kHz for $7° < \Theta \leq 9.2°$;
3. $[24 - 25*\log_{10}(\Theta)]$ dBW/4kHz for $9.2° < \Theta \leq 48°$;
4. -18 dBW/4kHz for $48° < \Theta \leq 85°$;
5. -8 dBW/4kHz for $85° < \Theta \leq 180$.

The allowed off-axis EIRP density for digital earth stations (Section 25.218(f)) is 6 dB more restrictive. Assuming GSO satellites with a separation of 2°, a conservative upper bound can be obtained by integrating the allowed EIRP density for analog earth stations across all off-axis angles, and assuming an equivalent transmission with this EIRP density to the target GSO satellite's transponder. Performing this integration yields an equivalent EIRP density of about -18 dBW/Hz. Accounting for the GSO G/T of 2 dB/K and -207 dB of path-loss at Ku-band, the resulting adjacent satellite interference-to-thermal noise ratio I/N turns out to be at most 5.6 dB. Thus, adjacent satellite interference, at worst, raises the noise floor by 6.6 dB. On the other hand, if all the interference produced by transmissions to adjacent satellites originated from

[47] *See* SIA Comments at 17-18.

digital earth stations, the noise floor would only be raised by, at most, 3 dB. As a practical matter, the likely interference will be caused by a mix of analog and digital earth stations, and the noise floor will be raised by between 3 to 6.6 dB. This eventuality can be handled by increasing the coherent integration time in the PN search processor by a factor of 4-5, in case the GSO transponder happens to suffer a large degree of adjacent satellite interference. This upper bound is very conservative because not all GSO satellite orbital slots are occupied and not all adjacent satellite transmissions occur in the 2 MHz band occupied by the test signal. Nonetheless, with small adjustments to the test procedure's parameters, even worst-case adjacent satellite interference can be handled comfortably without degrading the accuracy of the measurements.

The above interference measurement mechanism is designed to detect a signal at least 8 dB weaker than the GS nominal backlobe signal used in interference computations in the Petition. Thus, if a GS signal is not detected at the transponder it means that it is more than 8 dB weaker than the nominal GS backlobe signal. If all GS signals are 8 dB lower than the nominal GS signals used in interference computations, then the total interference seen at the satellite will be 8 dB lower than what was computed in the Petition. Therefore, one procedure to show that the Next-Gen AG system interference level is below the designed value is to monitor signals received at a transponder from all GSs and identify the signal levels of the GSs that are detected. Any GS signal that is not detected must be received at a level at least 8 dB below the nominal GS backlobe signal at the transponder. And since the number of GSs is known, the total interference from all GSs can be upper-bounded by summing two terms: (1) the sum of the powers of all detected GS signals; and (2) the product of the number of GSs whose signal is not detected times the signal power that is 8 dB below the nominal GS backlobe signal power at the transponder. Since GS signals that are not detected must be more than 8 dB below the nominal GS backlobe signal at the transponder, it follows that the above computation will in fact upper bound the interference seen at the transponder.

The same procedure also may be used to verify that the interference from all aircraft must be below a threshold. Under normal flight conditions, the aircraft signal received at the GSO satellite transponder will be as much as 20 dB below that received from a single GS beam. Even if an aircraft rolls at more than 20° so that the peak aircraft antenna gain is toward the geo-arc,

the interference received from this aircraft at the GSO satellite will still be lower than that received from a single GS beam backlobe. In other words, even in the highly-unlikely worst-case condition, an aircraft still will be unable to cause any measureable interference to the satellite uplink.

II. Determining The Effect Of Rain, Snow, And Ice Crystals On AMSS Operations

Row 44 claims that atmospheric conditions, such as rain, snow and ice crystals, cause omnidirectional reradiation of significant amounts of energy and interfere with AMSS services.[48] Row 44's claims are misplaced. Below, Qualcomm shows that the amount of such reradiation is negligible.

The power reflected from a reflector, such as an area covered by rain, at distance *d* from the Ground Station (GS) is given by:

$$P_r = \frac{P_t G_t \sigma}{4\pi d^2}$$

where $P_t G_t$ is the GS EIRP (P_t is the transmit power from GS, G_t is the GS transmit antenna gain), and σ is the radar cross section area.

Assume the rain cell is 1 km away (north) of the GS. The GS's 1 degree wide beam has a diameter of about 17.5 meters, and the beam area at that distance of 1 km is about 240 square meters. But instead of using the reflective properties of rain, a conservative upper bound assuming a perfect reflector is placed at the location of rain or snow cell is computed first. Then, the radar cross section off this perfect reflector is just the area of the reflector which is 23.8 $dB\ m^2$. The power density flux at 1 km distance is -71 dBW/m^2. Then, the total power reflected form this perfect reflector is $P_t G_t$ -71 + 23.8 = $P_t G_t$- 47.2 dBW, where $P_t G_t$ as is the GS EIRP. Recall from the Next-Gen AG Petition that the front to back ratio of the GS antenna is 37 dB, *i.e.*, the transmit EIRP toward the geo-arc from the GS antenna is $P_t G_t$-37 dBW. Therefore, the power reflected from the perfect reflector is 10 dB lower than that from the backlobe of the GS

[48] *See* Row 44 Comments at 5, 9 (claiming that Qualcomm has not described how Next-Gen AG antennas will continue to operate properly in the face of adverse weather events and other environmental changes).

itself. The computed reflected power is independent of the distance from the rain cell (*i.e.*, a perfect reflector in this case) and the GS.

In the case of rain or snow instead of a perfect reflector, only a fraction of the area covered by the GS beam at the location of the rain cell will contain rain droplets. Moreover, only a fraction of the power that hits a rain droplet is reflected. Finally, the reflected power from the rain droplet is in many directions, *i.e.*, only a fraction of the reflected power will be toward the geo-arc. Therefore there is likely several tens of dB additional reduction in the rain scattered energy going toward the geo-arc compared to the upper bound computed above for the perfect reflector. Therefore, by examining a perfect reflector Qualcomm shows that the reflection from rain or snow has practically no contribution to interference seen in the Geo-arc, and thus will have no effect on the AMSS uplink.