Henry Hultquist
Vice President
Federal Regulatory

AT&T Services, Inc.
1120 20th Street, NW
Suite 1000
Washington, DC 20036

T: 202.457.3821
F: 214.486.1592
henry.hultquist@att.com
att.com

May 23, 2019

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

Re: Expanding Flexible Use of the 3.7 to 4.2 GHz Band, GN Docket No. 18-122

Dear Ms. Dortch:

By this letter, AT&T responds to the technical criteria proposed by the C-Band Alliance ("CBA"),[1] which would govern the introduction of terrestrial broadband networks into the C-Band.[2] CBA's proposal represents a great deal of thoughtful effort, especially concerning the protection of Fixed Satellite Service ("FSS") earth stations from interference. AT&T believes, however, that it would be possible to build upon and refine the CBA's proposal to enhance the ultimate utility of the spectrum cleared for mobile terrestrial 5G operations by streamlining the FSS/5G coordination processes and eliminating fallow spectrum—without increasing the risk of harmful interference to earth stations. Such an optimized outcome would benefit stakeholders on both sides of any C-band reallocation—space station operators, earth station operators, and participants in the mobile 5G ecosystem—by maximizing the value of the reallocated spectrum.

Towards that end, AT&T, in conjunction with CommScope,[3] undertook an objective review of the CBA plan to determine if the proposal could be further optimized for all stakeholders. Based on this analysis, AT&T recommends some modifications to CBA's proposal, and believes some issues should be further analyzed. In particular, the Commission should:

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[1] The CBA is "a consortium of satellite operators with four founding members: Intelsat, SES, Eutelsat and Telesat, which . . . account for virtually all of the operational C-Band satellite downlink service in the continental United States." Letter from Jennifer D. Hindin, Counsel for the CBA, to Ms. Marlene H. Dortch, Secretary, Federal Communications Commission, GN Docket No. 18-122 (Oct. 9, 2019) ("*CBA October Letter*"). CBA's proposal has generally been described in a number of filings in GN Docket No. 18-22. *See, generally*, *CBA October Letter*; Comments of the C-Band Alliance, GN Docket No. 18-122 at 9 (filed Oct. 29, 2018) ("*CBA Comments*"); Reply Comments of the C-Band Alliance, GN Docket No. 18-122 (filed Dec. 7, 2018) (including Technical Annex as Exhibit) ("*CBA Technical Annex*"); Letter from Jennifer D. Hindin, Counsel for the C-Band Alliance, to Ms. Marlene H. Dortch, Secretary, Federal Communications Commission, GN Docket No. 18-122 (Apr. 9, 2019) (including C-Band Alliance Transition Implementation Process as Exhibit) ("*Transition Plan*").

[2] The current downlink portion of the C-band is 3700-4200 MHz ("C-band").

[3] CommScope, and its predecessor-in-interest Comsearch, have been at the forefront of spectrum sharing and RF modeling for decades. *See* https://www.commscope.com/solutions/spectrum-management-solutions/.

(i) Designate as unrestricted most of the spectrum reallocated for terrestrial mobile 5G use, thereby allowing terrestrial mobile licensees to deploy facilities free of any FSS coordination obligations;

(ii) Between the spectrum reallocated for unrestricted mobile terrestrial 5G use and any remaining FSS spectrum, define spectrum for one or more "Adjacent Licenses" where terrestrial users would be required to either employ defined mitigation measures or coordinate with nearby earth stations;

(iii) Investigate less restrictive alternatives than protecting a 150-meter radius around all registered earth station locations;

(iv) Validate, on the record, the protection thresholds for earth stations, the ability of 5G base stations to meet the proposed emissions criteria, and the performance of FSS receive filters;

(v) Develop a more detailed record on the satellite viewable arc required for FSS C-band operations post-transition, including whether opportunities may arise for repacking post-transition users in a way that facilitates co-existence;

(vi) Investigate further the spectrum needed for, and operational requirements of, satellite earth stations that will remain in the portion of the band reallocated for terrestrial mobile operations and the large 150-kilometer coordination zones for those stations;

(vii) Determine a more appropriate user device out-of-band ("OOB") emissions limit than the mask proposed by the CBA; and,

(viii) Encourage all interested stakeholders to closely collaborate to reach consensus where possible regarding technical criteria governing coexistence between mobile wireless 5G deployments and FSS, *e.g.*, comparing modeling and testing parameters to facilitate better spectrum utilization, while protecting incumbent users of FSS in the upper portion of the C-band..

Executive Summary and Overview

The CBA Proposed Plan. Parties in this docket have proposed reallocating the entire C-band for flexible terrestrial use, preserving the entire C-band for FSS, and splitting the band in a variety of shared use arrangement between those polar extremes.[4] There is little, if any, dispute that FSS

[4] *See, e.g.*, Letter from Steve B. Sharkey, Vice President, Government Affairs, T-Mobile USA, Inc., to Marlene H. Dortch, Secretary, Federal Communications Commission, GN Docket No. 18-122 (dated Mar. 28, 2019) (advocating incentive auction of entire C-band); Reply Comments of Qualcomm Inc., GN Docket No. 18-122, at 2 (advocating "opening up the full 500 MHz-wide band for flexible use"); Letter from Alexi Maltas, SVP & General Counsel, Competitive Carriers Association, to Marlene H. Dortch, Secretary, Federal Communications Commission, GN Docket No. 18-122 (dated Apr. 26, 2019) (advocating reallocation of "at least 300 MHz of spectrum for terrestrial services"); Letter from Pantelis Michaelopoulos, counsel for ACA-America's Communications Association, to

and terrestrial mobile services are not compatible as co-channel uses.[5] Thus, if the Commission ultimately allocates an amount greater than 0 MHz but less than 500 MHz in the C-band for terrestrial mobile licensing, the Commission will need to adopt rules to minimize harmful interference by terrestrial mobile 5G deployments to earth stations in adjacent FSS spectrum.

To date, only the CBA has proposed comprehensive co-existence regulations. AT&T greatly appreciates the hard work by the CBA reflected in its proposal. Based on the examination AT&T has conducted with CommScope, AT&T now believes the technical provisions of CBA's proposal can be optimized to create even better spectrum efficiency by allowing some terrestrial use of ***all*** of the spectrum not retained for FSS use, impose fewer burdens on terrestrial mobile licensees, and avoid extraneous protection of FSS.

Several portions of CBA's technical proposal are ripe for optimization. First, as shown in *Figure 1* below, the CBA's current proposal relies on a 20 MHz guard band in which no use is contemplated in conjunction with coordination and mitigation requirements applicable to all terrestrial flexible use licensees:

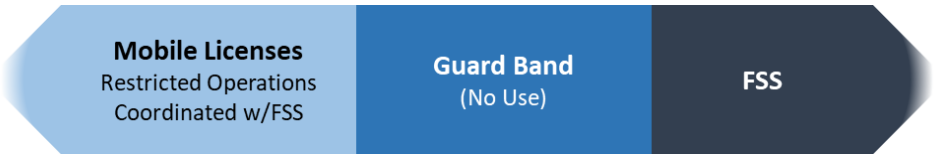

Figure 1: CBA-Proposed C-Band Use (not to scale)

Second, the CBA proposed regulations for all new mobile licenses in the C-band that are modeled on Section 27.19. These regulations include both in-band and OOB received signal thresholds that must be met by each terrestrial licensee on an aggregate basis considering all 5G base stations within 40 kilometers of each of the more than 17,000 registered FSS earth stations.[6] Notably, in calculating compliance with the protection thresholds proposed by the CBA, terrestrial licensees would be obliged to consider full-band, full-arc use of all registered earth stations. Third, the CBA also proposes that terrestrial licensees should have to assess not only the impact on earth station locations registered with the FCC, but also within a 150-meter radius around those locations. Finally, the CBA also would establish large 150-kilometer radius coordination zones—over 70,000 square kilometers each—around four telemetry, tracking and

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Marlene H. Dortch, Secretary, Federal Communications Commission, GN Docket No. 18-122 (dated Mar. 25, 2019) (arguing "any 5G refarming . . . would produce serious harm").

[5] *See, e.g.*, *Expanding Flexible Use of the 3.7 to 4.2 GHz Band*, Order and Notice of Proposed Rulemaking, GN Docket No. 18-122 at ¶50 (rel. Jul. 13, 2018) (recognizing "that co-channel sharing of spectrum between the FSS and more intensive terrestrial wireless use in the same geographic area may be difficult").

[6] CBA Reply Comments at 10 (noting "[a]s of November 6, 2018, more than 17,000 C-band earth stations were registered with the Commission").

control ("TT&C") and/or teleport earth stations that will continue to operate in portions of the band reallocated for terrestrial mobile services.[7]

AT&T values the CBA's obviously extensive effort to design a technical proposal that would enable terrestrial mobile use of the C-band alongside FSS use thereof. However, the CBA's technical proposal does not sufficiently account for the fundamental principle that, if interference mitigation measures are required for the C-band due to adjacent terrestrial mobile and FSS operations, sound spectrum policy dictates that the coordination obligations should apply only to the smallest possible subset of the terrestrial band. As a result, the CBA proposal overlooks the potential for (i) productive terrestrial use of "Adjacent Licenses" positioned between the FSS allocation and the terrestrial mobile allocation and (ii) by virtue of the separation achieved through the Adjacent Licenses, allowing the remaining spectrum available for terrestrial use to be wholly unconstrained by any coordination obligations vis-à-vis FSS. By freeing the majority of terrestrial licenses from coordination obligations, the utility of the spectrum for mobile 5G deployments is enhanced, which will in turn increase license value and the potential revenues available to make the entire reallocation plan work. In addition, allowing full use of the spectrum, both by avoiding fallow guard bands and excessive exclusion areas, also achieves higher spectral efficiency and creates higher value from this spectrum band for both terrestrial and satellite use. The Commission should, accordingly, carefully scrutinize proposals that constrain spectrum use and should mandate reasonable engineering practices that maximize co-existence capabilities, like the deployment of state-of-the-art filters. Within those broader goals and where possible, the burdens on licensees should be minimized while still preserving reasonable flexibility for future expansion by all users of the band.

AT&T/CommScope Modeling and Proposed Modified Band Plan. With these objectives in mind, AT&T commissioned radio frequency ("RF") engineering firm CommScope to conduct preliminary modeling using actual network architecture plans and earth station registration data. The goal of the modeling was to advance the specificity of the record in this proceeding by understanding the implications of the CBA technical proposal on 5G network operations and to identify potential improvements to the CBA proposal that would achieve higher spectrum efficiency and accelerate 5G deployment while continuing to fully protect FSS earth stations. While additional input from 5G equipment manufacturers and the FSS community is necessary to fully address these technical questions, this preliminary modeling, as discussed further below, provides significant insights into the implications of the CBA's radio frequency management proposal and ways to achieve these goals.

Based on CommScope's results, and as shown in *Figure 2* below, AT&T proposes a band plan that designates unrestricted terrestrial licenses that allow full power operation free of any

[7] *See Transition Plan* at 10 ("[a]cknowledging that [the originally specified] 14 such exclusion zones would create network restrictions for mobile operators that would affect the deployment of 5G in certain metropolitan markets, the CBA member companies have agreed to consolidate TT&C and Gateway sites into no more than four sites and to ensure those sites are in the least impactful areas possible"). The limits proposed by the CBA, while similar to other thresholds in magnitude, are particularly difficult because emissions in the relevant band cannot be mitigated either through base station emissions masks or earth station filters as the operations would be co-channel.

obligation to coordinate with FSS earth stations.[8] Between these unrestricted licenses and the FSS band, AT&T proposes one or more Adjacent Licenses that would require terrestrial users to operate either using lower power (or subject to other constraints) or subject to coordination obligations with nearby FSS earth stations. Importantly, AT&T's proposal would avoid any C-band spectrum remaining fallow.

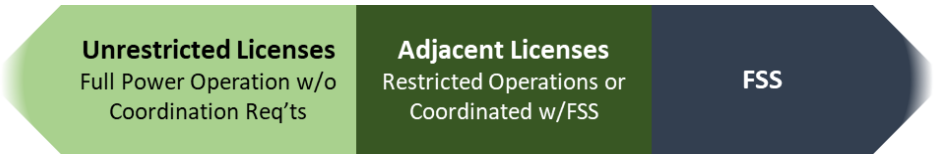

Figure 2: AT&T-Proposed C-Band Spectrum Use (not to scale)

The size of the Adjacent Licenses block will depend on the OOB emissions protection levels ultimately adopted as well as the performance of base station filters used by terrestrial networks and the receive filters installed by FSS users. Hence, AT&T recommends that the Commission seek additional vendor input to fine tune this proposal.

Coordination Scope and Procedures. CommScope's results also highlight that the related coordination burdens on terrestrial licensees resulting from the CBA's proposal are highly sensitive to the proposed 150-meter protection zone around each registered earth station. Considering the major impact on 5G deployment these measures would have, the Commission should consider a more balanced approach to FSS growth than universal full-arc coordination and overly conservative protection zones.

In addition, the CBA's proposed large, 150-kilometer radius coordination zones (over 70,000 square kilometers each) around four TT&C/teleport sites across the mainland U.S. would have significant repercussions for the communities in and around those locations. AT&T submits that more information is needed on the record to evaluate this proposal. At a minimum, the Commission should ensure that all existing engineering and commercial tools to manage interference challenges are exhausted prior to resorting to such massive coordination areas.

AT&T also suggests that a stronger record should be developed on the satellite arc views that will be necessary to support post-transition FSS operations. While the CBA has proposed that all earth stations be protected down to a 5° look angle and all GSO satellite positions, the actual protection a station will require will depend upon the arc of satellites it could potentially communicate with and the longitude of the earth station. Although the longitude can be determined from the station's location, the record should be supplemented with additional detail on whether all stations really need access to all orbital slots, and whether repacking prioritizations could be implemented in a way that potentially allows more terrestrial use on a geography-specific basis without undue constraints on future FSS flexibility.

[8] In this letter, AT&T has used "full power" to mean base station EIRPs that comply with the limits in Section 27.50(d), or 3280 W/MHz (65 dBm/MHz) in rural areas and 1640 W/MHz (62 dBm/MHz) in non-rural areas. *See* 47 C.F.R. §27.50(d).

All of these points are discussed in further detail below. AT&T first discusses the current interference protection scheme proposed by the CBA, and how that scheme has evolved over time. Next, AT&T describes the key factors that will drive the sizing of the Adjacent License block. Third, AT&T summarizes the findings from CommScope's modeling, and the impact those results predict that the CBA proposal will have on practical 5G network deployment. Fourth, AT&T examines the practical ramifications of the full arc coordination requirements, including the possibility that the transition repacking could be prioritized in a manner that frees additional spectrum in some areas for terrestrial use. Fifth, AT&T discusses the impact of the 150-kilometer coordination zones for TT&C/teleport earth stations that will continue to operate in the reallocated terrestrial mobile portions of the band. Finally, AT&T discusses the user device OOB emissions mask the CBA has proposed for the C-band and its impact on 5G deployment.

The CBA-Proposed Protection Thresholds

The CBA has proposed regulating terrestrial services adjacent to FSS using received signal thresholds for in-band and OOB emissions—in this context, "in-band" meaning RF energy within the terrestrial mobile portion of the C-band and OOB meaning RF energy resulting from 5G transmissions but within the FSS band. Separate in-band and OOB emissions thresholds are needed because potential in-band RF energy can be filtered out by an earth station—OOB emissions, by contrast, are within the FSS band, and therefore within the passband of any filter that could be deployed by the earth station. As a result, the amount of interference resulting from OOB RF energy is solely a factor of the terrestrial base station's emissions mask and the spectral separation between the earth station and the base station. Potential in-band interference, in contrast, can be partially mitigated by an earth station receive filter and therefore earth station protection will be dictated by the performance of the FSS filter.

The CBA has stated that "-60 dBm/MHz beyond 40 MHz outside the band edge is necessary to protect earth stations against the aggregate effect of [OOB] emissions of multiple base stations."[9] In its reply comments, the CBA proposed a 20 MHz guard band wherein base stations would be required to attenuate their signals down to -13 dBm/MHz. The proposal in the reply comments, however, assumed a maximum 5G base station power of 46 dBm/MHz. Even at that lower power, as shown in *Figure 4* below, there will be constraints on 5G deployment because a 20 MHz guard band would mean that 5G base stations would generate signals up to -50 dBm/MHz (above the CBA's specified -60 dBm/MHz) within a portion of the remaining FSS spectrum.

[9] *CBA Comments* at 9. Under the original emissions mask outlined by the CBA in their comments, 5G base stations would be required to attenuate their signal to -60 dBm/MHz at a 50 MHz offset. This correlates with the CBA's proposal at the time, which specified a 50 MHz guard band. That 50 MHz guard band proposal was subsequently modified in the CBA's reply comments.

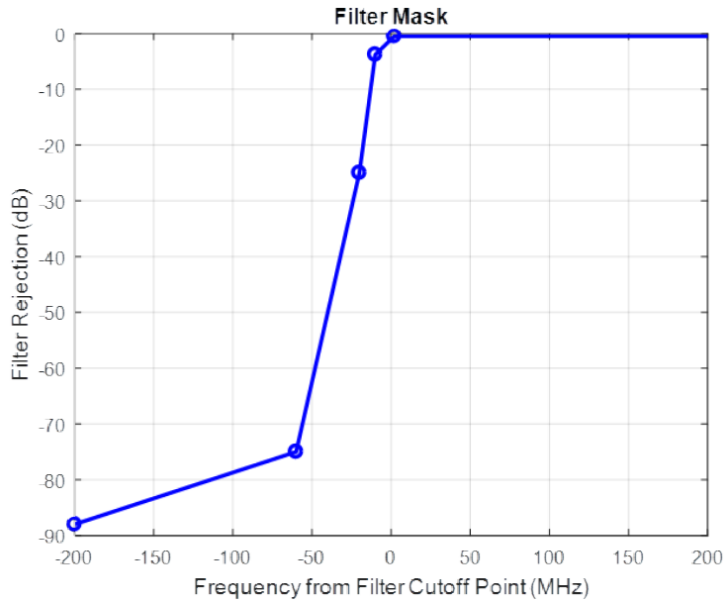

Figure 3: CBA-Specified 5G Base Station Filter Mask

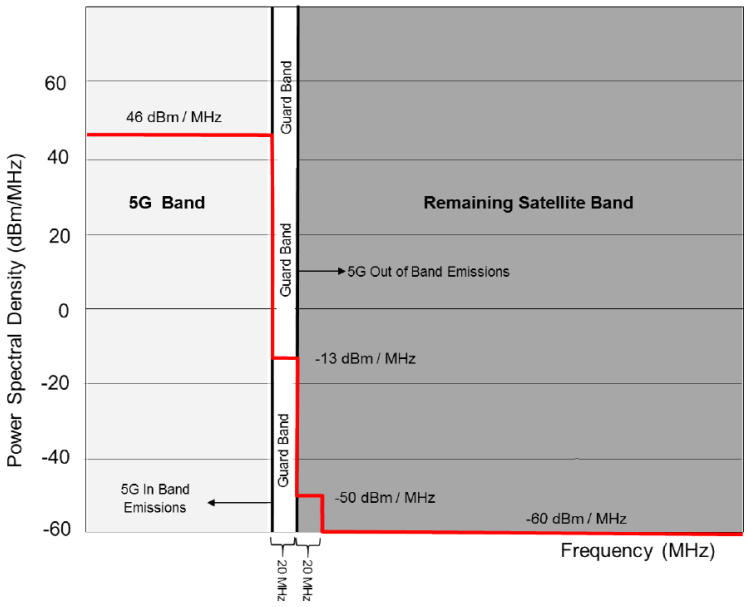

Figure 4: CBA Base Station Signal Mask

Importantly, other commenters have proposed that -50 dBm/MHz should be adequate to protect FSS earth station from 5G OOB emissions.[10] Because that protection level—and the consequent

[10] *See, e.g.*, Letter from Mark Racek, Sr. Director, Spectrum Policy, Public Affairs and Regulations, Ericsson, to Marlene H. Dortch, Secretary, Federal Communications Commission, GN Docket No. 18-122 at 3 (filed Apr. 26, 2019) (noting "Ericsson conducted an adjacent channel study that confirms that coexistence is feasible with a 20 MHz guard band and an OOBE limit of -40 dBm/MHz plus an additional 10 dB shielding or clutter loss at the FSS earth station antenna"); *see also* Reply Comments of Ericsson, GN Docket No. 18-122 at 7 (Dec. 11, 2018);

separation required to achieve that degree of attenuation—will define the size of the Adjacent License block, it is imperative that the Commission—working with the broader 5G and FSS expert community—conduct further research to determine the appropriate protection threshold for OOB emissions.

The CBA's filings also detailed the proposed RF specifications for the filters that it plans to install in every earth station between the antenna and the low-noise block converter ("LNB"). *Figure 5* depicts the rejection below the FSS lower band edge (using 3900 MHz as proposed by the CBA), provided by these filters:

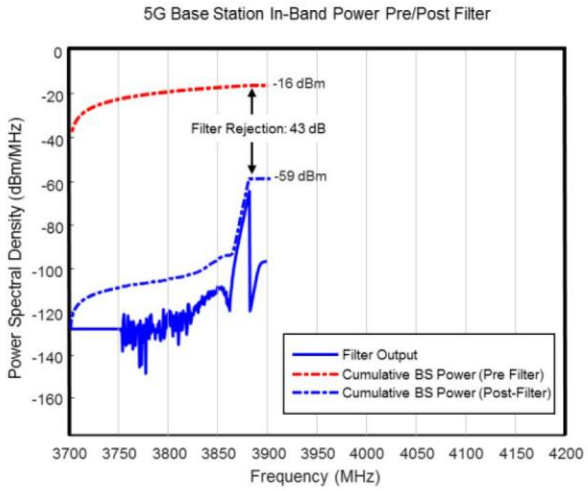

Figure 5: CBA Test Data on FSS Filter Rejection

The CBA's test data shows that the RF filter provides 43 dB of attenuation to 5G transmissions with 20 MHz of separation from FSS (*i.e.*, at or below the edge of their proposed guard band). The data also shows increased filter roll-off—73 dB of attenuation—with 40 MHz of separation from the FSS. The filter roll-off will help to reduce the 5G power at the FSS receiver. While this performance seems reasonable, the FCC should work with equipment vendors and validate that these levels are state-of-the-art and that better performing filters could not be implemented.

Ultimately, as previously noted, the CBA revised the FSS protection framework it was proposing based on "a deeper understanding of mobile technology [achieved] through research and analysis, and a direct dialogue with mobile equipment manufacturers and operators."[11] Instead of the 46 dBm/MHz EIRP limit on 5G base stations and 20 MHz guard band, the CBA proposed

Technical Appendix: 5G and FSS Coexistence Simulations, Nokia Bell Labs, attached to Comments of Nokia, GN Docket No. 18-122 (Oct. 29, 2018).

[11] *CBA Technical Annex* at 2.

rules based on Section 96.17 for the protection of FSS earth stations.[12] Specifically, the CBA proposed that:

- For in-band emissions, "the aggregate radiofrequency (RF) power density at the output of a reference RF filter and antenna of an FSS earth station, produced by emissions from all Fixed and Base Stations of a 5G licensee within 40 kilometers shall not exceed a value of -81.6 dBm/MHz in the [5G band]";[13] and,

- For OOB emissions in the FSS band, "the aggregate passband [RF] power spectral density at the output of a reference RF filter and antenna at the location of an FSS earth station operating in the [FSS] band, produced by emissions from all … Fixed and Base Stations of a 5G licensee within 40 kilometers shall not exceed a value of -133 dBm/MHz for earth stations used for satellite [TT&C] operations and -128 dBm/MHz for other earth stations."[14]

In addition to requiring a 20 MHz guard band, the CBA also specified that these limits must "be complied with for any pointing of the antenna towards the [Geostationary Orbit ("GSO")] arc with an elevation angle greater than or equal to 5 degrees," and must "be complied with for all earth station antennas within a radius of 150 meters of the location of the registered earth station."[15]

Size of the Adjacent License Block

While AT&T appreciates the CBA's continued efforts to refine the technical protections for FSS earth stations, AT&T believes the current proposal could be enhanced to achieve greater spectral efficiency. For example, a coordination obligation that extends to licensees that are spectrally distant from the FSS band—as the current CBA proposal would have—makes little policy sense and diminishes the practical and financial value of all terrestrial C-band licenses unnecessarily. Such a conservative measure is unnecessary to protect the FSS band and should be avoided as it creates significant compliance burdens for terrestrial licensees that will ultimately delay and increase the costs of 5G deployment. Similarly, creating a guard band of any magnitude where spectrum must remain unused is unnecessary. Instead, AT&T proposes that an appropriately sized Adjacent Licenses be implemented where coordination or other mechanisms would be required by rule to ensure adequate protection of FSS earth stations. This would significantly improve spectral efficiency by enabling most licenses to be unrestricted terrestrial mobile licenses where licensees are permitted to operate at full power without any FSS-interference based constraints. The key questions that remain are the appropriate size of the Adjacent License

[12] 47 C.F.R. §96.17.

[13] *CBA Technical Annex* at 3 (footnotes omitted).

[14] *Id*. at 5 (footnotes omitted).

[15] *Id*. at 3, 6.

block, the constraints that should be applied to licensees operating in that block, and the repositioning flexibility to be provided for FSS earth stations.

As noted above, the separation required between full power base stations and FSS earth stations is a function of the response of both the 5G base station filter and the FSS earth station filter. Although the record is unclear whether -60 dBm/MHz is the appropriate protection level for earth stations, AT&T worked with its 5G equipment vendors to better understand the spectrum offset required for full power 5G base stations to achieve that level of protection. Preliminary estimates from vendors range from 30-50 MHz.[16] AT&T's analyses suggest strongly that the size of the Adjacent License Block will depend on the OOB emissions from 5G base stations and the protection threshold ultimately adopted by the FCC. Because the OOB emissions from base stations are dependent upon the filter roll-off from the maximum EIRP and the ability of 5G equipment to meet that emission standard, AT&T urges the FCC to solicit input from the terrestrial 5G and FSS equipment vendor community on these topics.

5G Network Implementation Ramifications of the CBA's Co-Existence Proposal

To determine the practical impact of the CBA-proposed restrictions on 5G operations and assess their effectiveness in protecting FSS earth stations, AT&T engaged CommScope to model the performance of the base stations in AT&T's Miami network and the resultant received signal levels at FSS earth stations in that region.[17] This simulation thus assumes a natural terrestrial mobile architecture as would be deployed by a service provider unencumbered by RF constraints aimed to protect FSS earth stations. CommScope reviewed data from over 2,000 sectors in AT&T's deployed Miami mobile network, including heights ranging from 10 ft. to 300 ft. and orientations ranging from 0° to 357°. CommScope combined that information with data from the FCC's earth station registration database,[18] and then applied the same propagation model that will be utilized for 3.5 GHz Citizen's Band Radio Service ("CBRS") coordination.[19]

For purposes of this analysis, CommScope assumed base station EIRPs of 65 dBm/MHz in rural areas and 62 dBm/MHz in non-rural areas with a 65° antenna beamwidth, parameters appropriate for mid-band 5G deployment, and transmissions occupying 10 MHz immediately adjacent to the

[16] Based upon AT&T/CommScope modeling, as discussed below, and taking the filter response from the CBA filings into consideration, initial results show that OOB interference dominates and will be the key factor for determining the size of the Adjacent License Block.

[17] A summary of the CommScope study has been attached as Exhibit A. While this study was conducted using AT&T's Miami network architecture, AT&T does not believe results are sensitive to particular idiosyncrasies of this network.

[18] The database of FSS earth stations used in this study included a total of 78 known earth stations from the FCC's earth station registration database. This database is known to be incomplete, however, as it does not include the thousands of receive-only earth station that were registered in 2018 and are still under evaluation by the International Bureau.

[19] The CBRS propagation model has been extensively vetted by industry experts to assess interference—including mobile network to FSS earth station interference—in an immediately adjacent band. That propagation model, therefore, is well suited to consider interference effects in the C-band.

CBA guard band (*i.e.*, 20 MHz offset from the FSS band edge). To simplify the analysis, CommScope simulated the GSO orbital range by assuming service is offered from satellites located at 18° W and 139° W, which are the extreme limits for authorized FSS operations in the Miami market.[20] The assumptions on filter rejections were based on the CBA technical filing, *i.e.* -40 dBm/MHz for OOB emissions for 5G base stations and 43 dB of rejection from FSS filters at a 20 MHz offset.

With those assumptions, CommScope determined the in-band and OOB emissions that would be received by each individual registered earth station in the region and which earth stations received signal levels in excess of the proposed limits. CommScope then determined the in-band and OOB emissions exceeding that threshold increasing the protection zone around each earth station to 150 meters (over 70,000 m^2 or over 84,000 $yards^2$), as proposed by the CBA. CommScope's analysis also considered the implications of the CBA proposal for an aggregate interference threshold not to be exceeded by each licensee across all 5G deployments located within a 40 kilometer radius of each registered FSS earth station.

Assuming protection thresholds apply only to the actual registered earth station location (*i.e.*, ignoring the CBA-proposed 150 meter radius protection zone), CommScope found that a number of the FSS earth stations in the Miami market would be impacted by "natural" 5G mobile network deployments—*i.e.*, would receive signals exceeding the CBA-proposed in-band and OOB protection thresholds. Specifically, CommScope calculated that 14 of 78 FSS earth stations in the market (or 17.9%) would receive signal strengths above the CBA in-band protection thresholds and 33 of 78 (or 42.3%) would receive signal strengths above the CBA OOB protection thresholds. These results reveal that the CBA's proposal for protecting FSS earth stations would impose significant architectural constraints on 5G deployments. The proposed protection constraints would force 5G deployment to significantly deviate from natural, organic network architecture growth plans resulting in costlier, more time-consuming and possibly less efficient deployments than those accomplished for 4G networks.

If the protected zone is expanded to a radius of 150 meters around each earth station's registered location, the simulation results are significantly aggravated. In order to test the impact of extending the earth station protection in this manner, CommScope created a 50-meter x 50-meter grid centered at each earth station and tested the 29 grid points within a 150-meter radius of the actual earth station location. CommScope found that with such a 50-meter grid, the implementation of the CBA-proposed protected zones would significantly increase the constraints on terrestrial network deployment. Accounting for the 150-meter protection radius, the number of earth station protected zones impacted above the CBA-proposed in-band protection threshold would almost double, going from 17.9% to 33.3% and the number of earth station protected zones impacted above the proposed OOB protection threshold would increase from 42.3% to 60.3%.

[20] The 18° W and 139° W limits were derived by considering only FCC authorized space stations for C-band GSO FSS operations that would have resulted in look angles no less than the 5° specified by the CBA for the Miami area.

Independent of the work done by CommScope, AT&T also undertook some "back of the envelope" calculations to assess the impact of the CBA's proposed coordination rules. For purposes of these calculations, AT&T used free space path loss assumptions and varying 5G base station height, EIRP, and downtilt parameters, as well as FSS parameters like elevation angle, and estimated that the network restrictions on 5G networks resulting from the CBA's proposed coordination rules would impact base stations that are up to 1.5 miles away from any protected FSS earth station. In the Miami market, which includes five Cellular Market Areas, AT&T estimates that 5G deployment affected by these restrictions would impact areas with a population of approximately 700,000 to 1.4 million, or approximately 12% to 24% of the total market population. Based on these results, AT&T proposes that at a minimum, any earth station protection threshold established by rule should apply only to the location of approved earth stations and should not include artificial geographic buffer zones.

CommScope also analyzed the practical consequences of the CBA's proposal to require aggregate interference calculations—the CBA proposed that 5G licensees evaluate compliance with the relevant thresholds aggregating all base stations within 40 kilometers of each registered FSS earth station. CommScope's study concludes that, in cases where the CBA's proposed thresholds were exceeded, the interference was dominated by a single 5G base station, and not by aggregate effect. In other words, CommScope's results demonstrate that aggregating interference contributions across a license offers little to no additional protection for FSS earth stations. Yet, the proposal would drive significant burden for 5G deployments. Based on these results, AT&T urges the Commission to reject the proposal to require aggregate interference protection thresholds.

Full Arc Coordination Requirements

After reviewing the CBA's Transition Plan, AT&T suggests the Commission should develop a further record on whether the amount of terrestrial mobile spectrum could be expanded, and burdens on terrestrial deployment minimized, by structuring the FSS repacking to group certain applications in the upper portion of any remaining FSS band. The CBA has proposed full band coordination for all remaining FSS earth stations—in this context, "full band" meaning that earth stations have access to the entire portion of the C-band retained for FSS use. The benefits of allowing each earth station to "virtually" occupy the entire band, however, must be weighed against the public policy cost. If only certain applications have capacity needs at the extreme requiring large bandwidths, it makes more sense to provision those needs as exceptional cases and not allow that application to drive the size of the overall allocation.

Unless the Commission decides to clear all 500 MHz of the C-band, AT&T agrees with the CBA that incumbent FSS earth stations would need some protection from 5G terrestrial interference. The burden of that coordination requirement for 5G deployment is directly proportional to the number of earth stations that would need to be protected. Current estimates of the total number of C-band registered earth stations is still in flux pending the review of applications underway at the Commission, but currently ranges upwards of 17,000. The CBA's proposal would have each one of these earth stations protected, and protected for full-band, full-arc operations going

forward. Yet, AT&T believes that a smarter FSS repacking strategy could significantly reduce the number of theoretical earth stations pointing options that 5G operators would need to protect while still ensuring full protection of all current C-band *use*, thus significantly improving spectral efficiency use of the band.

The key to this strategy is recognizing that the amount of spectrum needed for the actual C-band capacity load in use to support an FSS application at any given location differs significantly across earth stations and ranges from the remaining FSS full arc to, in some cases, at most one transponder. For example, a cable head-end or satellite collection facility receiving linear content for hundreds of channels and using upwards of 15 earth stations, such as DIRECTV's broadcast centers, likely will use all remaining C-band transponders and use more bandwidth than an FM affiliate receiving an audio feed from its radio network,[21] or an earth station supporting one or two religious channels. Similarly, occasional use, transportable earth stations typically only need to use a limited number of transponders. And, as noted below, based on available public information, AT&T estimates that 32% or less of C-band registered earth stations will in fact use 100% of the remaining C-band full arc.[22]

Taking this into consideration, if the Commission ultimately decides to split the C-band into terrestrial and FSS use, it should consider a repacking strategy that allocates applications using only a portion of the remaining FSS spectrum to the upper portion of the C-band (just below 4200 MHz). By doing so, these applications would have sufficient spectral distance from the lower FSS band edge to ensure protection of these earth stations without the need for coordination from 5G deployments in the Adjacent License block. By contrast, protection rules would apply to licensees in the Adjacent License block to ensure protection of earth station that will use the remaining C-band full arc. That subset of earth stations that would need to be protected by the Adjacent Licenses would be established by the Commission. This strategy could drastically simplify coordination requirements for 5G deployments by reducing—by a factor of ten—the number of earth stations that must be addressed. The reduction in coordination obligations would significantly expand use of this block for terrestrial licensees, without impeding or burdening projected FSS use in the adjacent band – a win-win strategy.

In a similar vein, the CBA has proposed rules that would require protection for elevation angles down to 5°. Yet, in most cities, such conservative elevation angle is unnecessary because it implies protection for earth stations to communicate with orbital slots where there are no U.S. authorized C-band GSO satellites. Because the elevation angles that require protection for FSS earth stations are related both to the satellite orbital locations in use and longitude of the earth station, the earth station elevation angles that should be protected should be analyzed on a city by city basis considering authorized satellites. Thus, deriving the range of elevation angles that

[21] *See, e.g.*, Comments of National Public Radio, Inc., GN Docket 18-122 at 4-5 (May 31, 2018).

[22] The CBA's filing indicates that the sites needing the most capacity appear to fall into the category of "Cable," supporting approximately 2,000 head-end sites where approximately 13% of earth stations are located, and possibly "TV Broadcast and Affiliates," involving approximately 200 affiliate sites for each major network and including approximately 19% of all registered earth stations.

must be protected will not affect FSS flexibility or use, but will have a dramatic impact on the ability of terrestrial base stations in the Adjacent Licenses block to successfully coordinate with nearby earth stations.

Organizing the repacking of FSS earth stations and use would result in significantly more spectral efficiency at the boundary between the FSS and 5G ecosystem. The earth station facilities needing the most FSS capacity appear to be cable television and broadcast uses that are also pointed at "the broadcast and cable arc satellites," which appears to be a subset of the full GSO arc. In other words, by organizing 68% of earth stations (*i.e.*, non-broadcast, non-cable uses) to the high end of the band, there is the potential that: (i) a number of additional mobile channels could be freed up in areas that do not include "cable" or "broadcast" sites,[23] and (ii) that coordination obligations relating to the FSS use closest to the mobile band could be substantially reduced, both because there would be fewer earth stations near the mobile band and because those earth stations would require access to a smaller satellite arc, which would result in less conservative elevation angles. Note, however, that the possibility of locating non-broadcast, non-cable uses at the high end of the band should be balanced against other important uses, such as programmers' use of the same spectrum for production of high-value sporting and political events using mobile C-band satellite trucks.

Protection of TT&C and Teleport Sites Operating in the Re-Allocated Terrestrial Mobile Band

The CBA's proposal includes large coordination zones around what the CBA says will be four sites in the continental U.S. Specifically, the CBA has proposed that:

> [T]he aggregate passband [RF] power spectral density at the output of a reference antenna of an FSS earth station operating in the [terrestrial mobile] band, produced by emissions from all Fixed and Base Stations of a 5G licensee within 150 kilometers shall not exceed a value of -133 dBm/MHz for earth stations used for satellite [TT&C] operations and -128 dBm/MHz for other earth stations.[24]

Each 150-kilometer radius coordination zone equates to over 70,000 square kilometers, or over 27,000 square miles, an area larger than the state of West Virginia.[25] In its latest *ex parte* addressing this issue, the CBA explains that such coordination zones would apply to four sites in the continental U.S., from a universe of fourteen sites it identified in a prior pleading.[26] Some of

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[23] Additional mobile use could only be authorized if non-cable, non-broadcast FSS stations were outfitted with a filter that rolled off at a higher point in the band, but is a solution that warrants further consideration, especially as many earth station locations supporting non-broadcast and non-cable uses may be clustered.

[24] *CBA Technical Annex* at 7.

[25] *See* Population, Housing Units, Area, and Density: 2010 - United States -- States; and Puerto Rico, 2010 Census Summary File 1; available at: https://factfinder.census.gov/faces/tableservices/jsf/pages/productview.xhtml?src=bkmk (last visited May 10, 2019).

[26] *Transition Plan* at10.

the fourteen sites identified by the CBA, however, are in some very densely populated areas, including some of the top 10 markets:

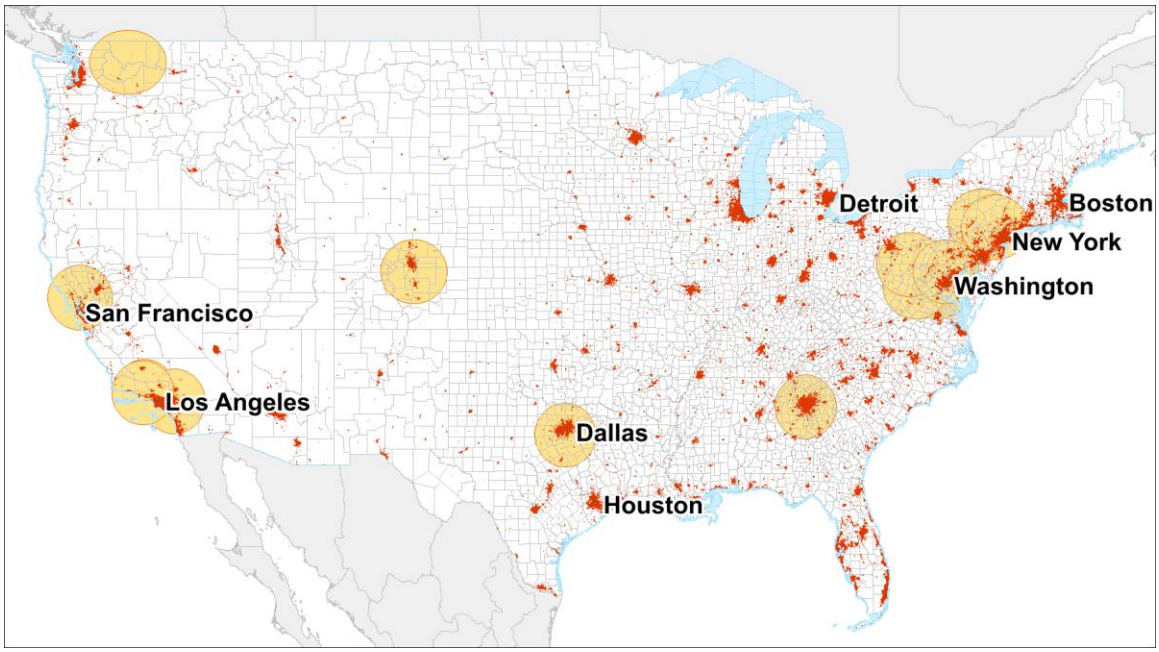

Figure 6: TT&C/Teleport Site Exclusion Zones (tan) and Urbanized Areas (red)

Because the primary emissions from 5G base stations in these areas will be co-channel to the earth station operating frequencies, filtering—either on the mobile transmit side or using a receiver filter—will be ineffective. This implies significant impacts on use of C-band 5G for major regions and could potentially impact the quality and scope of 5G networks serving tens of millions of Americans.

Given the stakes involved, additional information on the record is merited regarding the reasons for the CBA's proposal. To date, the CBA has explained on the record that these protection zones are necessary for two core reasons: first, to conduct TT&C for the fleet of C-band satellites across various orbital slots (both active and backup satellites); and, second, to monitor data streams of satellites offering service internationally (and therefore presumably still utilizing all 500 MHz for downlink) which are controlled from teleports located in the continental U.S.[27]

Regarding the first use, TT&C satellite fleet control—while critically important—is supported by very little bandwidth (possibly as little as 1 MHz). While reliable TT&C links are critical for a satellite fleet, that use clearly does not require full 500 MHz band use. To shed light into this, the CBA should clarify on the record the precise spectrum that is currently in use for TT&C at these facilities, which facilities it envisions retaining, and commit that any newly launched satellite will utilize TT&C links that are in the portion of the band that will remain available for FSS use. Additionally, the CBA should explore all commercial or technical solutions that may

[27] *Id.*

enable TT&C use to be relocated to the upper portion of the C-band downlink or other FSS bands, alternative interference amelioration techniques for narrowband TT&C links other than this vast geographic separation proposal, and whether such operations can be relocated to largely unpopulated areas of the country.

Regarding the second use, the CBA should explain why quality control of satellite data streams serving areas outside of the U.S. must be conducted within the continental U.S. and merits such large exclusion zones.[28]

The CBA-Proposed OOB Emissions Mask for Mobile Devices

As a final matter, AT&T believes the OOB emissions mask that the CBA has proposed for mobile user equipment ("UE") operating in the C-band is excessively restrictive and would seriously impair the deployment of 5G services in the U.S. The CBA proposes maximum UE OOB emissions levels of -28 dBm/MHz from up to a 20 MHz offset, -55 dBm/MHz from 20 to 40 MHz, and -65 dBm/MHz for offsets greater than 40 MHz.[29] The required attenuation for UE, in fact, is considerably greater than what the CBA has proposed for base station equipment where filter size and cost are relatively less important and even orders of magnitude lower than the spurious emissions levels permitted under the Part 15 FCC rules for intentional and unintentional radiators.[30] As Qualcomm observed, "those limits would require massive reductions in mobile transmit power levels and thus cripple U.S. deployment of 5G technology in this band," as well as "destroy any economies of scale and any worldwide harmonization for devices that use this band."[31] Nor has the CBA explained why the "unprecedented and extreme"[32] OOB emissions limits are justified, especially since the existing FSS earth stations in the immediately adjacent CBRS band do not receive such protection from UE operating. On balance, AT&T does not believe the restrictive mask the CBA has proposed is in the public interest.

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[28] It should be noted that CBA's insistence on 150 kilometers of separation between TT&C earth stations and terrestrial base stations is more than twice the distance that is likely needed to avoid interference. Others have concluded that as little as 30 kilometers and no more than 70 kilometers would be needed. See Letter from Mark Racek, Sr. Director, Spectrum Policy, Public Affairs and Regulations, Ericsson, to Marlene H. Dortch, Secretary, Federal Communications Commission, GN Docket No. 18-122 at 2 n.6 (Apr. 26, 2019) (citing Letter from Gerry Oberst, SES Americom, to Marlene H. Dortch, Secretary, Federal Communications Commission, GN Docket No. 18-122 at Technical Annex p. 1 (Mar. 2, 2018) (noting that the necessary separation distances "would make deployment of terrestrial mobile services impossible in significant portions of the country," and that co-channel sharing "would create a lose-lose situation for the satellite community and prospective terrestrial service providers"); Letter from Jeffrey A. Marks, Nokia, to Marlene H. Dortch, Secretary, Federal Communications Commission, GN Docket No. 18-122 at 2 and "NOI Technical Inputs" at 20 (Jan. 22, 2018)).

[29] *See* Letter from Jennifer D. Hindin, Counsel for the C-Band Alliance, to Marlene H. Dortch, Secretary, Federal Communications Commission, GN Docket 18-122 at Att., p. 13 (dated May 13, 2019).

[30] *Id*. at Att, p. 12.

[31] Reply Comments of Qualcomm Incorporated, GN Docket 18-122 at 2 (filed Dec. 11, 2018).

[32] *Id*.

Conclusion

AT&T, as both a user of FSS C-band services and a leading 5G wireless provider, has supported the Commission's objective of revising the usage of the FSS C-band to address the critical need for additional mid-band 5G spectrum. As discussed above and in the attached CommScope analysis, the CBA's proposal to govern the potential interaction between terrestrial mobile licensees and FSS earth stations can be enhanced to create more efficient use of the spectrum and to minimize burdens on terrestrial licensees. If FSS and mobile services co-exist as adjacent uses, AT&T believes the Commission should: (i) designate the majority of mobile licenses as unrestricted, where terrestrial licensees are free of any coordination obligations with FSS earth stations; (ii) between the unrestricted licenses and any remaining FSS spectrum, define one or more Adjacent Licenses where terrestrial users would be required to either employ defined mitigation measures or coordinate with nearby earth stations; (iii) consider alternative protection of registered earth station locations rather than the overly conservative protection zone across a 150 meter radius around those registered locations; (iv) seek further record clarification to validate the protection thresholds for earth stations, the ability of 5G base stations to meet the proposed emissions criteria, and the performance of FSS receive filters; (v) develop a more detailed record on the satellite viewable arc required for C-band operations post-transition, including whether opportunities may arise for repacking post-transition users in a way that facilitates co-existence; (vi) investigate further the spectrum needed for, and operational requirements of, satellite earth stations that will remain the portion of the band reallocated for terrestrial mobile operations and the large 150 kilometer coordination zones for those stations; (vii) consider alternatives to the extremely restrictive user device OOB emissions limits proposed by the CBA; and, (viii) encourage all interested stakeholders to closely collaborate to reach consensus where possible regarding technical criteria governing coexistence between mobile wireless 5G deployments and FSS, *e.g.*, comparing modeling and testing parameters to facilitate better spectrum utilization, while protecting incumbent users of FSS in the upper portion of the C-band.

Should any questions arise concerning this *ex parte*, please do not hesitate to contact the undersigned at (202) 457-3821.

Sincerely,

Henry G. Hultquist

C-Band Fixed Satellite Service/5G Co-Existence Analysis – Miami, FL

AT&T Inc.
Commscope
May 2019

Objective & Conclusions

Objective

- Evaluate the impact of CBA Fixed Satellite Service ("FSS") coordination proposal* on an existing AT&T network grid layout using Miami, FL as a sample market
- Simulate and study both In-Band and Out-of-Band ("OOB") interference modes

Conclusion

- 20 MHz guard band proposed by CBA is not adequate
- Current CBA proposal significantly constrains 5G deployments

Study is ongoing and additional markets will be evaluated that provide a different perspective on geography and look angles on the U.S. satellite arc

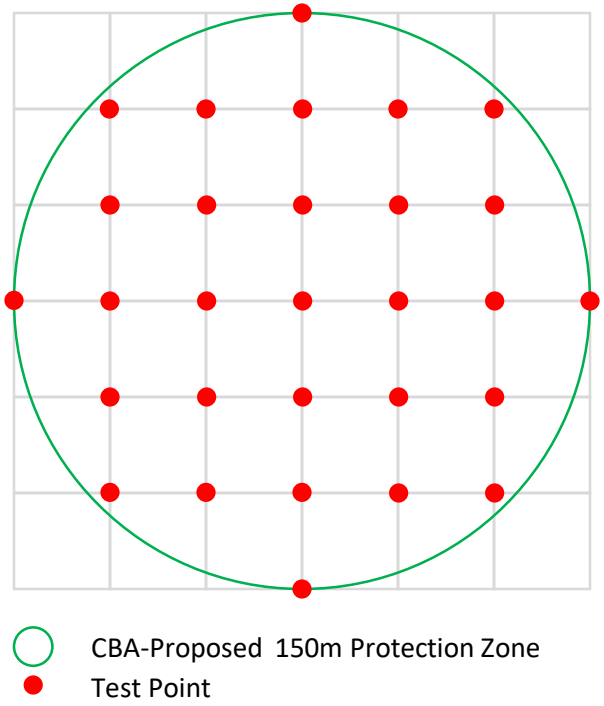
* Coordination proposal based on CBA Reply Comments, GN Docket 18-122 (filed Dec. 11, 2018)

CBA Proposed C-band FSS Protection Req'ts

- CBA proposal would aggregate radiofrequency (RF) power density at the output of a reference RF filter and antenna of an FSS earth station produced by emissions from all Fixed and Base Stations of a 5G licensee within 40 kilometers:
  - For in-band emissions, the RF power density "shall not exceed a value of -81.6 dBm/MHz in the band 3700-3900 MHz"
  - For OOB emissions in the FSS band, the RF power density "shall not exceed a value of -133 dBm/MHz for earth stations used for satellite [TT&C] operations and -128 dBm/MHz for other earth stations."
- The protection requirement must be complied with:
  - "for any pointing of the antenna towards the [GSO] arc with an elevation angle greater than or equal to 5 degrees" and
  - "for all earth station antennas within a radius of 150 meters of the location of the registered earth station."

Simulation Assumptions

- Propagation model and protection methodology identical to FCC-approved CBRS model for adjacent spectrum
  - NTIA ITS Irregular Terrain Model (ITM) (Longley-Rice) (20MHz-20 GHz) model in point-to-point mode
  - CBA proposed an FSS antenna pattern similar to the 25.209 rules
- Protection assessed for 150m radius around registered ES
  - A 50m x 50m grid is generated for the area around each registered ES
  - Protection requirements assessed at each grid point within 150m radius



Simulation Assumptions (Cont'd)

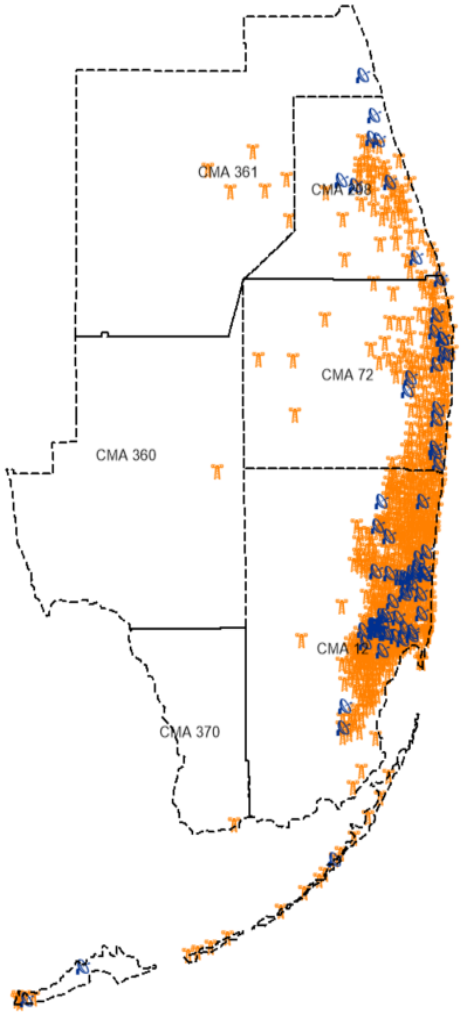
- Used extreme satellite arc positions at 18° W and 139° W*
  - ES antenna azimuth angle is a key factor, with antenna elevation, to determine receive (Rx) antenna gain.
  - Where interference is close to the protection threshold, variations in the Rx antenna gain could cause thresholds to be exceeded; further work will be conducted to evaluate the impact over the entire satellite arc.

ES Reference Antenna Mask	
G = 52.6 dBi	for $0^\circ \le \varphi < 1.5^\circ$
G = 2 - 25 log φ dBi	for $1.5^\circ \le \varphi < 7^\circ$
G = 8 dBi	for $7^\circ \le \varphi < 9.2^\circ$
G = 32 - 25 log φ dBi	for $9.2^\circ \le \varphi < 48^\circ$
G = -10 dBi	for $48^\circ \le \varphi \le 180^\circ$

* The 18° W and 139° W limits were derived by considering only FCC authorized space stations for C-band GSO FSS operations that would have resulted in look angles no less than the 5° specified by the CBA for the Miami area.

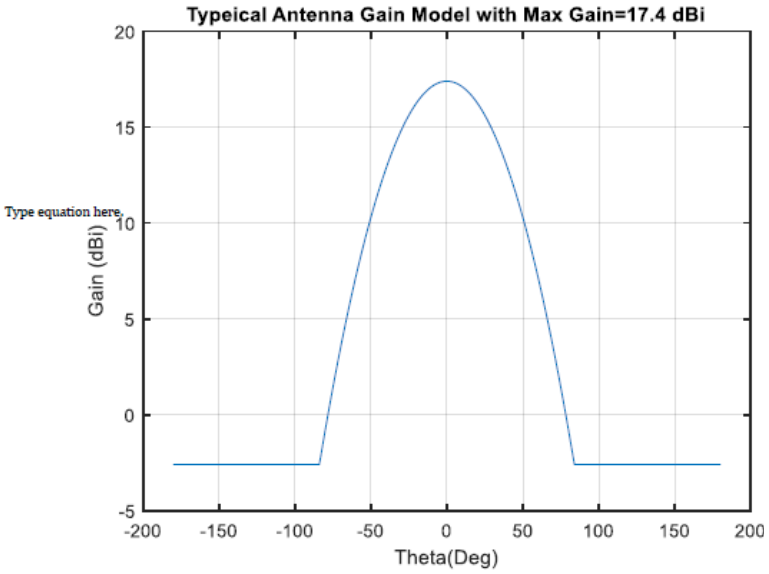
5G Network Parameters

- Used AT&T Miami market grid layout
  - Included 2000+ sectors belonging to urban, suburban & rural site geographies
  - Base station heights ranged from 10 to 300 ft
  - Sector orientations ranged from 0 to 357 degrees North
  - 78 unique FSS earth station (ES) locations analyzed, using the 40 km “neighborhood” defined by CBA



5G Network Parameters (Cont'd)

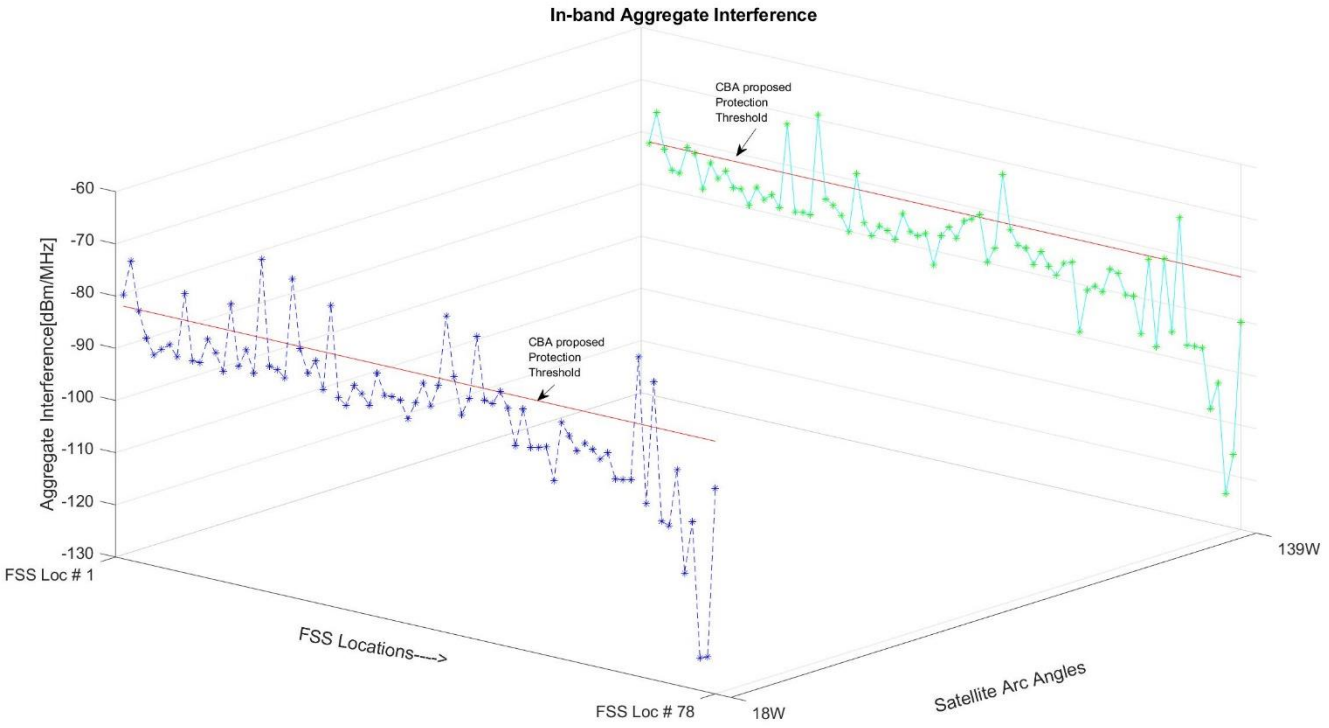
- The study assumed FCC Part 27 parameters:
  - Base Station EIRP is 75 dBm/10 MHz channel (65 dBm/MHz) in rural areas
  - Base Station EIRP is 72 dBm/10 MHz channel (62 dBm/MHz) in other areas
  - 65° antenna beamwidth and antenna pattern consistent with current CBRS modeling and AT&T network
  - 10 MHz carrier adjacent to CBA–specified 20 MHz guard band (*i.e.*, 20 MHz offset from FSS band edge)



$$G(\theta) = -min\left[12\left(\frac{\theta}{\theta_{3dB}}\right)^2, \quad A_H\right] \ (dBi)$$

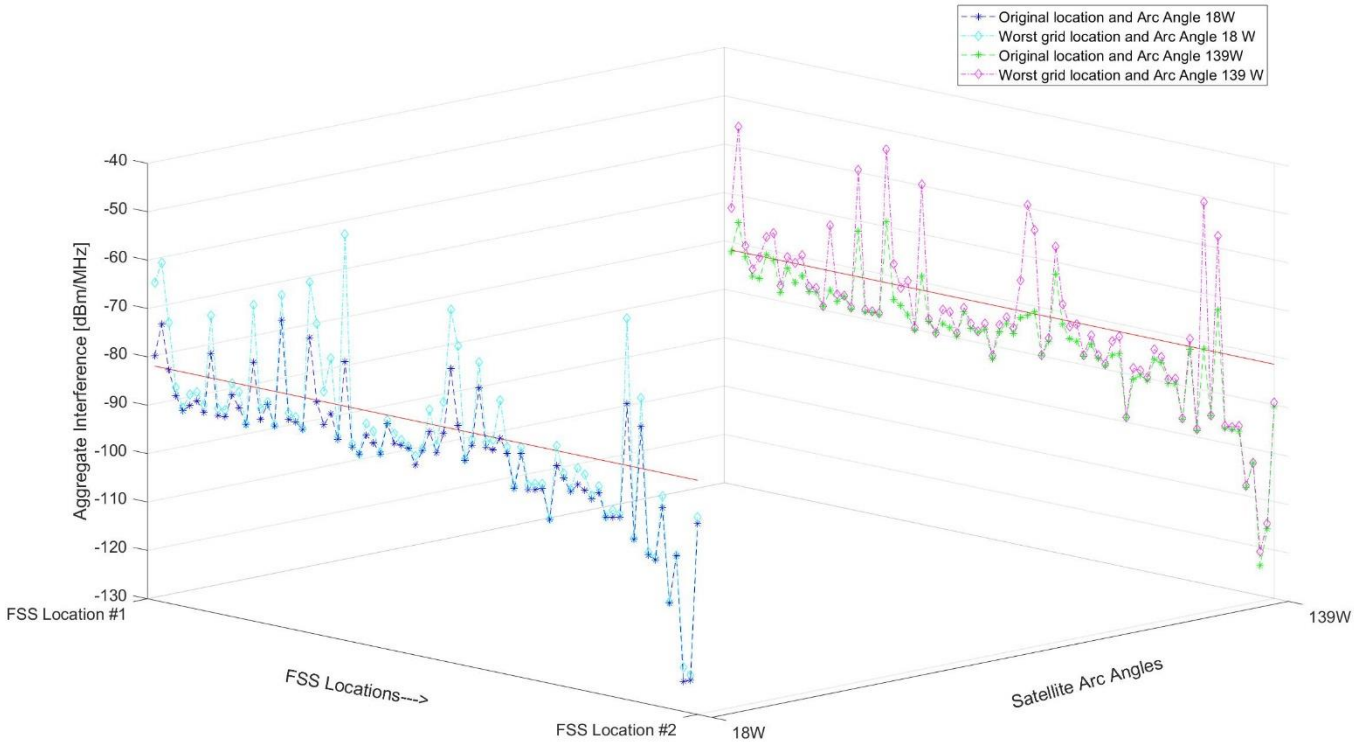
$$Gain(\theta) = G(\theta) + MaxGain$$

In-Band Interference Testing Results



- The aggregate mean interference from BS crosses the CBA-proposed threshold in 14 out of 78 FSS ES locations analyzed
- The CBA-proposed threshold is exceeded at **17.9%** of ES locations

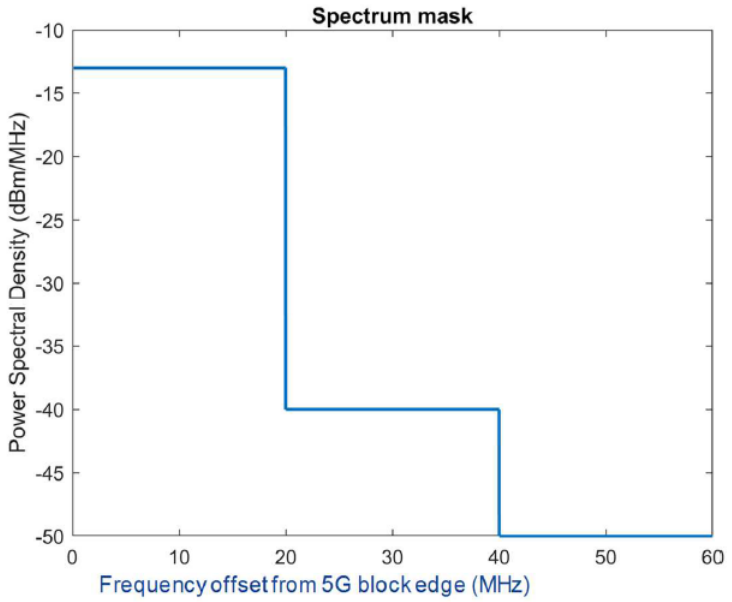
In-Band Interference Testing Results w/150m Radius Protection Zone



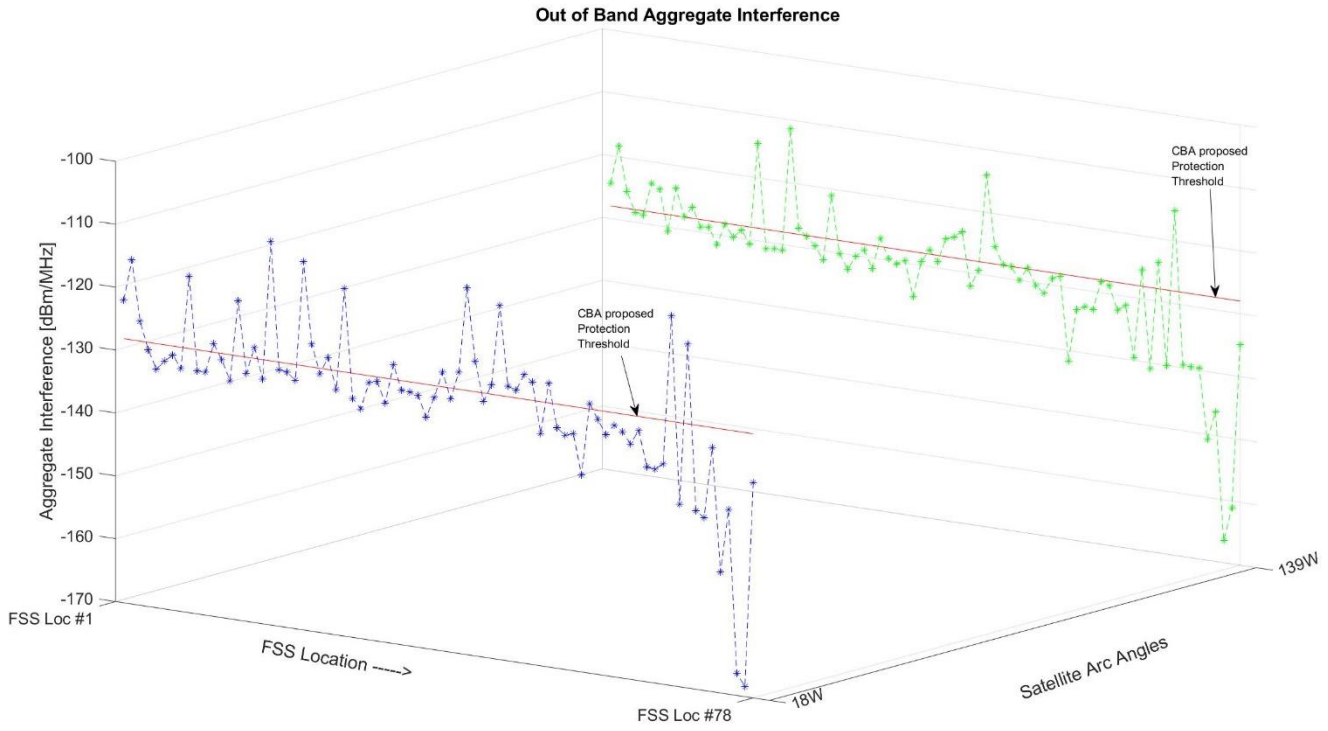
- The aggregate mean interference from BS crosses the CBA-proposed threshold in 26 out of 78 FSS ES protection zones analyzed
- The CBA-proposed threshold is exceeded at **33.3%** of FSS protection zones

Additional Assumptions for OOB Analysis

- OOB Analysis uses an emission mask based on CBA filing
  - -13dBm/MHz from 0 to 20 MHz frequency offset
  - -40 dBm/MHz from 20 to 40 MHz frequency offset
  - -50 dBm/MHz for frequency offsets greater than 40 MHz
- Base Station OOB emission power into the FSS passband is -40 dBm/MHz
- Used OOB threshold of -128 dBm/MHz used
  - Does not implement added CBA-proposed protection for TT&C ES locations where more stringent requirement (-133 dBm/MHz) would apply

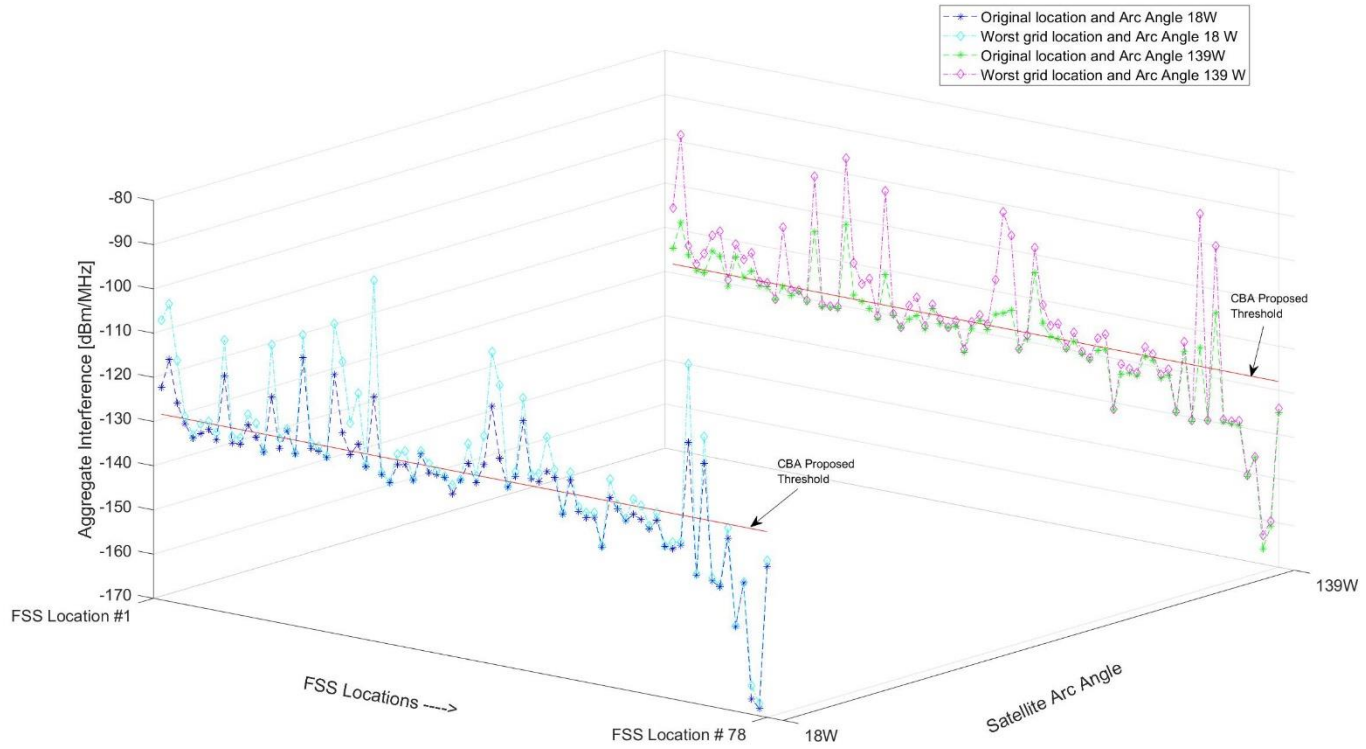


OOB Interference Testing Results



- The aggregate mean interference from BS crosses the CBA-proposed threshold in 33 out of 78 FSS ES locations analyzed
- The CBA-proposed threshold is exceeded at **42.3%** of ES locations

OOB Interference Testing Results w/150m Radius Protection Zone



- The aggregate mean interference from BS crosses the CBA-proposed threshold in 47 out of 78 FSS ES protection zones analyzed
- The CBA-proposed threshold is exceeded at **60.3%** of FSS protection zones

In Depth Review of ES Locations

- Analyzed FSS ES locations where in-band/out-of-band thresholds exceeded
  - Representative situations, not worst or best case
  - Goal is identification of cause of high mean aggregate interference at FSS
- Three locations analyzed
- A single dominant interferer uses most of the protection margin and therefore aggregation cap is unnecessary and complex rule

In Depth Review ES Location 1

- Viacom Services Corp.
  - Callsign E090157
  - 25.9240, -80.2180
  - 4.5m antenna height
- 1342 impacting BS locations

	Sat. Arc Pos.: 18° W Az: 102.9702° El: 16.4426°	Sat. Arc Pos.: 139° W Az: 255.1603° El: 19.5911°
Aggregate Power In-Band, dBm	-66.5671	-72.1264
Aggregate Power OOB, dBm	-108.9661	-114.5235

Registered Earth Station Location

Fixed/Base Station site

Azimuth direction for the Earth Station Antenna for the given Satellite arc positions

Azimuth direction for one of the Base Station at the site location

In Depth Review ES Location 1

- BS w/greatest impact
  - 25.9242, -80.2174
  - Antenna Height: 29.5732m
  - Antenna Azimuth: 230°
  - EIRP: 62 dBm/MHz
  - Antenna Gain: 17.6 dBi

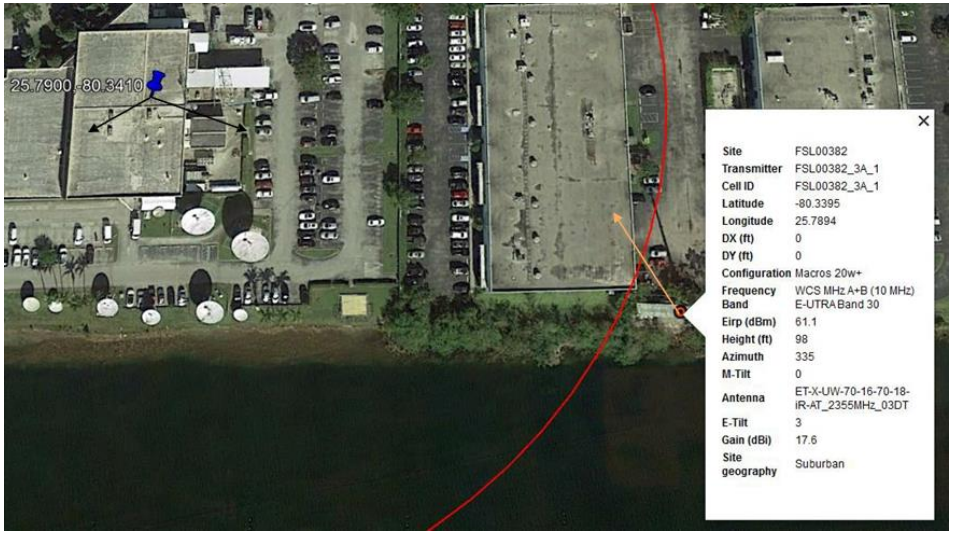
	Sat. Arc Pos.: 18° W Az: 102.9703° El: 16.4426°	Sat. Arc Pos.: 139° W Az: 255.1603° El: 19.5911°
Mean Power In-Band, dBm	-66.7108	-72.3276
Mean Power OOB, dBm	-109.1108	-114.7276

	5G BS Tx Power (dBm)	Path Loss (dB)	5G BS Antenna Gain (dBi)	FSS RF Filter Attenuation (dB)	FSS ES Rx Antenna Gain (dBi)	In-Band Median Power (dBm)
Sat. Arc Pos.: 18° W Az: 102.9702° El: 16.4426°	44.4	-79.7524	16.0689	-43	-4.3832	-66.6667
Sat. Arc Pos.: 139° W Az: 255.1603° El: 19.5911°	44.4	-79.7524	16.0689	-43	-10	-72.2835

	5G BS Tx Power (dBm)	Path Loss (dB)	5G BS Antenna Gain (dBi)	FSS RF Filter Attenuation (dB)	FSS ES Rx Antenna Gain (dBi)	OOB Median Power (dBm)
Sat. Arc Pos.: 18° W Az: 102.9702° El: 16.4426°	-40	-79.7524	16.0689	-1	-4.3832	-109.0667
Sat. Arc Pos.: 139° W Az: 255.1603° El: 19.5911°	-40	-79.7524	16.0689	-1	-10	-114.6835

In Depth Review ES Location 2

- CBS Television Stations, Inc.
  - Callsign E8359
  - 25.7900N, -80.3410W
  - 5m antenna height
- 1181 impacting BS locations



	Sat. Arc Pos.: 18° W Az: 102.8451° El: 16.3611°	Sat. Arc Pos.: 139° W Az: 255.1601° El: 19.7400°
Aggregate Power In-Band, dBm	-69.3013	-82.1932
Aggregate Power OOB, dBm	-111.7006	-124.6591


Registered Earth Station Location


Fixed/Base Station site

Azimuth direction for the Earth Station Antenna for the given Satellite arc positions

Azimuth direction for one of the Base Station at the site location

In Depth Review ES Location 2

- BS w/greatest impact
  - 25.7894, -80.3395
  - Antenna Height: 29.8780m
  - Antenna Azimuth: 335°
  - EIRP: 62 dBm/MHz
  - Antenna Gain: 17.6 dBi

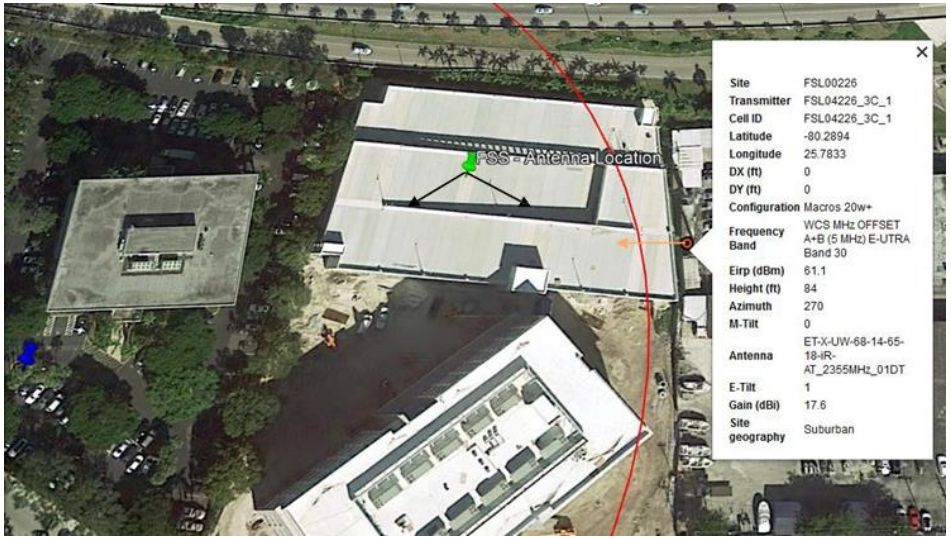
	Sat. Arc Pos.: 18° W Az: 102.8451° El: 16.3611°	Sat. Arc Pos.: 139° W Az: 255.1601° El: 19.7400°
Mean Power In-Band, dBm	-69.7507	-83.9139
Mean Power OOB, dBm	-112.1507	-126.3139

	5G BS Tx Power (dBm)	Path Loss (dB)	5G BS Antenna Gain (dBi)	FSS RF Filter Attenuation (dB)	FSS ES Rx Antenna Gain (dBi)	In-Band Median Power (dBm)
Sat. Arc Pos.: 18° W Az: 102.8451° El: 16.3611°	44.4	-87.919	12.6492	-43	4.1632	-69.7066
Sat. Arc Pos.: 139° W Az: 255.1601° El: 19.7400°	44.4	-87.919	12.6492	-43	-10	-83.8698

	5G BS Tx Power (dBm)	Path Loss (dB)	5G BS Antenna Gain (dBi)	FSS RF Filter Attenuation (dB)	FSS ES Rx Antenna Gain (dBi)	OOB Median Power (dBm)
Sat. Arc Pos.: 18° W Az: 102.8451° El: 16.3611°	-40	-87.919	12.6492	-1	14.2744	-46.7364
Sat. Arc Pos.: 139° W Az: 255.1601° El: 19.7400°	-40	-87.919	12.6492	-1	-10	-71.0108

In Depth Review Loc. 3 w/150m Protection Zone

- Salem Comm. Hldg Corp.
  - Callsign E181290
  - 25.7835N, -80.2900W
  - 3.8m antenna height
- 1182 impacting BS locations



	Sat. Arc Pos.: 18° W Az: 102.8451° El: 16.3611°	Sat. Arc Pos.: 139° W Az: 255.1601° El: 19.7400°
Mean Power In-Band, dBm	-69.7507	-83.9139
Mean Power OOB, dBm	-112.1507	-126.3139


Registered Earth Station Location


Fixed/Base Station site

Azimuth direction for the Earth Station Antenna for the given Satellite arc positions

Azimuth direction for one of the Base Station at the site location

In Depth Review Loc. 3 w/150m Protection Zone

- BS w/greatest impact
  - 25.7833, -80.2894
  - Antenna Height: 25.6098m
  - Antenna Azimuth: 270°
  - EIRP: 62 dBm/MHz
  - Antenna Gain: 17.6 dBi

	Sat. Arc Pos.: 18° W Az: 102.8690° El: 16.4094°	Sat. Arc Pos.: 139° W Az: 255.1919° El: 19.6950°
Mean Power In-Band, dBm	-46.7805	-71.0549
Mean Power OOB, dBm	-89.1805	-113.4549

	5G BS Tx Power (dBm)	Path Loss (dB)	5G BS Antenna Gain (dBi)	FSS RF Filter Attenuation (dB)	FSS ES Rx Antenna Gain (dBi)	In-Band Median Power (dBm)
Sat. Arc Pos.: 18° W Az: 102.8690° El: 16.4094°	44.4	-79.3407	16.9299	-43	14.2744	-89.1364
Sat. Arc Pos.: 139° W Az: 255.1919° El: 19.6950°	44.4	-79.3407	16.9299	-43	-10	-113.4108

	5G BS Tx Power (dBm)	Path Loss (dB)	5G BS Antenna Gain (dBi)	FSS RF Filter Attenuation (dB)	FSS ES Rx Antenna Gain (dBi)	OOB Median Power (dBm)
Sat. Arc Pos.: 18° W Az: 102.8690° El: 16.4094°	-40	-79.3407	16.9299	-1	4.1632	-112.1066
Look Angle: 139° W Az: 255.1919° El: 19.6950°	-40	-79.3407	16.9299	-1	-10	-126.2698