Before the
FEDERAL COMMUNICATIONS COMMISSION
Washington, DC

In the Matter of	)	
	)	
Petition to Modify Parts 2 and 101 of the Commission's Rules to Enable Timely Deployment of Fixed Stratospheric-Based Communications Services in the 21.5-23.6, 25.25-27.5, 71-76, and 81-86 GHz Bands	)))))	RM-11809
	)	
Use of Spectrum Bands Above 24 GHz For Mobile Radio Services	))	GN Docket No. 14-177

REPLY COMMENTS OF ELEFANTE GROUP, INC.

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SUMMARY

By promptly placing the Petition for Rulemaking ("Petition") of Elefante Group, Inc. ("Elefante Group") on public notice, the Commission took a critical step toward enabling transformative Stratospheric-Based Communications Services ("SBCS") to be realized. None of the comments on the *Petition* identify concerns that should impede the Commission from swiftly commencing a rulemaking to consider technical, operations, and licensing rules for SBCS in the 21.5-23.6, 25.25-27.5, 71-76, and 81-86 GHz bands (respectively, the "22-23 GHz Band," the "26 GHz Band", the "70 GHz Band," and the "80 GHz Band").

Given that the *Petition* and the *Spectrum Frontiers* proceeding simultaneously raise the question of future uses of the 26 GHz Band, Elefante Group agrees with CTIA and T-Mobile that the Commission should proceed in a comprehensive fashion. Specifically, the Commission should consolidate consideration of rules for SBCS (in the 22-23 and 70/80 GHz Bands, in addition to the 26 GHz band) with other issues contemporaneously raised in the *Spectrum Frontiers* proceeding regarding the 26 GHz Band.

In addition, some comments appear to misunderstand SBCS or misinterpret the *Petition*. First, contrary to the claims in some comments, SBCS is a fixed service because it will provide communications paths between fixed points on the ground, namely two (or more) User Terminals ("UTs") or between UTs and gateway stations, switched through overhead stratospheric platform stations ("STRAPS") stationed at nominally fixed points. Consequently, as well, Part 101 is the appropriate location for SBCS-specific regulations.

Second, the *Petition* proposes SBCS definitions and technical rules that would accommodate system designs different and in addition to the particular solution planned by

Elefante Group. It is incorrect, as some commenters attempt, to conflate Elefante Group's SBCS design and the scope of the broader SBCS proposal in the *Petition*.

Third, and similarly, several commenters miss the mark when they claim that STRAPS are identical to high altitude platform stations ("HAPS"). The *Petition* proposes that STRAPS be permitted to operate over a range between 18 and 26 km altitude. By contrast, HAPS by definition would operate between 20 and 50 km. SBCS would also use different spectrum than that being considered for HAPS to achieve the proposed data throughput performance requirements and spectrum efficiency. In any event, the important thing is that the Commission move swiftly to enable SBCS and foster continued innovation, investment, and deployment to make real the many benefits from SBCS.

Fourth, some of the comments mislabel LTA airships as "balloons." Unlike "balloons," which are at the mercy of the wind for navigation and ability to serve an intended coverage area, LTA airships have a significant control, power, and propulsion system, and sophisticated aviation and navigational capabilities that allow them to station keep over the desired coverage area independent of local conditions. LTA airships are also designed to remain in service for over 10 years, while unmanned balloon solutions typically are only limited re-use vehicles.

Fifth, the *Petition* did not address airworthiness, the use of navigable airspace, protocols for expedited or emergency landings, and similar issues because these are the jurisdiction, not of the Commission, but the Federal Aviation Administration ("FAA").

In addition, attempts by a few commenters to cast aspersions that SBCS will be limited to "niche markets" and are speculative are unavailing. As explained in the *Petition*, SBCS will support next-generation network rollouts of 4G and 5G cellular backhaul services, enterprise WAN (local loop replacement), fixed broadband access for residential and small to medium size businesses, and fixed broadband services to enterprises. Leveraging the experience and expertise of Lockheed Martin for both airship and communications technologies, as well as a number of technological breakthroughs, Elefante Group will be able to timely, efficiently, and cost-effectively support and complement the principal rollout of 5G services in this country, and also to fill in "urban deserts" and rural areas. Urban deserts and rural areas are locations that may be deferred by providers for 5G services until sometime in the far future, for a variety of reasons, including infrastructure challenges, if history is any indicator.

The *Petition* underscored that SBCS is capable of operating on a compatible basis in encumbered spectrum with existing users in the spectrum proposed for SBCS. Elefante Group explained that it has already contacted numerous stakeholders to collaboratively explore sharing, and it will continue to do so. Consequently, one commenter's claim that the *Petition* seeks to exclude other services from this spectrum is fundamentally wrong, not to mention mystifying.

The *Petition* was supported by numerous compatibility analyses. A number of commenters, with interests in the spectrum bands proposed by Elefante Group, raised some questions regarding the compatibility of SBCS. Elefante Group addresses those issues, supported by further analysis prepared in conjunction with Lockheed Martin. For example, in the 22-23 GHz Band, further analysis confirms, in response to the Fixed Wireless Communications Coalition ("FWCC"), that the potential for interference from SBCS uplinks to STRAPS is far less concerning for ground-based fixed systems than that from other fixed transmitters. Also, the only potential for interference into SBCS in this Band is for interference into STRAPS receivers positioned high overhead, further confirming the basic compatibility of conventional and SBCS fixed links. Elefante Group appreciates the constructive spirit of FWCC's comments and addresses several other issues raised by FWCC regarding SBCS UT power levels, enterprise UT coordination, the lack of a proposed SBCS channel plan, coordination databases, adjacent channel protection, and conditional authorization.

Elefante Group also responds to the comments of Audacy Corporation to clarify, once again, that any potential SBCS interference into the Audacy User-to-Relay ("U2R") Return Link in the 22.55-23.55 GHz range (the "23 GHz Band") is "unlikely and would be a transient condition." Elefante Group supplements the analysis provided with its *Petition* with a study of the percentage time of interference to confirm this conclusion for Audacy's Base Service, and points to Audacy's own explanations why its Advanced Service is even less likely to experience interference. Elefante Group reiterates the importance of an interference protection criterion ("IPC") for Audacy Relay-to-User ("R2U") Forward Links, creating certainty for Audacy, its customers, and fixed service operators, including SBCS. Audacy's comments overstate the potential for interference from SBCS because it uses a limited-use case for an omnidirectional User antenna for T&C purposes to drive the 23 GHz interference analysis. Not only are other bands typically used for T&C, but Audacy contradicts its application, where it made clear that its User satellites would use highly direction antennas pointed toward the Relay Satellites.

Turning to the 26 GHz Band, where Elefante Group proposes SBCS downlinks from STRAPS to UTs, Elefante Group reiterates in response to the NRAO that its proposal does not seek to utilize the 23.6-24.0 GHz band. With this reply, Elefante Group also updates previous single-STRAPS analysis to show that, using very conservative worst-case assumptions, a multi-STRAPS scenario operating downlinks in the 26 GHz Band will not cause adjacent channel interference to Radio Astronomy that exceeds relevant interference protection criteria.

Further, Elefante Group explains that, contrary to the suggestions of CTIA and T-Mobile, the opportunity for commercial mobile in the 26 GHz Band is not unique. Commercial mobile already has access to 5.5 gigahertz of mmW spectrum, and the Commission currently has another 4.3 gigahertz under consideration. Moreover, the rationale of international harmonization for making 26 GHz available for commercial mobile is undermined because equipment frequency tuning range already makes 24 and 28 GHz harmonized with any countries that use 26 GHz for mobile. But the 26 GHz Band for STRAPS downlinks does present a unique opportunity for the realization of SBCS in this country, based on the analysis of candidate spectrum options throughout the 17-43.5 GHz range, as explained in the *Petition*. That said, Elefante Group invites commercial mobiles proponents, along with the incumbent users, to the table to discuss whether and the ways in which flexible mobile services might be able to share spectrum.

Further, focusing on the 70/80 GHz bands, or E-Band, through a number of new analyses, Elefante Group addresses FWCC's comments regarding the viability of SBCS sharing this spectrum with conventional fixed services. Regarding SES's comments seeking assurance that SBCS would not preclude FSS in the E-band, Elefante Group reviews the results of its study finding basic compatibility with OneWeb's proposed use of the E-Band for its Feeder links. Elefante Group anticipates good prospects for compatibility with a variety of other possible airborne and satellite services, although each scenario would have to be considered based on system characteristics. Moreover, SBCS Feeder downlinks in the 70 GHz Band can adequately protect radio astronomy in the adjacent 76-81 GHz band, as supported by analysis.

Finally, none of the commenters directly challenge the *Petition's* request for Section 7 treatment. Prompt action on Elefante Group's request for a rulemaking is warranted by consolidating Elefante Group's full proposal with consideration of other mmW wireless issues in the *Spectrum Frontiers* proceeding.

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REPLY COMMENTS
OF ELEFANTE GROUP, INC.

Elefante Group, Inc. ("Elefante Group"), by its attorneys, hereby replies to the comments filed in response to its Petition for Rulemaking ("Petition") seeking rules to enable transformative Stratospheric-Based Communications Services ("SBCS") in this country.[1] Elefante Group is pleased that the Commission promptly put the *Petition* on public notice within days after it was filed as a key step toward realizing a regulatory framework for SBCS. As explained herein, none of the comments identify matters that necessarily constitute a stumbling block to the Commission swiftly commencing a rulemaking to consider licensing and operational rules for SBCS in the 21.5-23.6, 25.25-27.5, 71-76, and 81-86 GHz bands.[2] Indeed, as detailed below, Elefante Group agrees with CTIA and T-Mobile that the Commission should promptly

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[1] *Petition to Modify Parts 2 and 101 of the Commission's Rules to Enable Timely Deployment of Fixed Stratospheric-Based Communications Services in the 21.5-23.6, 25.25-27.5, 71-76, and 81-86 GHz Bands*, Petition for Rulemaking, RM-11809 (May 31, 2018) ("*Petition*"). *See Consumer & Governmental Affairs Bureau Reference Information Center Petition for Rulemakings Filed*, Public Notice, Report No. 3093 (June 11, 2018).

[2] Respectively the "22-23 GHz Band," the "26 GHz Band," the "70 GHz Band," and the "80 GHz Band."

proceed in a comprehensive fashion and consolidate consideration of rules for SBCS with issues contemporaneously raised in the *Spectrum Frontiers* proceeding.

After addressing issues of consolidation in Section I, this reply proceeds in Section II to respond to those comments that misconstrue aspects of SBCS and the *Petition*. Elefante Group continues in Section III, despite the self-serving skepticism of some commenters, to reiterate that SBCS, far from being limited to a niche market, will serve critical requirements of next-generation network deployment in ways other platforms cannot, and will do so in a technically, spectrum efficient, and economically feasible fashion. In Section IV, Elefante Group responds to questions raised by commenters regarding certain compatibility issues, none of which raise insurmountable concerns. As emphasized throughout the *Petition*, Elefante Group and Lockheed Martin designed the Elefante Group SBCS system to be compatible with a broad range of incumbents, which is in large part due to leveraging the altitude in which all SBCS would operate (and so not unique to Elefante Group's design).[3] In this reply, Elefante Group refines certain aspects of its proposals for SBCS rules, supported by considerable further analysis conducted by Lockheed Martin and Elefante Group, which is appended hereto.[4] Finally, in Section V, Elefante Group notes that none of the commenters question that the *Petition* qualifies for Section 7 treatment and prompt action on Elefante Group's request for a rulemaking.[5]

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[3] *Petition* at 2.

[4] *See infra* Exhibits 1-9. The technical parameters used for the analyses are set forth in Exhibit 1.

[5] 47 U.S.C. § 157.

I. THE COMMISSION SHOULD CONSOLIDATE THE ISSUES RAISED IN THE *PETITION* WITH THE *SPECTRUM FRONTIERS* PROCEEDING

At the time Elefante Group filed its *Petition*, it urged the Commission to promptly put the *Petition* out for Public Notice.[6] Elefante Group appreciates that the Commission did exactly that. At the same time, Elefante Group urged the Commission to consider future uses of the 26 GHz Band – *i.e.*, SBCS and flexible mobile use – in a comprehensive fashion.[7] In their comments, CTIA and T-Mobile, focused on the same band, also effectively embrace this consolidated approach.[8] While these two commenters are concerned with the extent to which the Commission might consider rules for SBCS separately from addressing to what extent, and under what conditions, other new services might be granted access to the 26 GHz Band, Elefante Group believes that their espousal of a comprehensive examination is generally the correct approach.

Given the current circumstances, where the *Petition* and the *Spectrum Frontiers* proceeding simultaneously raise the question of future uses of the 26 GHz Band, the Commission should take advantage of the situation and address both in a single consolidated fashion. This will best preserve the Commission's flexibility to develop a coherent regulatory

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6 *See* Letter of Edward A. Yorkgitis, Jr., Counsel to Elefante Group, Inc., to Marlene Dortch, Secretary, FCC, GN Docket Nos. 17-183, 14-177, IB Docket No. 17-95, WT Docket No. 10-112, File No. SAT-LOA-20161115-00117, 5 (May 29, 2018) (requesting that the Commission expeditiously place the *Petition* on Public Notice and incorporate consideration of the *Petition* as part of the *Spectrum Frontiers* proceeding) ("*May 29 Ex Parte*"); Letter of Edward A. Yorkgitis, Jr., Counsel to Elefante Group, Inc., to Marlene Dortch, Secretary, FCC, GN Docket Nos. 17-183, 14-177, IB Docket No. 17-95, WT Docket No. 10-112, 2 (May 31, 2018) ("*May 31 Ex Parte*").

7 *See May 29 Ex Parte* at 5; *May 31 Ex Parte* at 2.

8 *See* Opposition of CTIA, RM-11809, 1 (July 11, 2018) ("[I]f the Commission determines to evaluate the issues raised by the Elefante Petition relating to the 25.25-27.5 GHz ('26 GHz') band, it should do so within the context of the pending *Spectrum Frontiers* docket.") ("*CTIA Opposition*"); Opposition of T-Mobile USA, Inc., RM 11809, 8 (July 11, 2018) (recommending that Elefante Group's *Petition* should be "considered in light of the Commission's ongoing *Spectrum Frontiers* proceeding") ("*T-Mobile Opposition*").

framework for the 26 GHz Band that best serves the public interest in terms of access to and compatible operations with the federal systems that currently use and are planned for the Band. More specifically, the Commission should either clarify the *Third FNPRM* in *Spectrum Frontiers* to allow a comprehensive examination and timely adoption of rules or swiftly issue a FNPRM in *Spectrum Frontiers* to effectuate the consolidation.[9] Issuing a new *FNPRM* in the *Spectrum Frontiers* proceeding would have the added advantage of permitting all aspects of the *Petition*'s SBCS proposal to be included (*i.e.*, use of the 22-23 and 70/80 GHz Bands for SBCS, in addition to the 26 GHz Band), which will allow the Commission to take comprehensive action to make SBCS a reality.[10]

II. COMMENTS DISPLAYING A MISUNDERSTANDING OF SBCS AND THE *PETITION* WARRANT CONFIRMATION AND CLARIFICATION

A. SBCS Are a Fixed Service

As set out in the *Petition*, SBCS are a fixed service, contrary to some of the comments received.[11] SBCS will provide communications paths between fixed points, namely two (or more) fixed User Terminals ("UTs") on the ground or between UTs and fixed gateway stations. These fixed points are identifiable to the exacting geometric specificity quoted from Section

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[9] *Use of Spectrum Bands Above 24 GHz For Mobile Radio Services*, *et al.*, GN Docket No. 14-177, *et al.*, Third Report and Order, Memorandum Opinion and Order, and Third Further Notice of Proposed Rulemaking, FCC 18-73 (June 8, 2018) ("*Third FNPRM*").

[10] By way of comparison, the Commission has issued multiple notices within the *Spectrum Frontiers* proceeding to address the regulatory framework in the shared 37.0-37.6 GHz range, the so-called Lower 37 GHz Band. *See, e.g.*, *Third FNPRM* at ¶¶ 26-29; *Use of Spectrum Bands Above 24 GHz For Mobile Radio Services*, *et al.*, GN Docket No. 14-177, *et al.*, Report and Order and Further Notice of Proposed Rulemaking, 31 FCC Rcd 8014, ¶ 105 (2016) ("*First Spectrum Frontiers Order*" or "*First Spectrum Frontiers Further Notice,*" as applicable).

[11] *See* Comments of Audacy Corporation, RM No. 11809, 4-6 (July 11, 2018) (arguing that SBCS does not qualify as a fixed service under Part 101 of the Commission's rules) ("*Audacy Comments*").

101.103(d) of the Commission's rules.[12] For multiple reasons, including dramatically increasing spectrum reuse, reducing compatibility issues, and possessing the ability to service high rate fixed terminals anywhere within a large area (rather than being constrained by the need to create a mix of multiple local loops using fiber laydowns or shorter microwave hops), SBCS radio communication is relayed through an overhead platform with network capabilities positioned at a nominally fixed point. While the paths would go through stratospheric platform stations ("STRAPS") exhibiting a certain amount of mobility, they would be authorized only to operate, and obligated to station keep, within a prescribed volume (which will facilitate coordination and compatibility, not undermine it).[13] Moreover, the STRAPS are *not* one of the points of communication in the way the UTs and gateways are, which define the service, and the STRAPS serve much the same role as a satellite, whether non-geostationary or geostationary (but still moving within a certain volume), in the *Fixed* Satellite Service ("FSS").[14]

Of the Commission's existing rule parts, the most appropriate location for SBCS rules, therefore, is Part 101. Notably, Part 101 is used to regulate a number of different fixed services. In addition to both the common carrier and private operational fixed point-to-point microwave service links, Part 101 is used to regulate, for example, the Local Multipoint Distribution Service, Digital Electronic Message Service, Multichannel Video Distribution and Data Service, and Multiple Address Service, each of which have specific rules in separate subparts.[15] It is

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[12] 47 C.F.R. § 101.103(d).

[13] *See Petition* at 12-16.

[14] Further, as explained in the *Petition*, STRAPS would only operate UT and feeder links when they are at station, not during ascent or descent or while *en route* to or from station. *See id.* at 86.

[15] *See* 47 C.F.R. §§ 101.501-101.538, 101.1001-101.1017, 101.1301-101.1333, 101.1401-101.1440.

entirely appropriate to include regulations for radio communications between two fixed SBCS stations – UTs and gateway stations – within Part 101 rather than generating an entirely new allocation and a new part within Title 47 to regulate it. Further, the coordination of SBCS UT links with ground-based fixed links fits best as a modification to Part 101 rules, as set out in the *Petition* and discussed further in this reply.[16] Similarly, the same is true regarding the coordination of SBCS feeder links.[17]

Nonetheless, some commenters question whether the Part 101 rules are the appropriate location for SBCS-specific regulations.[18] For the reasons set out above, Elefante Group submits that they are. Tellingly, none of the commenters with clear fixed service interests – such as the Fixed Wireless Communications Coalition (representing a multitude of fixed service licensees) and T-Mobile (with many Part 101 licenses) – take issue with Elefante Group's proposal to incorporate SBCS rules in Part 101. At the end of the day, however, whether the SBCS rules are contained in a modified Part 101 including a new subpart[19] or a new rule part does not affect the status of SBCS as a Fixed Service or its priority within the bands in question.[20] If the Commission believes that a new Fixed Services rule part for SBCS is administratively convenient, Elefante Group has no objection.

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16 *Petition* at 85-103.

17 *Id.*

18 *See Audacy Comments* at 4-6; Comments of SES Americom, Inc. and O3b Limited, RM No. 11809, 3-4 (July 11, 2018) ("*SES Americom/O3b Comments*").

19 *SES Americom/O3b Comments* at 3-4 (supporting a subpart to Part 101 to address sharing between SBCS and FSS).

20 While the Commission determined to create a new Part 30 to accommodate Upper Microwave Flexible Use Services ("UMFUS"), which included converted Part 101 Local Multipoint Distribution Services in the 28 and 39 GHz Bands, that was appropriate given that the UMFUS licenses were envisioned as primarily mobile in nature. *See First Spectrum Frontiers Order* at ¶ 161.

B. The Proposed SBCS Category Includes More than the Elefante Group's Proposed System

Certain commenters' conflation of Elefante Group's SBCS design and the broader SBCS proposal in the *Petition* are simply off the mark and reflect a misreading of the *Petition*.[21] The *Petition* proposes SBCS definitions and technical rules that would accommodate system designs different and in addition to the particular solution planned by Elefante Group. The regulatory provisions that Elefante Group included in the *Petition* for SBCS were designed to achieve and maintain compatible access and operation, yet provide reasonable flexibility for variance in SBCS system design. For example, the *Petition* envisions a sharing framework that minimizes the need for protection zones and other measures that would place restrictions on incumbents or SBCS that preclude operation at certain times or places.[22] Rather, these are broader parameters under which a variety of SBCS can operate on a shared basis, including those which rely on fixed-wing aircraft and lighter-than-air ("LTA") airships, which may plan to operate at different altitudes, with differing coverage areas, and serve different markets. At the same time, the parameters Elefante Group proposes for SBCS cannot be unlimited in their flexibility. Without some basic technical and operational rules of the road within narrow, but not restrictive, parameters, the high degree of sharing and maximum spectrum utilization by SBCS that Elefante Group envisions will not be achievable.

In pursuing rules for SBCS, Elefante Group has intentionally been as general as possible to permit innovation in development of implementations for nominally fixed stratospheric platforms efficiently enabling connections between fixed locations on the ground. These

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21 *See Audacy Comments* at 1-2; Comments of Loon LLC, RM-11809, 3 (July 11, 2018) ("*Loon Comments*").

22 *Petition* at 79-81.

include, for example, incorporating power flux density ("PFD") limits adopted from FSS for STRAPS downlinks to UTs and proposing UT effective isotropic radiated power ("EIRP") density limits to ensure compatibility of SBCS uplinks to STRAPS with other services by protecting them without dictating the implementation of uplinks like aperture size or power.[23] Elefante Group also proposed regulations governing UT gain pattern envelopes be specified only to the extent necessary to ensure compatibility between two or more SBCS so their coverage of markets is not mutually exclusive or incompatible with incumbent services.[24] As such, Audacy's and Loon's claims that Elefante Group looks for rules tailored solely to its operational system are completely misplaced.

C. STRAPS and HAPS Are Not Equivalent Categories

Several comments miss the mark when they claim that STRAPS are identical to HAPS, implying vaguely that this is a reason not to grant the *Petition*.[25] That this is even relevant is not clear, but in any event the assertion of equivalence is wrong.

The *Petition* proposes that STRAPS of SBCS operators be permitted to operate over a range between 18 and 26 km altitude.[26] (Elefante Group has chosen to operate at a nominal altitude of 19.8 km with small variances above and below that mark depending on stratospheric wind conditions as the right altitude for its airship system design.)[27] Elefante Group made this

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23 *Id.* at 92-101.

24 *Id.* at 94-95, Appendices T-U.

25 Further, while HAPS are not equivalent to SBCS, the scattered spectrum bands designated for HAPS in the United States Table of Frequency Allocations, even including those that are being considered at WRC-19 in Region 2, would be incapable of supporting SBCS as envisioned by Elefante Group. For example, 1 Tbps capacity in each direction would be impossible, and sufficient spectrum for feeder links would not be available either.

26 *Petition* at 86.

27 *Id.* at 13.

proposal recognizing that other STRAPS designs may contemplate different configurations operating at higher altitudes than it plans to – including systems with STRAPS that would operate by design above 20 km and qualify for the technical definition of HAPS.[28]

Thus, the altitude range proposed by the *Petition* would accommodate *some* systems that qualify as HAPS, which by definition in the ITU and the Commission's rules operate above 20 km and below 50 km, as well as those that operate below the HAPS threshold, such as the Elefante Group system in light of operational considerations for station keeping.[29] The STRAPS definitions would exclude platform stations that operate above 26 km, which would include certain stations that qualify as HAPS.[30] Moreover, SBCS would also use different spectrum than that being considered for HAPS to achieve the proposed SBCS data throughput performance targets and spectrum efficiency. As a result, the suggestion of Audacy Corporation and the National Radio Astronomical Observatory ("NRAO") that the proposed SBCS and HAPS categories are identical is misguided.[31]

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[28] This is the case with several of the systems being considered as reference HAPS systems in the ITU's Agenda Item 1.14 for WRC-19. World Radiocommunication Conference 2019 (WRC-19), Agenda and Relevant Resolutions, Agenda Item 1.14 (revised Aug. 15, 2017), available at https://www.itu.int/dms_pub/itu-r/oth/14/02/R14020000010001PDFE.pdf. *See* references to platform altitude between 18 and 26 km for various "systems" in Table 2 in Annex 14 of the Report on the 19th meeting of Working Party 5C (Geneva, November 6-15, 2017), available at https://www.itu.int/md/R15-WP5C-C-0410/en/.

[29] *See* 47 C.F.R. § 2.1(c).

[30] As discussed below, the regulatory framework Elefante Group advocates for is not intended to and does not require that all SBCS look like the planned Elefante Group system. *Petition* at 48.

[31] *See Audacy Comments* at 6 ("Elefante's balloon-based communications proposal represents a near-textbook example of a HAPS system."); Opposition and Comments of the National Radio Astronomy Observatory, RM-11809, 1-2 (June 25, 2018) ("Elefante Group's version of HAPS is still HAPS.") ("*NRAO Comments*").

In any event, the overlap between HAPS and STRAPS categories is a red herring. The important thing is that the Commission move swiftly to enable SBCS so as to foster continued innovation, investment, and deployment in stratospheric communications platforms. Such action will allow Elefante Group and others to bring the benefits of such services to the public in a timely fashion. Of particular importance, the Commission should not wait for the ITU to act with regard to HAPS before it moves to develop SBCS rules. Not only will such delay negatively impact the timeliness of SBCS deployment, but there are strong policy reasons for the Commission to act independently of the ITU's consideration of HAPS designations to ensure adequate spectrum is available for SBCS in the United States to bring about the many public interest benefits of SBCS, as detailed in the *Petition*.[32] Indeed, as the Commission is well aware, it has many times in the past not felt itself constrained in its domestic decisions either in terms of timing or scope by what has or might happen in the ITU processes.[33] Of course, this is wholly consistent with ITU regulations which, in the end, preserve national sovereignty over domestic

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32 *Petition* at 6-12, 110-13.

33 Recent examples abound in the *Spectrum Frontiers* proceeding, where the Commission acted at variance with bands that the ITU determined to examine for international mobile telecommunications ("IMT"). *See, e.g., First Spectrum Frontiers Order* at ¶¶ 58-89 (licensing 27.50-28.35 GHz for UMFUS on a shared basis with FSS even though the frequencies were not an ITU study band); *Use of Spectrum Bands Above 24 GHz For Mobile Radio Services*, *et al.*, GN Docket No. 14-177, *et al.*, Second Report and Order, Second Further Notice of Proposed Rulemaking, Order on Reconsideration, and Memorandum Opinion and Order, 32 FCC Rcd 10988, ¶¶ 200 (2017) ("*Second Spectrum Frontiers Order*") (declining to authorize mobile operations in the 71-76 GHz and 81-86 GHz bands, contrary to ITU studies looking at IMT in those bands). The Commission also has acted ahead of the ITU to make spectrum available for next-generation technologies. *See, e.g., Auctions of Upper Microwave Flexible Use Licenses for Next Generation Wireless Services*, AU Docket No. 18-85, Public Notice, FCC 18-109, ¶¶ 28-120 (Aug. 3, 2018) (establishing auction procedures for the 24.25–24.45 GHz, 24.75–25.25 GHz, and 27.5–28.35 GHz bands ahead of completion of ITU studies); *Use of Spectrum Bands Above 24 GHz For Mobile Radio Services*, GN Docket No. 14-177, Fourth Further Notice of Proposed Rulemaking, FCC 18-110, ¶¶ 9-54 (Aug. 3, 2018) (proposing rule changes and revised band plans in the 37.6-38.6 GHz, 38.6 GHz-40 GHz, and 47.2-48.2 GHz bands ahead of completion of ITU IMT studies).

spectrum decisions consistent with treaty obligations related to avoiding cross-border interference consistent with ITU frequency allocations. Nothing in the *Petition* would run contrary to the United States' abilities to fulfill its treaty obligations, as Elefante Group consistently proposed SBCS, a fixed service, in bands allocated internationally in Region 2 to the Fixed Service.

D. STRAPS Are Airships under Power and Very Different from Balloons

Some of the comments display a basic misunderstanding of what LTA airships are, calling them "balloons."[34] Unlike "balloons," which rely upon changes in winds for navigation and targeting coverage areas, LTA airships have a significant control, power, and propulsion system, as well as sophisticated aviation and navigational capabilities that free them from being victim to local conditions and allow them to station keep over the desired coverage area within narrow parameters in the face of considerably strong stratospheric winds for greater than 6 months.[35] These LTA systems are critical for ascent, transit, and descent in the highly controlled manner needed for large-scale operation and aviation safety. LTA airships are also designed to operate and be maintained out of near-space ports in order to remain in service for over 10 years, while balloon solutions, typically, are only single-use craft, typically with unknown landing sites.

For similar reasons, suggestions that STRAPS operating in an SBCS configuration are mobile or itinerant misconstrues Elefante Group's proposal.[36] As noted earlier, SBCS radio

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34 *Audacy Comments* at 6.

35 The same is the case with reported fixed-wing stratospheric solutions. *See, e.g.*, Facebook, "The technology behind Aquila" (July 21, 2016), available at https://www.facebook.com/notes/mark-zuckerberg/the.../10153916136506634/; Airbus, "Zephyr" (June 12, 2017), available at https://www.airbus.com/defence/uav/zephyr.html. *See also Petition* at 48-50 (discussing other planned stratospheric communications solutions).

36 Note that pursuant to individually granted waivers, "itinerant" operation may be possible, and could serve important public interest benefits in cases of storms and natural disasters to support recovery. *See generally* Comments of the Elefante Group, Inc., PS Docket No. 17-344

communication will be switched through STRAPS located at nominally fixed points in the stratosphere, meaning it would be authorized only to operate and obligated to station keep within a prescribed volume.

E. The *Petition* Need Not Address Issues Within the FAA's Jurisdiction

Curiously, Audacy faults the *Petition* for not addressing issues regarding the use of navigable airspace, protocols for expedited or emergency landings, and the specifics of the station-keeping systems of STRAPS.[37] However, as Audacy should know, these issues are not within the jurisdiction of the Commission. Elefante Group and Lockheed Martin are addressing STRAPS' airworthiness certification and these issues directly with the Federal Aviation Administration ("FAA"), just as Lockheed Martin has done in the past with previous LTA manned and unmanned airships and aircraft. The Commission should not hold off moving to a rulemaking while the companies address these matters with the FAA, particularly given that there will potentially be many different types of SBCS and STRAPS designs.

III. SBCS WILL PROVIDE KEY SUPPORTS TO NEXT-GENERATION NEEDS: DENSIFICATION, 4G/5G BACKHAUL, ENTERPRISE WAN, AND FIXED BROADBAND ACCESS

Several of the commenters seek to cast the *Petition* in a negative light by suggesting SBCS will be limited to "niche markets" and by calling SBCS speculative.[38] As further detailed in this Section, building on the extensive discussion already in the *Petition*, SBCS deployments will serve urban and rural markets, offering low-latency, high-capacity capabilities that will be

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(Jan. 22, 2018). But that is not the core operating scenario behind the SBCS proposal and need not be addressed at this time.

[37] *Audacy Comments* at 7.

[38] *T-Mobile Opposition* at 1; *Audacy Comments* at 2. *See CTIA Opposition* at 2 (stating that SBCS represent "untested" technology).

critical to next-generation network deployments.[39] SBCS, with day-one ubiquitous reach within large service areas (after a STRAPS deployment), will be able to support network densification in urban areas, providing the critical elements of backhaul to small cell deployments *regardless of frequency band* for 5G, 4G, and IoT applications.[40] Similarly, in less populated and rural areas, SBCS will provide critical connectivity in hard-to-access and bypassed areas.[41] Further, SBCS will support enterprise WAN and fixed consumer Internet access throughout an airship's coverage area, and in combination with inter-airship capabilities – whether cross-links[42] or using terrestrial or satellite networking capabilities – over much larger areas.[43] None of these markets are "niche," either in coverage or in terms of service, and any suggestion that they are may just be a manifestation of the concerns of competitors in the face of emerging SBCS. And, again, the SBCS solutions envisioned by Elefante Group are completely flexible and are not dependent on the spectrum in which the SBCS wholesale customers have licenses.

Moreover, as Elefante Group explained in detail in the *Petition*, its SBCS systems will leverage significant investment and operational experience with LTA craft gained by Lockheed

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39 *Petition* at 3.

40 *Id.* at 22.

41 *Id*.

42 As noted in the *Petition,* Elefante Group did not propose spectrum bands for cross-links between STRAPS. *Id.* at 19-20. Audacy, perhaps coming from its perspective as a hopeful provider of inter-satellite service, a type of cross-link, questions the lack of such a proposal. *Audacy Comments* at 2. There is nothing particularly notable in this. While cross-links are not a requirement for SBCS, Elefante Group acknowledged some SBCS deployments may want to involve cross-links (as Elefante Group itself may want to employ in the future). Elefante Group reiterates its request that, even though it has not proposed cross-links rules at this time, the frequencies addressed in the *Petition* not be precluded from being considered in the future for possible use as SBCS cross-links upon a proper demonstration. *Petition* at 19-20.

43 *Petition* at 25-27.

Martin in work for its government customers.[44] Building on technological breakthroughs in material science, avionics, solar cells, batteries, and communication architectures, SBCS are both technically feasible and commercially viable.[45] Moreover, major commitments to developing and deploying stratospheric platforms are occurring not only in the United States, but also Europe and Asia.

A. 4G/5G Backhaul and Advanced Broadband Services for All Are Vital Existing Markets, Not Niche or Unproven Markets

In its comments, T-Mobile makes the unsupported claim that SBCS are "an untested service that may serve a niche market less efficiently than existing proven services."[46] On the contrary, the innovative services that can and will be provided by Elefante Group and other SBCS operators will carry on the disruptive tradition of wireless communications. The types of services outlined in the *Petition*[47] are central to next-generation network rollouts of 4G and 5G cellular backhaul services, enterprise WAN (local loop replacement), fixed broadband access for residential and small- to medium-size businesses, and fixed broadband services to enterprises. Wholesale customers of Elefante Group's SBCS, for example, will be provided connectivity to their customers' UTs throughout a 15,400 km^2 service area on day one, something no other service provider can offer.[48] These are hardly niche markets.

Moreover, while some of the needs that SBCS will support may be offered by other network providers, none of these providers can offer a complete turnkey backhaul and

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44 *Id.* at 7, 108.

45 *Id.* at 6-12, 107-110.

46 *T-Mobile Opposition* at 1.

47 *See Petition* at 22-29.

48 *Id.* at 3.

networking solution, ubiquitously and rapidly, in such a large coverage area – or solutions that can be as readily upgraded market-wide as can SBCS solutions. In the *Petition*, Elefante Group explained the advantages of SBCS in deployment efficiency (scope and speed of ubiquitous coverage),[49] spectral efficiency, payload, customizability and upgradability, and network adaptation.[50]

T-Mobile's attempted criticisms are misplaced in other ways, too. Although T-Mobile and Elefante Group agree that Internet traffic will continue to increase dramatically in the coming years, by faulting Elefante Group for not discerning that data over mobile devices are projected to soon exceed that of fixed services,[51] T-Mobile reveals that it misunderstands the capabilities of SBCS. SBCS will support the growing capacity needs for both fixed and mobile services because both types of services are dependent on backbone, fixed network capabilities. Indeed, a recent PWC report showing mobile data overtaking fixed broadband data consumption (in 2019) noted that both categories of data are supported by fixed broadband networks.[52] Rarely is any wireless service completely wireless end-to-end. According to a 2017 Deloitte Consulting LLP report, "[w]ireline broadband access supports as much as 90 percent of all Internet traffic

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49 *Id.* at 42-43. Within a 70 km radius service area, nearly any point within that service area is provided coverage immediately without the encumbrance faced by other, ground-based solutions characterized by incremental network builds involving multiple hops and equipment, which often have bypassed areas to create urban deserts and failed to reach rural communities in a timely fashion.

50 *Id.* at 43-48. SBCS also offers distinct advantages over ground-based systems in terms of communications reliability and restoration during and after natural disasters.

51 *T-Mobile Opposition* at 3 (showing mobile data surpassing fixed in 2018) (citing *Industry Data*, CTIA, https://www.ctia.org/the-wireless-industry/infographics-library).

52 PWC "Perspectives from the Global Entertainment & Media Outlook 2018-2022," 10 (2018), available at https://www.pwc.com/gx/en/industries/tmt/media/outlook.html. As noted in the report, "Wi-Fi hot spots are becoming ubiquitous in public spaces." *Id.*

even though the majority of the traffic ultimately terminates on a wireless device."[53] The source of the data consumed by a mobile device, handset, or tablet requires point-to-point fixed services including switching and backhaul, which can be cost-effectively met by SBCS as proposed by Elefante Group. The needs SBCS will support are characteristics of mobile network operators, hot spot operators, wireless Internet service providers, Internet transit providers, and cable companies for services they offer today and the next-generation services and applications that will place additional demand for backhaul.

B. Elefante Group's Planned Deployments will be Timely Relative to Planned Deployments of Next-Generation Services by the Major Carriers

Elefante Group plans to begin commercial launches of its SBCS solutions in 2022.[54] This will be timely in terms of supporting major rollouts of 5G by this nation's largest mobile carriers. While the major mobile carriers are to be lauded for accelerating earlier plans to begin rollout of 5G fixed or mobile services in some cities starting this year and others in 2019,[55] more

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53 *See* Deloitte Consulting LLP, "Communications Infrastructure Upgrade: The Need for Deep Fiber," 4 (July 2017) ("*Deloitte Infrastructure Report*") (internal citation omitted), available at https://www2.deloitte.com/us/en/pages/consulting/articles/communications-infrastructure-upgrade-deep-fiber-imperative.html. AT&T also has recognized the need for fiber backhaul for fixed 5G services. AT&T CFO John Stephens argued that backhaul is a key component to any fixed wireless 5G service, and that AT&T believes it might be more effective to just deliver Internet services via its growing fiber network. *See* FierceWireless, "AT&T CFO throws shade on Verizon's fixed 5G plans" (Apr. 25, 2018), available at https://www.fiercewireless.com/5g/at-t-cfo-throws-shade-verizon-s-fixed-5g-plans.

54 *See Petition* at 21-22.

55 *See, e.g.*, AT&T, "AT&T to Launch Mobile 5G in 2018" (Jan. 4, 2018), available at http://about.att.com/story/att_to_launch_mobile_5g_in_2018.html (describing plans to introduce mobile 5G service in a dozen markets by late-2018); FierceWireless, "Verizon's 5G plans begin to sharpen" (May 4, 2018), available at https://www.fiercewireless.com/5g/verizon-s-5g-plans-begin-to-sharpen (stating that Verizon will deploy fixed 5G service in 3-5 cities by the end of 2018); engadget, "T-Mobile promises 30 '5G-ready' cities this year, but no actual 5G" (Feb. 27, 2018), available at https://www.engadget.com/2018/02/27/t-mobile-will-prep-30-cities-for-5g-in-

full scale deployments are still likely several years away in the early 2020s. Even in the markets that are the first beneficiaries of the carriers' 5G rollouts, there may remain areas of various sizes that will not receive next-generation capabilities.

In all cases, the timing of 5G deployment in any given locality will depend, among other factors, upon additional fiber build out or other forms of network connectivity, connectivity which SBCS solutions can provide and accelerate when and where alternatives are not available due to difficulty of buildout, municipal regulation, cost, or other considerations. Tellingly, according to the *Deloitte Infrastructure Report*, the United States is not well prepared to take advantage of 5G and its potential for dramatic economic stimulation because the country as a whole will not have the fiber infrastructure to support the projected four-fold increase in mobile data traffic ***by 2021*** that will come with 5G rollout.[56] As discussed above, the same report notes that wireline facilities support 90 percent of all Internet traffic, even though the majority may terminate at a mobile device.[57] Elefante Group submits that fiber alone will not be capable of ensuring ubiquitous rollout in markets in a timely fashion due to all of the issues being address in the *Wireline Infrastructure* proceeding, and other similar matters.[58] SBCS will be a key contributor to a comprehensive solution that wins the race to 5G.

Public statements of the major mobile carriers regarding their 5G rollout plans suggest that at first they will be geographically limited and that they will face a number of issues that will

2018/ (discussing T-Mobile announcement to deploy mobile 5G service to 30 cities by the end of 2018 and nationwide coverage by 2020).

[56] *See Deloitte Infrastructure Report* at 3-4.

[57] *Id.* at 4.

[58] *See, e.g.*, *Accelerating Wireline Broadband Deployment by Removing Barriers to Infrastructure Investment*, WC Docket No. 17-84, Notice of Proposed Rulemaking, Notice of Inquiry, and Request for Comment, 32 FCC Rcd 3266 (2017).

complicate and delay widespread buildout. For example, AT&T has announced that it plans to begin introduction of 5G mobile service in portions of twelve cities based on the current – *i.e.*, non-final – 3GPP standards by the end of 2018[59] by utilizing its millimeter wave spectrum and to make 5G-capable devices (what types is not clear) available starting in early 2019.[60] However, that leaves the vast majority of American markets for subsequent deployment by AT&T, and it is also unclear how extensive the rollouts will be within those first dozen markets. Questions remain regarding how much 5G service will cost, how good 5G coverage will be as compared to LTE in areas that have it, and how reliable it will be versus LTE.[61]

A similar story applies to Verizon. It intends to launch fixed 5G service in at least four markets by the end of 2018, based on Verizon's proprietary 5G Technology Forum standard.[62] While Verizon plans subsequently to update its networks to conform to 3GPP standards, it has

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59 *See* AT&T, "AT&T to Launch Mobile 5G in 2018" (Jan. 4, 2018), available at http://about.att.com/story/att_to_launch_mobile_5g_in_2018.html.

60 *See, e.g.*, AT&T, "AT&T Builds on 5G Foundation in More Than 100 New Markets" (Apr. 20, 2018), available at http://about.att.com/story/att_builds_on_5g_foundation_in_more_than_100_new_markets.html; AT&T, "Ready to Launch: How 2 Years of 5G Trials is Preparing Us for Commercial Deployment" (Apr. 10, 2018), available at http://about.att.com/innovationblog/two_years_of_5g_tria; engadget, "AT&T will launch real mobile 5G in 12 cities this year" (Jan. 4, 2018), available at https://www.engadget.com/2018/01/04/att-true-mobile-5g-launch-plans/; CNN.com, "AT&T names first three cities to get its ultra-fast 5G network" (Feb. 21, 2018), available at https://money.cnn.com/2018/02/20/technology/att-5g-mobile-network-cities/index.html.

61 *See, e.g.*, CNET, "AT&T shows how fast US 5G could be" (Apr. 10, 2018), available at https://www.cnet.com/news/5g-att-how-fast-us-speeds/; telecompetitor, "AT&T: The Business Case for Fixed 5G is Ugly, Verizon Seems to Beg to Differ" (May 30, 2018), available at https://www.telecompetitor.com/att-the-business-case-for-fixed-5g-is-ugly-verizon-seems-to-beg-to-differ/.

62 *See* engadget, "Verizon will turn on 5G in LA this year" (May 15, 2018), available at https://www.engadget.com/2018/05/15/verizon-5g-coming-to-los-angeles/; techradar.pro, "Verizon and Samsung get 5G boost" (May 8, 2018), available at https://www.techradar.com/news/verizon-and-samsung-get-5g-regulatory-boost.

understandably not provided a timetable for this conversion. Verizon plans additional rollouts in 2019, ultimately targeting 25%-30% of all broadband households for its 5G service deployment.[63] Verizon has said it cannot estimate until late-2019 the cost of building out service nationwide,[64] but acknowledged that billions of dollars in investment for fiber deployment will be required. Industry observers suggested that 5G network expansions will be slow and depend on whether Verizon can make the business case to offset high deployment costs.[65]

T-Mobile has announced that it plans to deploy 5G mobile service to 30 cities by the end of 2018 relying on its recently acquired 600 MHz band (spectrum subject to transition from current broadcast licensees through mid-2020),[66] but will not begin providing "nationwide"

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63 *See* VentureBeat, "Verizon CEO: 5G coming end of 2018; expect competition on capability, not price" (May 4, 2018), available at https://venturebeat.com/2018/05/04/verizon-ceo-5g-coming-end-of-2018-expect-competition-on-capability-not-price/; ZDNet, "Verizon launching 5G in Los Angeles" (May 16, 2018), available at https://www.zdnet.com/article/verizon-launching-5g-in-los-angeles/; FierceWireless, "Verizon CFO: Mobile 5G 'not a 2018 activity'" (Oct. 19, 2017), available at https://www.fiercewireless.com/wireless/verizon-cfo-mobile-5g-not-a-2018-activity; Business Insider, "Verizon just announced Los Angeles will be the second city to receive 5G" (May 18, 2018), available at https://www.businessinsider.com/verizon-5g-los-angeles-2018-5; Fortune, "Why Verizon's 5G Home Internet Service Isn't Coming to You Anytime Soon" (Nov. 30, 2017), available at http://fortune.com/2017/11/30/verizon-5g-home-internet/.

64 *See* Fortune, "Why Verizon's 5G Home Internet Service Isn't Coming to You Anytime Soon" (Nov. 30, 2017), available at http://fortune.com/2017/11/30/verizon-5g-home-internet/.

65 Telecompetitor, "Analyst: Verizon 5G Fixed Wireless Competitive Threat is Modest at Best" (Jan. 15, 2018), available at https://www.telecompetitor.com/analyst-verizon-5g-fixed-wireless-competitive-threat-modest-best/.

66 T-Mobile, "T-Mobile Announces Plans for Real Nationwide Mobile 5G" (May 2, 2017), available at https://www.t-mobile.com/news/nationwide-5g; T-Mobile, "T-Mobile Building Out 5G in 30 Cities This Year . . . and That's Just the Start" (Feb. 26, 2018), available at https://www.t-mobile.com/news/mwc-2018-5g; T-Mobile, "T-Mobile Ready to Rock New Spectrum With First 600 MHz LTE Smartphone & 5G-Ready Network Gear" (Aug. 30, 2017), available at https://www.t-mobile.com/content/t-mobile/corporate/news/articles/2017/08/tmobile-600mhz.html.

coverage until 2020.[67] It is unclear how well and how quickly T-Mobile will be able to advance toward this goal.[68]

C. Wireless Buildouts have Left Urban Deserts and have Failed to Address Rural Infrastructure Obstacles

To date, broadband solutions have not yet served all Americans to close the Digital Divide, even in urban areas. Even when the mobile carriers announce completion of rollout for a new technology like 4G within any given service area, urban deserts still remain. The cause of an urban desert may be financial, regulatory, or the limits of a technology. For example, though 4G technologies have been deployed for many years, anyone with a mobile phone knows that there are urban and suburban areas where they cannot get service or routinely drop a call (or lose mobile Internet connectivity) despite the ongoing network optimizations undertaken by mobile network operators. The reality is that there are limits to the technology and the ability of operators to consistently deploy service throughout a market that results from a variety of factors. In addition to helping wholesale customers initiate, augment, and upgrade next-

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67 *See* engadget, "T-Mobile plans to launch a national 5G network by 2020" (May 2, 2017), available at https://www.engadget.com/2017/05/02/t-mobile-plans-national-5g-network-by-2020/; T-Mobile, "Setting the 5G Record Straight: Announcing Plans for Nationwide 5G from T-Mobile" (May 1, 2017), available at https://www.t-mobile.com/news/nationwide-5g-blog.

68 Some observers have raised questions about T-Mobile's level of detail in its 5G network announcements and its ability to provide reliable 5G service over its existing spectrum holdings, suggesting that the company needs to deploy significantly more cell sites to meet its proposed service goals. *See* FierceWireless, "T-Mobile to build – but not necessarily sell – 5G in 30 cities this year" (Feb. 27, 2018), available at https://www.fiercewireless.com/5g/t-mobile-to-build-but-not-necessarily-sell-5g-30-cities-year (noting concerns regarding service speeds and limited propagation in high-band spectrum); The Verge, "T-Mobile says it will launch a nationwide 5G network in three years" (May 2, 2017), available at https://www.theverge.com/2017/5/2/15514998/t-mobile-nationwide-5g-network-2020-three-years-600-mhz-spectrum (highlighting lack of detail in T-Mobile's deployment plans); eWeek, "T-Mobile Achieves Major Milestone in Deploying 5G Wireless" (July 30, 2018) (discussing challenges faced by T-Mobile in deploying additional cell sites to support its nationwide network).

generation solutions in those parts of the market where wholesale carrier customers are most interested, STRAPS deployment will lower the barriers to deploying broadband and next-generation solutions throughout the service areas.

In short, with SBCS, as envisioned by Elefante Group, there will be a massive reduction in urban deserts or unreached areas within the 15,400 km^2 coverage area served by STRAPS and there is no discrimination or lack or delay of coverage based on the inability to obtain rights of way, higher costs for deployment in certain areas, or commercial decisions not to deploy network services in areas that may be expected to have reduced adoption of the services offered. There will be no disadvantage due to economic conditions, population density, or technological limits. Even overbuild cost recovery concerns are minimized due to the "instant" coverage over 15,400 km^2 with a single STRAPS.

By way of further illustration of the benefits SBCS offers, fiber-to-the-home ("FTTH") broadband and voice is not available to the majority of U.S. households. The Fiber Broadband Association reports that FTTH services passed approximately 30.4 million households in the United States in 2016[69] (out of the nearly 126 million households at the time).[70] The challenge for fiber deployment is often the cost of overbuilding existing cable networks to gain a commercial foothold in the market. Finally, other technologies, such as copper-based digital subscriber lines are disappearing as the copper lines are retired by the major incumbent carriers in many markets, reducing availability of broadband in many locations. As explained in the

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69 *See* Comments of the Fiber Broadband Association on the Thirteenth Section 706 Report Notice of Inquiry, GN Docket No. 17-199, 4-5 (Sept. 21, 2017).

70 *See* U.S. Census Bureau, Table HH-1. Households by Type: 1940 to Present, available at https://www2.census.gov/programs-surveys/demo/tables/families/time-series/households/hh1.xls.

Petition, one of the markets that Elefante Group envisions its SBCS solutions serving is fixed residential (and small business) broadband.[71]

Rural infrastructure obstacles mirror those in urban areas described above, but with magnified effect. Rural areas often only have lower-speed satellite broadband options because the cost to build ground-based networks to support high-speed IP access or mobile services in rural areas is not always supported by the economic return. In any event, rural areas are often the last areas built out – if they are ever built out – as an operator needs to recoup the cost of developing and deploying the new technology. Again, by drastically reducing the barriers to deployment, SBCS hold the promise to allow rural areas to receive the advantages of next-generation solutions much faster than they would if history continues to repeat itself in terms of unbalanced capabilities in urban versus rural areas.

D. SBCS Are Technically Feasible, as Demonstrated in the *Petition*, Not Speculative

As detailed in Sections II and X.B of the *Petition*, by drawing on Lockheed Martin's decades of experience with LTA system development and communications technologies, and further breakthroughs in the relevant technologies pursuant to the collaboration between Elefante Group and Lockheed Martin over the past thirty months, Elefante Group's plans for SBCS are technically feasible.[72] Lockheed Martin has an unparalleled airship legacy that traces its LTA origins back more than a century with the development of manned and unmanned vehicles for the military and the construction of over 300 airships to date. Further, recent advances in

71 *See Petition* at 3.

72 *Id.* at 6-12, 107-108.

communications technologies that can be deployed at relatively low size, weight, and power have enabled significant increases in the communications capacity possible on LTA platforms.[73]

By working with Lockheed Martin, Elefante Group has the advantage of drawing on world-class expertise to deploy reliable state-of-the art communications on stratospheric platforms. The STRAPS payload is based on the well-established Lockheed Martin heritage commercial satellite technologies operating in a much more benign environment as compared to the satellites orbiting in space. The payload proposed by Elefante Group builds on the foundation of well-established satellite spot beam technologies used on Ka and Ku band geostationary orbit ("GSO") satellites. Similarly, the Elefante Group payload radio electronics leverage existing technologies used for operational high-throughput satellites for first-time use in the stratospheric environment. Further underscoring the feasibility of Elefante Group's solution, the STRAPS environment does not require radiation hardening to the same level as a low earth orbit, medium earth orbit, or GSO satellites, which significantly reduces the relative risk of building the STRAPS payload.

[73] Development of unmanned technologies, flexible materials (fabrics), control systems, solar arrays, rechargeable batteries, and propulsion systems has also accelerated rapidly within the past 15 years by both commercial and government investments. Lockheed Martin continues to develop these technologies for the commercial marketplace beyond that proposed by Elefante Group. Lockheed Martin is also developing the Hybrid Airship to revolutionize remote transportation. Lockheed Martin, "Hybrid Airship," available at https://www.lockheedmartin.com/en-us/products/hybrid-airship.html. The Hybrid Airship is designed to affordably deliver heavy cargo and personnel to remote locations around the world. The first demonstrator was flown more than 10 years ago, attesting to the maturity of the technology. Additional key technologies in advanced hull materials have been developed over decades of internal research and development funding as well as successful flight operations. Lockheed Martin has developed unique flexible materials, power systems, operational models, advanced computational fluid dynamics analytic methods, and airship command and control systems. Indeed, Lockheed Martin was the first company to demonstrate the first large LTA unmanned airship that was approved to fly in the U.S. National Airspace System outside of restricted areas.

In the last 15 years, Lockheed Martin led the development of two stratospheric airship programs (High Altitude Airship or "HAA"[74] and Integrated Structure is Sensor) for U.S. government agencies. Both programs developed foundational technologies essential for successful deployment of SBCS, including fabric development, hull designs, power systems, propulsion, vehicle management, communications, and ground systems. In addition, power cell technologies from Lockheed Martin Space have been developed based on decades-long experience in the design of highly reliable power subsystems for space systems.[75]

Further, Elefante Group and Lockheed Martin are not the only industry leaders that have explored the technical feasibility of stratospheric airships. Efforts to develop stratospheric airships are still underway within Airbus[76] and Thales,[77] and possibly others including the Chinese. Additionally, at least one entity previously involved in the development of such an aircraft continues to be heavily involved in component development to support stratospheric

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[74] The HAA program morphed into the High Altitude Long Endurance-Demonstration ("HALE-D") program, as discussed in the *Petition*. *See Petition* at 7, n.4.

[75] Solar-based regenerative power systems on HALE-D included the first use of flexible substrate solar cells, producing twice the power density of conventional satellite solar arrays. Lockheed Martin has flown the largest single lithium ion battery on an aerial platform that included state-of-the-art energy density, 30% higher than previous lithium ion cells. Continuing development of solar array and battery technologies will only enhance the capabilities and proven technologies used on the proposed STRAPS.

[76] *See* Lavars, Nick, "Airbus' Solar-Powered Zephyr Smashes Flight Duration Record on Maiden Outing," New Atlas (Aug. 9, 2018), available at https://newatlas.com/airbus-zephyr-s-flight-duration-record/55824/ (reporting that Zephyr recently completed an unmanned, solar powered flight of 25 days, 23 hours and 57 minutes).

[77] *See* Thales, "Stratobus: Why this Stratospheric Airship is Already Being Called a 'Swiss Knife' in the Sky" (May 22, 2018), available at https://www.thalesgroup.com/en/worldwide/space/magazine/stratobus-why-stratospheric-airship-already-being-called-swiss-knife-sky.

flight by others,[78] collaboration with another stratospheric airship developer,[79] and leadership worldwide in securing spectrum for high altitude airships.[80]

E. Elefante Group's Services will have Cost Advantages over Other Deployments

The *Petition* detailed the operational advantages for next-generation networks over other delivery systems.[81] In addition, Elefante Group believes STRAPS-based services will have significant cost advantages over deployment of other technologies. With a significantly large payload capability when compared to other small stratospheric platforms targeting only rural/remote coverage and able only to provide low-capacity services, plus the ability to station-keep over the long mission duration of 6 to 12 months, SBCS platforms can avoid significant cost and delays in deployment. Deployment of ground-based networks requires multiple design and deployment processes beyond just the installation of customer premises equipment. These processes can include access to rights of way, multi-site leasing, outside plant construction of both the main network to pass the location of interest and the lateral run to connect the location, various electronic installations across the network to link the various elements together, vendor

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78 *See* Business Insider, "Facebook abandons its plans to build giant drones and lays off 16 employees" (June 26, 2018), available at https://www.businessinsider.com/aquila-facebook-scraps-plans-build-its-own-internet-drones-2018-6 ("'We've decided now is the right moment to focus on the next set of engineering and regulatory challenges for HAPS connectivity,' Facebook's Yael Maguire wrote in a blog post.").

79 Facebook, "Facebook and Airbus Working Together to Advance High Altitude Connectivity" (Nov. 19, 2017), available at https://code.fb.com/connectivity/facebook-and-airbus-working-together-to-advance-high-altitude-connectivity/; Business Insider, "Facebook abandons its plans to build giant drones and lays off 16 employees" (June 26, 2018), available at https://www.businessinsider.com/aquila-facebook-scraps-plans-build-its-own-internet-drones-2018-6.

80 FlightGlobal, "Facebook, Airbus team up on high-altitude UAVs" (Nov. 21, 2017), available at https://www.flightglobal.com/news/articles/facebook-airbus-team-up-on-high-altitude-uavs-443533/ (noting Facebook's ITU lobbying efforts).

81 *See Petition* at 41-51.

and weather delays, multi-jurisdictional entanglements, and other cost elements not required for an SBCS platform.[82] These processes are compounded when they need to cover large market-sized areas, similar to what a single STRAPS can cover within its footprint without facing these same concerns to anywhere near the same degree.

The Commission currently has two ongoing proceedings to address some of the barriers to wireline and wireless broadband infrastructure investment and deployment.[83] The record in those proceedings is replete with examples of barriers and costs impacting broadband deployment that SBCS solutions will allow providers to avoid in large part, if not completely.

For example, a June 27, 2018, letter filed by CTIA identifies "five specific types of regulations or requirements that have been identified as substantially delaying or deterring service,"[84] which are:

- Moratoria, whether express or *de facto*;
- Denial of access to municipal-owned utility poles and other structures;
- Requirements that all facilities along rights-of-way be underground;

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[82] The cost advantage is significant when considering the area covered by a single STRAPS platform of approximately 15,400 km^2. Building a terrestrial network to service such an area would normally be a multi-year event. Construction would likely begin in dense urban areas with the most challenges. Expansion of networks outside the urban core to suburban, and then adjacent rural areas covering an equivalent coverage area of a single STRAPS would only occur over years. In comparison, once airborne over a desired service area, SBCS are available over the entire 15,400 km^2 area.

[83] *See Accelerating Wireline Broadband Deployment by Removing Barriers to Infrastructure Investment*, WC Docket No. 17-84, Notice of Proposed Rulemaking, Notice of Inquiry, and Request for Comment, 32 FCC Rcd 3266 (2017); *Accelerating Wireless Broadband Deployment by Removing Barriers to Infrastructure Investment*, WT Docket No. 17-79, Votice of Proposed Rulemaking and Notice of Inquiry, 32 FCC Rcd 3330 (2017).

[84] Letter of Kara Romagnino Graves, Director, Regulatory Affairs, CTIA, to Marlene Dortch, Secretary, FCC, WT Docket Nos. 17-79, 16-421, WC Docket No. 17-84, 2 (June 27, 2018).

- Requirements to prove a service coverage gap or other business need; and
- Subjective or unpublished aesthetic restrictions or those that discriminate against wireless deployment.[85]

All of these categories of restrictions have costs associated with them and can lead to substantial delays. Elefante Group is encouraged to see the Commission trying to address these types of barriers to broadband deployment. However, there are limits to the Commission's jurisdiction and therefore its ability to help reduce these costs. For example, many companies trying to deploy broadband facilities have complained about exorbitant fees charged by railroads for rights-of-way crossing and other application related costs.[86] In such cases, the Commission's authority to address such charges by railroads is unclear.

What is clear is that SBCS and STRAPS deployments enjoy a large advantage by being able to scale almost instantly with fewer network elements to deploy (just an airship and the customers' UT are needed) and are not impacted by the same barriers and costs to deployment as traditional ground-based networks. This provides SBCS with up to a five times lower total cost of ownership based on the premises connected.

Enabling SBCS deployments by providing access to spectrum and adopting appropriate technical, operational, and licensing rules are important ways the Commission can help providers overcome such deployment obstacles.

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85 *Id.*

86 *See, e.g.*, Letter of Robert Milar, Associate General Counsel, Crown Castle, WC Docket No. 17-84, WT Docket No. 17-79, 1 (July 3, 2018).

F. Elefante Group will Deploy Over Urban Areas, Providing Significant Rural Service Incidentally, and Later Expand to More Rural-Centric Locations

Often, the single greatest obstacle to ground-based network buildouts in remote and rural areas – areas with fewer potential customers and frequently challenging topographical features – is the associated economic costs of network buildout relative to potential return on investment. That is why in the history of new ground-based telecommunications deployments, service providers have typically deployed first in urban and more developed areas.

While Elefante Group has not hidden its intentions to first center STRAPS deployments over more urban areas to make the best business case at the outset, there is a key difference between ground-based broadband deployments and SBCS on this point. The coverage area of Elefante Group's STRAPS will be 15,400 km^2, equivalent to 6,000 mi^2.[87] Consequently, as a general matter, an Elefante Group STRAPS over an urban area will be able to serve UTs throughout an entire metro area as well as surrounding rural areas on day one of deployment. In many places within the United States, population density drops rapidly from the metro core to adjacent rural areas. Even if positioning a service area over an urban area, except in the very largest markets, there will be significant capacity that extends into rural areas.[88] This is a unique characteristic of SBCS among high-capacity terrestrial systems.

Further, Elefante Group expects that as its SBCS business becomes established, its deployments will become more rural in nature by taking advantage of increasing scale and lowered costs of STRAPS construction, deployment, equipment, and ongoing operations. Therefore, Elefante Group intends to deploy in regions surrounding its initial STRAPS coverage

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87 *Petition* at 3.

88 *See id.* at 14 (providing example of coverage over the City of San Antonio).

areas, as well as in smaller new markets, such that STRAPS service footprints would cover even higher percentages of rural and low-population territory.

IV. ELEFANTE GROUP WILL OPERATE COMPATIBLY WITH OTHER USES AND NOT EXCLUDE OTHER USES OF THE BAND

As Elefante Group made clear in the *Petition*, SBCS are capable of compatible operations with many types of incumbent users and services because of unique geometries of UT-STRAPS links and other factors.[89] Indeed, the bands chosen for SBCS in the *Petition* were the result of making compatibility a highest priority. Accordingly, one of the bedrock principles of the Elefante Group SBCS proposal is compatible operation in encumbered spectrum under a regulatory framework that allows both SBCS operators and the existing users and services to grow.[90] For this reason, Elefante Group, with the support of Lockheed Martin analyses, made careful examination of candidate spectrum bands for SBCS in the United States and the incumbent users in the band. The *Petition* was supported by twenty compatibility studies, and further complementary analysis is provided with this reply, as detailed below.[91]

The more specific regulatory provisions that Elefante Group contained in the *Petition* for SBCS were designed to achieve and maintain this sort of compatible access and operation. Elefante Group sought to minimize the need for protection zones and other measures that placed restrictions on incumbents or SBCS that precluded operation at certain times or places.[92] The regulatory specifics Elefante Group advocated for in the *Petition* were intended to allow those interested in deploying SBCS solutions to have flexibility consistent with remaining compatible

89 *Id.* at 66-79.

90 *Id.* at 2.

91 *Id.* at Appendices.

92 *Id.* at 79-81.

with incumbents in the bands in question.[93] They are parameters – including PFD limits for STRAPS downlinks and UT EIRP density limits for SBCS uplinks[94] – under which Elefante Group submits that a variety of SBCS can operate on a shared basis at different altitudes (within 18-26 km), with differing coverage areas, and serve different markets.[95] Elefante Group has intentionally been as general as possible to encourage ongoing innovation in development of implementations for nominally fixed stratospheric platforms efficiently enabling connections between fixed locations on the ground. At the same time, the parameters Elefante Group proposes for SBCS cannot be unlimited in their flexibility. Without some basic technical and operational rules of the road within narrow but not restrictive parameters, a high degree of sharing and maximum spectrum utilization will not be achievable.

In this light, any claim that the *Petition* seeks to exclude other services from the spectrum is both fundamentally wrong and extremely ironic.[96] Throughout the *Petition* (and these reply comments), Elefante Group has underscored its attempts to operate collaboratively and compatibly. Gaining access to spectrum inherently need not be the same as excluding others. And while Elefante Group continues to believe that mobile operations would have difficulty sharing with other existing and potential users in the same band without complex coordination and operational requirements, whether the others users be SBCS, federal ground-based fixed services, or federal aeronautical mobile systems, Elefante Group continues to analyze those

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[93] *Id.* at 48.

[94] *Id.* at 92-101.

[95] These are the same sorts of limits that often apply to FSS but still allow a variety of solutions to be deployed while protecting co- and adjacent-band services.

[96] *See T-Mobile Opposition* at 2.

prospects and would welcome a good faith exploration of compatibility issues with advocates of mobile service in the 26 GHz Band.

Elefante Group avers that it is no secret that, if any type of service has historically sought to exclude co-band operation (or clear spectrum, same difference), it has been commercial mobile spectrum services. Band clearing and exclusive licensing has been the model long espoused by many in the commercial mobile industry.[97] However, the tide may be turning against exclusive licensing where sharing is possible, even for mobile services. Recently, at the National Spectrum Symposium in Washington DC held in June, there was a broad recognition among administration officials as well as the representative of CTIA that the need to develop sharing frameworks is upon us.[98] Elefante Group is trying to stay out ahead of, if not help,

[97] *See* Reply Comments of T-Mobile USA, Inc., GN Docket No. 14-177, *et al.*, 14-23 (Oct. 31, 2016) (urging the Commission to make all of the many gigahertz designated for possible consideration in the 2016 *Spectrum Frontiers* Further Notice of Proposed Rulemaking, about 18 GHz in addition to the 3.85 gigahertz of spectrum made available in the First Report and Order, available for flexible mobile use on an exclusive licensed basis); Comments of T-Mobile USA, Inc., GN Docket No. 14-177, *et al.*, 20 (Sep. 30, 2016) (same). T-Mobile was not alone in this call for exclusive spectrum. *See, e.g.*, Verizon's Comments on Further Notice, GN Docket No. 14-177, *et al.*, 3 (Sep. 30, 2016); Comments of CTIA, GN Docket No. 14-177, *et al.*, 10 (Sep. 30, 2016); Comments of AT&T, GN Docket No. 14-177, *et al.*, 11-12 (Sep. 30, 2018).

[98] *See, e.g.*, NTIA Spectrum Policy Symposium Transcript at 54 (June 12, 2018) (Remarks of Rachael Bender, Wireless Policy Advisor to FCC Chairman Ajit Pai) ("So we're going to have to go with these types of sharing-from-the-beginning ideas and regimes, and that's the way we're going to be able to get more spectrum as we balance with our federal and non-federal partners. And so, I think that we don't have a choice. We're going to be doing that going forward."), available at https://www.ntia.doc.gov/files/ntia/publications/transcript-ntia-spectrum-policy-symposium-06122018.pdf; *id.* at 8-9 (Remarks of David J. Redl, Assistant Secretary for Communications and Information, NTIA) ("We need to ensure sufficient mechanisms exist to increase spectrum access, including through spectrum sharing, when that is the most effective approach . . . . We also need to leverage spectrum research, development, testing and engineering processes to elevate and deploy advanced spectrum sharing tools, dual-use technologies, and innovative ways to access these spectrum resources. We need to make meaningful progress toward establishing secure, enterprise-level spectrum management tools to help us both identify areas of greater spectrum efficiency, and to manage the coordination of shared spectrum access."); *see also id.* at 27 (Remarks of Tom Powers, General Counsel, CTIA) ("[T]his does not have to be a zero-sum game. The reality of sharing is here. Technology is improving. The idea

define the wave of promoting compatible use of spectrum among disparate types of users. In the 26 GHz Band, where permitting access by SBCS and flexible mobile users is being considered at the same time – albeit currently in two different procedural vehicles – there is a real opportunity to determine whether a sharing framework can be developed at the ground level for the benefit of the public.[99] T-Mobile's attempt to cast Elefante Group as an exclusionary force is misplaced, and, in response, Elefante Group invites T-Mobile and any other commercial proponents, along with the incumbent users, to the table to discuss whether and the ways in which flexible mobile services can share spectrum with the incumbent users in the 26 GHz Band as well as inherently compatible SBCS.

In the remainder of this section, Elefante Group addresses band-specific issues raised in the opening comments, proceeding from the 22-23 GHz Band, where Elefante Group proposes UT-STRAPS uplinks, to the 26 GHz Band, where the *Petition* advocates STRAPS-UT downlinks, and then to the 70/80 GHz Bands, where Elefante Group plans to deploy feeder links between STRAPS and ground-based gateway stations for access to terrestrial networks and facilities.

A. 22-23 GHz Band

1. 22 GHz Band Compatibility with Conventional Fixed Service

In its comments, the Fixed Wireless Communications Coalition, Inc. ("FWCC") expressed a concern that the proposed SBCS regulatory framework for the 22-23 GHz Band as described in the *Petition* – to be used for SBCS UT uplinks – might unreasonably frustrate new

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that we can do more with a finite amount of spectrum I think is something we all need to be striving for. So it doesn't have to be, as Administrator Redl was saying, you're taking from one and giving to the other. Hopefully we can make this a win/win across the board.").

99 *Third FNPRM* at ¶¶ 79-92.

conventional fixed services links.[100] In short, FWCC characterizes the existing coordination process for fixed links as providing "full protection to each existing and proposed link, while leaving the maximum practical room for the coordination of future links."[101] FWCC questions the extent to which the proposed plan for 22-23 GHz in the *Petition* would do the same, but expresses a welcome intent to work toward a solution if not. As amplified below, Elefante Group submits that it seeks no special treatment for SBCS uplinks in the 22-23 GHz Band relative to conventional ground-based fixed services and, to the extent required, clarifies its proposal on coordination to address FWCC's apparent concerns. More importantly, Elefante Group reiterates that the potential for interference from SBCS uplinks, all and all, should be no more concerning than that from ground-based fixed links among themselves.

FWCC claims that SBCS operators "would have the right to reject coordination requests anywhere in the pre-coordinated region" of a deployed STRAPS.[102] This central characterization in the FWCC comments of the *Petition*'s proposal regarding use of the 22-23 GHz Band reveals a perception that the potential for interference into SBCS systems is relatively high. In response, Elefante Group wishes to reiterate certain aspects of the framework it has proposed to correct any misunderstanding behind this perception. Indeed, Elefante Group appreciates that FWCC states that "[i]f our reading is wrong, we ask Elefante Group to clarify its view of the proposed coordination rights of SBCS vis-à-vis the FS."[103] While the STRAPS coverage area would be

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[100] Comments of the Fixed Wireless Communications Coalition, RM-11809, 4 (July 11, 2018) ("*FWCC Comments*").

[101] *See id.* at 3.

[102] *Id.* at 3. *See also id.* at 4 ("Elefante Group claims the right to reject an FS coordination request anywhere in a 15,400 square km pre-coordinated region, on any frequency in the band, even if the request does not threaten interference to a registered SBCS link.")

[103] *Id.* at 5.

pre-coordinated by an SBCS operator, it would be able to reject only those fixed links for which it receives a Prior Coordination Notice ("PCN") which would cause harmful interference to a registered STRAPS receiver. To be clear, the *Petition* proposes that the 22-23 GHz Band be available for UT uplinks only. Consequently, the airborne receiver, which is typically seen at a 15 degree or higher elevation angle over the maximum service area in the reference design, is the only SBCS node that can be interfered with by ground-based fixed service links. Based on Elefante Group's review of all domestic fixed link licenses described in the Commission's ULS database for the 22-23 GHz Band, only 3% of transmitters in the band have elevation angles higher than 15 degrees, and only 0.005% have elevation angles higher than 25 degrees. This means that very few conventional fixed links are likely to geometrically align to harmfully interfere with the STRAPS.

FWCC identifies several other aspects of the SBCS proposal that the Coalition is concerned might "further disadvantage the FS in coordinating with SBCS" or potentially expose fixed services licensees to harmful interference.[104] Elefante Group responds to each of these in turn.

Power and Geometric Isolation among Links. The Coalition expresses a worry that "[a]n SBCS link putting out maximum EIRP in a horizontal direction would take up far more frequency coordination space than a typical FS link."[105] As an initial matter, Elefante Group proposes that the maximum EIRP of UT uplinks will comply with Section 101.113 of the Commission's rules.[106] To further clarify: where adjacent band emissions described in Section

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104 *See id.* at 5-6.

105 *Id.* at 5.

106 47 C.F.R. § 101.113.

101.111(a)(2)(ii) of the Commission's rules set a required attenuation between the mean power of emission and levels out to 250% of the channel width to as low as -43 dB(W/MHz), Elefante Group's intent for SBCS is to present close to this same low level in the *co-channel* in the horizontal direction (where conventional fixed service receivers would be located) by virtue of beam roll-off from the peak, which is aimed at a high elevation angle.[107] There is no intent that SBCS would radiate at the regulatory limit in horizontal directions, and, indeed, SBCS uplinks will only present far side-lobes toward ground-based fixed service receivers.

As explained in the *Petition*, UTs will communicate with STRAPS operating only while at station, 18-26 km in altitude.[108] UTs at the edge of a STRAPS coverage area would have elevation of approximately 15 degrees and most would have elevations considerably higher, up to 90 degrees. In short, UT-STRAPS uplinks, unlike the typical conventional fixed link, are not "horizontal." As a result, the maximum EIRP density projected horizontally will be dramatically lower than conventional fixed services transmitters due to the overhead geometry.

There may be a small number of potential co-alignments in which conventional fixed service receivers are located near, and aim sufficiently close enough toward, UTs to receive potentially harmful side lobe interference from UTs. But even allowing for that, another key to coordination, already utilized heavily in the conventional fixed service environment, is frequency selection and separation. The choice of frequency can overcome virtually all pointing and side lobe problems. Rather than relocate the end of a fixed link to avoid interference by an existing link, a non-interfering channel can be selected instead.[109] With regard to frequency selection

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[107] *Petition* at 94. *See* 47 C.F.R. § 101.111(a)(2)(ii).

[108] *Petition* at 86 (mandating no payload communications operation during ascent and descent or while *en route* to and from station).

[109] Elefante Group also notes that, for inter-service compatibility reasons, the proposed SBCS user uplink band ranges from 21.5-23.6 GHz. However, the contiguous Fixed Services

solutions, in response to FWCC's comments and a discussion with FWCC representatives since the filing of FWCC's comments, Elefante Group is exploring multiple approaches to maintain flexibility for both SBCS operators and for future conventional fixed links planned for locations where they could potentially receive interference from registered and deployed SBCS UTs. The goal is to be protecting the UT links, providing transparency into the criteria used by SBCS operators, and not complicating the existing PCN process while preserving reasonable conventional fixed services operator flexibility. Elefante Group plans to meet again with FWCC to discuss some options and report back to the Commission after doing so.

Enterprise UTs. Because the *Petition* proposed enterprise links up to 450 megahertz, FWCC concludes that "just a few enterprises in the same area would risk squeezing out new FS links."[110] By definition, enterprise UT density will be low: broadband enterprise UTs, intended for backhaul or LAN connectivity, are expected to be far less frequent in number. Moreover, within any of the SBCS reference design's beams, only a small number of 450 megahertz UT links could be deployed, and they would exhibit the same geometric isolation and resulting compatibility as consumer UT links.

Channel Plan Considerations. As FWCC notes, the *Petition* does not propose a channel plan.[111] Elefante Group submits that the lack of a rigid channel plan for SBCS should not create additional obstacles for coordination.

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allocation ranges from 21.2-23.6 GHz. Therefore, 300 megahertz remains available to conventional fixed services where there is no overlap with the SBCS proposal. Moreover, as in the SBCS reference plan, there are significant guard bands between the 450 megahertz-wide "colors" totaling another 300 megahertz.

[110] *FWCC Comments* at 5.

[111] *Id.* at 5-6.

Conventional fixed service links use paired channels, and can promote spectral reuse efficiency between links by assessing interference on channel pairs in order from lower to higher frequency until a viable pair is located. In other words, 2.5, 5, 10, 20, 30, 40, and 50 MHz channels in the 21.2-22.4 GHz range are paired with same size channels in the 22.4-23.6 GHz band and segmentation guidelines are provided to follow except in cases where no other paired coordination options are available.

The *Petition* proposes that SBCS operators have flexibility in their choice of frequencies.[112] Elefante Group declined to specify a specific channelization scheme for SBCS in order to avoid over-prescribing the SBCS implementation different operators might take, and unnecessarily constrain innovation within the new service. With the Elefante Group reference design for SBCS, for example, there is no preference for where in the 450 megahertz-wide beams the spectrum used by consumer UTs, typically operating over 5-20 megahertz would be located. Because of the geometry of SBCS deployments in the 22-23 GHz Band, there is, regardless of frequency selection, already an inherently high degree of compatibility with conventional fixed links, as shown in Appendix B to the *Petition*[113] and discussed above. Consequently, in considering the interaction of the conventional ground-based and overhead SBCS geometries, in which SBCS UT uplinks appear to conventional fixed receivers much as

112 *Petition* at 100.

113 *Petition* at Appendix B, p. 6. Key to compatibility between SBCS overhead and conventional fixed service ground-based geometries is the spatial isolation providing antenna discrimination between the high and low elevation angle links, the use of power control for coordination advantage, and decoupling of interferer and victim path overlap through localized high intensity rain cells. As detailed in Exhibit 2, appended hereto, these factors combine to permit conventional fixed service receivers to operate closer to SBCS UTs (in both separation distance and angle discrimination) than to conventional fixed service transmitters. *See generally* Exhibit 2.

the backlobe of another conventional fixed transmitter, it is not clear that there is a need to harmonize channelization between the two to ensure compatibility.

Databases for Coordination. Elefante Group agrees with FWCC that "[r]eliable coordination will need a complete, accurate, and frequently updated FS receiver database."[114] Elefante Group welcomes the opportunity to collaborate with FWCC regarding the best approach to satisfying this prerequisite to the advantage of all fixed services users, both conventional operators as well as SBCS licensees. Although information from licenses described in the ULS was used for initial compatibility analysis and survey of conventional fixed link characteristics in the 21.5-23.6 GHz range, Elefante Group recognizes that the ULS only represents links that have completed the full licensing process, and neither records links that have entered prior coordination (and therefore have priority), but not yet been licensed, nor records detailing antenna pattern or receiver data necessary for a more refined interference analysis.

Adjacent Channel Interference. Elefante Group appreciates FWCC's comment that "[a]djacent channel interference originates mostly in the receiver, not the transmitter" and that frequency coordination must account for potential adjacent channel interference.[115] The Commission should encourage improved receiver design to reduce if not eliminate the potential for *in-band* channel transmissions to create an interference potential for receivers located in an adjacent or second adjacent channel, especially in this era when there are increasing demands for maximum spectral utilization by a growing array of spectrum users. FWCC's comments about adjacent channel interference highlight the continuing problem with historic receiver design.

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114 *FWCC Comments* at 6.

115 *Id.*

Nonetheless, Elefante Group proposes that the question of such adjacent channel interference, to the extent appropriate, can be taken into account under the proposed framework for the 22-23 GHz Band. Appendix B of the *Petition* explains that, as the result of pre-coordination with prior licensed and coordinated fixed service links, frequency-dependent contours will be established around the conventional fixed receiver locations establishing areas where SBCS UT uplinks can be located and on what frequencies they can transmit.[116] Because conventional fixed receivers have a filter rolloff, *i.e.*, are sensitive to power in adjacent channels and not just its own licensed channel, the contours can take this into account. While manufacturers and operators should be encouraged to use more efficient receiver designs wherever possible, Elefante Group acknowledges the reality that some receivers may be more susceptible to interference because of radiofrequency energy in adjacent or second adjacent channels. Rather than a single protection contour representing complete co-channel overlap, therefore, additional contours can be drawn by the SBCS operator during pre-coordination of UT uplinks representing different separations between the channel band edges or center frequencies of the UT transmitters and conventional fixed receivers.[117]

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[116] *Petition* at Appendix B, p. 9.

[117] In practice these could be calculated using emission characteristics of the UT transmitters and out-of-band fixed service receiver rolloff characteristics documented in manufacturer data. This information is often incorporated into Threshold to Interference ratio ("T/I") curves used in conducting coordination related interference analysis per TSB-10F "Telecommunications System Bulletin: Interference Criteria for Microwave Systems," as specified in Section 101.105(c) of the Commission's rules. 47 C.F.R. § 101.105(c). Where detailed receive filter information is unavailable or impractical (as in a survey or compatibility modeling prior to actual coordination), the regulatory mask for out-of-band emissions will be used as a bound on receiver filter characteristics for initial analysis.

Note also that in initial compatibility analyses, where detailed T/I curves are not easily available to establish thresholds for individual receivers, Elefante Group has used an I/N criterion of -6 dB. As illustrated in Figure B-1 of TSB-10F, measured co-channel T/I is largely equivalent to preventing a 1 dB increase in the receiver noise floor by keeping interference more than 6 dB lower than the thermal noise floor. Whereas manufacturer-measured T/I captures precisely the

Conditional Fixed Link Authorizations. Finally, FWCC notes that fixed services currently rely on conditional authorization on a subset of 23 GHz frequencies, and asks the Commission to ensure that SBCS licensees will manage their database updates and coordination consultations so as to preserve this option.[118] Links within the 21.8-22 and 23-23.2 GHz bands are eligible for conditional authorization, and are permitted to operate as soon as the license application is submitted (providing certain criteria are met) rather than waiting for license authorization.

Since filing the *Petition*, Elefante Group has met with FWCC regarding this concern. Elefante Group submits that SBCS operators could be encouraged to not use these bands when other frequencies are available to them in order to avoid coordination conflicts in what is effectively a preferred part of the band. In any event, conditionally authorized links would populate the database, just the same as licensed links, and links that are the subject of a PCN, allowing SBCS operators to take them into account when making frequency selections for UT uplinks.

2. Compatibility between SBCS and Audacy's Future Inter-Satellite Service in the 23 GHz Band Is Achievable

In the *Petition*, Elefante Group explained that potential interference into the Audacy User-to-Relay ("U2R") Return Link in the 23 GHz Band is "unlikely and would be a transient condition," and provided a compatibility analysis in support of that finding.[119] Elefante Group also explained the value of interference protection criterion ("IPC") to protect the Audacy Relay-

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criteria for maintaining a 1E-6 bit error rate, modeling I/N with a noise density floor estimated from an assumed receiver noise figure will yield similar results for co-channel interference results sufficient for preliminary analysis.

118 *FWCC Comments* at 6.

119 *Petition* at 71; *id.* at Appendix D, p. 7.

to-User ("R2U") Forward Link from fixed services in that same band, including SBCS uplinks, noting that an IPC would create certainty for Audacy customers and fixed services operators alike and allow compatibility analyses to be performed with increased confidence in the results.[120]

In its comments on the *Petition*, Audacy claims to have found a discrepancy in Elefante Group's statements worthy of mention.[121] However, Audacy conflated the two different subjects addressed by Elefante Group's *Petition*, mistakenly concluding that Elefante Group stated concerns with respect to potential interference to U2R Return Links while, at the same time, proffering compatibility analyses stating that such interference is unlikely and transient. Elefante Group wishes to take this opportunity to reaffirm, should there be any perceived ambiguity in the record, its distinct statements regarding any potential for interference into the U2R Return Links, on the one hand, and R2U Forward Links, on the other.

a. Compatibility with Audacy U2R Return Links

To recap, Elefante Group and Lockheed Martin's evaluation of potential interference from SBCS into the Audacy U2R Link is set out in Appendix D of the *Petition*.[122] The analysis found that, although the *worst-case* (static) interference geometry results in a small negative

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[120] *Petition* at 71-72. *See also* Elefante Group, Inc., Request for Clarification or, in the Alternative, Partial Petition for Reconsideration, File No. SAT-LOA-20161115-00117 (July 6, 2018) (corrected version filed July 18, 2018) ("*Elefante Request*"); Elefante Group, Inc., Reply to Opposition to Request for Clarification or, in the Alternative, Partial Petition for Reconsideration, File No. SAT-LOA-20161115-00117 (July 31, 2018) ("*Elefante Request Reply*").

[121] *Audacy Comments* at 8-10.

[122] *Petition* at Appendix D.

margin for the Audacy Base Service (-6.2 dB for the higher EIRP density Enterprise UTs[123]), associated interference events will statistically be infrequent and brief.[124] Elefante Group noted that the lack of specific information regarding User Satellites in the Audacy license application file[125] inhibited further examination of the potential for interference into U2R Return Links, in particular a detailed time-dynamic analysis. Nonetheless, Appendix D of the *Petition* described multiple reasons why the precise geometric alignment required was unlikely as well as other factors mitigating the possibility of interference, which justified Elefante Group's belief that SBCS systems can operate compatibly with Audacy's U2R Return Links.[126]

Despite a lack of additional information regarding Audacy's User Satellites, Elefante Group and Lockheed Martin have since performed an additional analysis regarding possible interference into U2R Return Links to complement that accompanying the *Petition* and to confirm such interference is "unlikely and transient."[127] Specifically, with the goal of quantifying the percentage time of interference, Elefante Group's new analysis assumes a typical polar-orbit satellite as a proxy for an Audacy Base Service User Satellite and performed a risk-based statistical analysis for interference into the Audacy U2R Return Link using worst-case operating and geometric assumptions. The results, as discussed in Exhibit 3, reinforce the conclusion that there are multiple factors that mitigate the likelihood of interference: 1) the need for a certain geometric alignment with relatively narrow tolerances among the User Satellite,

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[123] The numerical margin results for Enterprise and Consumer UTs were reversed in the *Petition* at Appendix D, Table 2. However, that did not change the significance of the results. Those figures are corrected in Exhibit 3.

[124] *Petition* at Appendix D, p. 7.

[125] File No. SAT-LOA-2016115-00117.

[126] *Petition* at Appendix D, p. 8.

[127] *See* Exhibit 3 at 3.14.

Relay Satellite, and STRAPS for potential interference to occur; 2) the quantity and diverse positioning and pointing of UTs within the STRAPS service area; 3) time dynamics associated with orbital alignment; 4) time dynamics associated with UT EIRP and return link utilization; 5) frequency overlap and matched polarization; and 6) the quantity of STRAPS service areas. To bound the results, several of these parameters have been treated as *worst-case*, ensuring that the results are still quite conservative.

As described in Exhibit 3, the percentage exceedance time for a single STRAPS coverage area in Miami, FL is a mere 0.000166%.[128] This means that it would take 601 STRAPS services operating under the described worst-case conditions within view of the Audacy medium earth orbit satellite to cause interference that would exceed the protection criteria,[129] a number that is well above expectations even given optimistic projections on the number of STRAPS that are likely to be deployed.

Elefante Group performed the risk-based statistical analysis only for the Audacy Base Service because, by Audacy's own acknowledgment, the Advanced Service would be less susceptible to interference. In its Narrative Exhibit, Audacy states that "[t]he orbital distribution of Users in each Relay's field of view means that the Advanced spot beams will *rarely intersect the Earth*, eliminating potential interference with terrestrial users of the same spectrum."[130] This is consistent with the fact that, unlike the Base Service, the Advanced Service does not have

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128 *Id.* at 3.13.

129 I/N < -10 dB and 0.1% allowable exceedance from ITU-R SA.1155 assumed to apply to Audacy's ISS return link.

130 Audacy Corp., Application, File No. SAT-LOA-2016115-00117, 20 (Nov. 15, 2016) (emphasis added) ("*Audacy Application*").

separate "inner" and "outer" beam coverage areas towards User Satellites, which avoids potential interference from low elevation angle fixed service users.[131]

As Exhibit 3 explains,[132] application of other factors such as the diversity of Audacy's U2R Return link channels, the use of ATPC by SBCS links, and Audacy's greater reliance on the outer beams than the inner beams of its system architecture[133] further reduce the already miniscule potential for interference into the U2R Return links.[134]

b. Compatibility with Audacy R2U Forward Links

Elefante Group has sought clarification or, in the alternative, reconsideration of the Audacy license grant on the limited basis of pursuing an IPC to protect R2U Forward Links, so as to provide certainty for Audacy, its customers, and fixed service operators.[135] Specifically, Elefante Group has requested the Commission consider adoption of Recommendation ITU-R SA.1155 ("SA.1155") as the foundation for an IPC to protect Audacy R2U Forward links from fixed services, including SBCS.[136] SA.1155 provides protection criteria (a threshold interference to noise ratio and a percent allocation for exceedance) relevant to systems with characteristics described in Recommendation ITU-R SA.1414-2. Elefante Group understands that the

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131 *Compare id.* at 16-17 (discussing Base Service), *with id.* at 19-20 (discussing Advanced Service).

132 *See* Supplemental Information Section in Exhibit 3, pp. 3.13-3.14.

133 In its July 7, 2017 Opposition and Response, Audacy verified that "[i]n a minority of cases, a User satellite will appear from the Relay satellites to be passing across the visible earth disc." Opposition and Response of Audacy Corporation, File No. SAT-LOA-20161115-00117, 11 (July 7, 2017). Audacy further maintained that "[i]t is highly unlikely that the Network would have a sufficiently large number of Users, all of whom are commanding their satellites simultaneously, to necessitate the concurrent operation of all Relay transmit beams." *Id.* at 11-12.

134 *See* Exhibit 3 at 3.13-3.14.

135 *Elefante Request* at 1.

136 *Elefante Request Reply* at 7-9.

characteristics of Audacy User Satellite systems are undefined, as well as the level of protection they are to receive in this shared band. Consequently, without an IPC and receiver characteristics, there is no firm basis for analysis.

Nonetheless, Audacy appears to overstate in its comments the potential for interference, although by doing so it appears to contradict its own license application. In its comments on the *Petition*, for the first time, whether in its application file or otherwise (to Elefante Group's knowledge), Audacy brings to the Commission's attention that User Satellites that will communicate with Audacy's satellite constellation may have omnidirectional receivers.[137] The characteristic plainly contradicts descriptions in Audacy's application, where Audacy states that its system will utilize "User spacecraft *employing antennas pointed away from the planet's surface towards overhead MEO Relays*."[138] Indeed, Audacy relies on this statement to assert that "[t]errestrial communications present no meaningful threat of harmful interference to [Audacy's] services due to (i) the significant levels of naturally occurring attenuation and isolation between the ground and any potentially affected spacecraft receiver, and (ii) the orientation and *highly directional qualities of both the terrestrial and space-based antennas*."[139]

By contrast, in its comments on the *Petition*, Audacy has apparently backed away from claims that its Users will have "highly directional" antennas on their satellites. Audacy's comments[140] describe one possible set of User Satellite receiver characteristics using 2 dBi omnidirectional antennas, which clearly are not directional antennas pointed toward its medium

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137 Opposition of Audacy Corporation to Request for Clarification or, in the Alternative, Partial Petition for Reconsideration, File No. SAT-LOA-2016115-00117, Call Sign S2982, 8-10 (July 19, 2018).

138 *Audacy Application* at 5-6 (emphasis added).

139 *Id.* at 6 (emphasis added).

140 *Audacy Comments* at 9.

earth orbit satellites. Omnidirectional antennas are significantly more sensitive to terrestrial interference than those User Satellites described in Audacy's application. While, on the one hand, Audacy states that these omnidirectional antennas will be primarily used for satellite health data and commanding in emergency and other non-nominal situations, Audacy proceeds to intimate that *all* satellites use such omnidirectional antennas for such purposes.[141]

Apart from this curious apparent contradiction in Audacy's description of User Satellites, omnidirectional satellites in the Ka ISS band would be counter to industry practice. Certainly, almost all satellites use Telemetry and Command ("T&C") systems with near omnidirectional coverage, but they do so in *other bands* (typically S-Band or UHF). Omnidirectional antennas in an ISS band shared with terrestrial services, such as the 23 GHz Band, are in no way the norm.

Considering Audacy's plans to use omnidirectional antennas are limited to T&C, the effect of this narrow, and incongruous, application to justify the protection to which Audacy believes User Satellites should be generally entitled in the 23 GHz Band will create an incompatible spectrum environment. Audacy seeks to apply the associated worst-case receiver characteristics of this narrowband non-standard and emergency type use-case across the entire 23 GHz Band, even though Elefante Group expects that a majority of this band would likely be used for high data rate services using directional antennas. The Commission should not condone this result. Consequently, Audacy's revelations in its comments on the *Petition* underscores the need for a reasonable R2U IPC based on directional antennas to promote maximum use and optimum sharing of the band by all users.[142]

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141 *Id.*

142 T-Mobile suggests in passing that the Commission consider making the 22-23 GHz Band available for commercial mobile use in the *Spectrum Frontiers* or *Mid-Band Spectrum* proceeding. *See T-Mobile Opposition* at 6. To the best of Elefante Group's knowledge, no party, including T-Mobile, has actually proposed that the Commission do so, let alone how it

B. 26 GHz Band

1. SBCS Downlink Operations in the 26 GHz Band will Adequately Protect Radio Astronomy in the 23.6-24.0 GHz Band

The *Petition* proposes to use 21.5-23.6 GHz for UT uplinks and 25.25-27.5 GHz downlinks.[143] As Elefante Group made clear, as the result of further study and analysis, it is *not* proposing to use the 23.6-24.0 GHz band despite earlier references in *ex parte* submissions that pre-dated the *Petition*.[144] While future analysis and mitigation methods may suggest the potential for such use, Elefante Group reiterates that it is not pursuing use of the 23.6-24.0 GHz band with the Commission at this time, so the NRAO should rest assured on that front.[145]

NRAO recognized that the analysis accompanying the *Petition* finding compatibility of a single STRAPS with radio astronomy operators at 23.6-24.0 GHz for downlink transmissions in the 26 GHz Band was "credible."[146] NRAO's comments raise the question, however, whether the same conclusion would be reached in cases when a large number of STRAPS are visible from the RAS Very Large Array ("VLA") site in New Mexico.[147] NRAO also inquires about the possible impact of higher RAS station altitude and Automatic Transmit Power Control ("ATPC")

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should go about doing so, in a current proceeding. In any event, for the reasons set forth in the *Petition* and herein, the Commission can and should open up the band for use by SBCS without disturbing incumbents' access to the spectrum. The compatibility of commercial mobile services in this spectrum with incumbents (and SBCS) may be another issue altogether.

143 *Petition* at 4.

144 *Id.* at 55, n.64.

145 *See NRAO Comments* at 3-4.

146 *See id.* at 2.

147 *See id.* at 2-3.

on the interference level.[148] As Elefante Group explains below, none of these presents difficulties that bring into doubt the compatibility of SBCS with RAS.

Exhibit 4, appended hereto, addresses NRAO's concerns about the multi-STRAPS scenarios.[149] Exhibit 4 extrapolates the same *worst-case* conditions assumed for the initial single STRAPS compatibility analysis appended to the *Petition* to the multi-STRAPS scenario:[150]

1) STRAPS are operating at the lowest altitude.
2) STRAPS are transmitting at the maximum power flux density limits authorized for satellite downlinks, per Section 25.208(c) of the Commission's rules, including consideration for ATPC.[151]
3) Multiple STRAPS downlink channels are operating simultaneously to encompass the full user downlink band (not considering that coverage is provided by multiple channel "colors" which are spread across hundreds of beams and that the nearest RAS station may not be making observations at 23.6 GHz).
4) Conservative RAS station characteristics including an 100 m antenna operating at 23.6 GHz at a minimum elevation angle of 5 degrees.

Note that the original single STRAPS and subsequent multiple STRAPS analyses both utilize maximum STRAPS downlink power from the total power range provided by ATPC. This fact effectively addresses NRAO's inquiry whether the platform EIRP used in the analysis reflects the impact of ATPC under inclement conditions.[152]

Results for various single and multiple STRAPS deployments are summarized in Table 1, with details shown in Exhibit 4.[153] These results illustrate the flexibility that exists in STRAPS

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148 See *id.* at 3.

149 Exhibit 4 is an updated version of Appendix M submitted with the *Petition.*

150 *See Petition* at Appendix M.

151 47 C.F.R. § 25.208(c).

152 *See NRAO Comments* at 3 ("And although this is an approximate envelope calculation, the platform's eirp could be 10 or more dB higher when conditions underneath it are inclement and ATPC is used.").

153 Exhibit 4, pp. 4.9-4.10.

deployments while ensuring that the RAS Protection Criteria[154] are met, including under extreme, indeed wholly unrealistic assumptions for multiple STRAPS deployments in the vicinity of an RAS site (*e.g.*, 63 straps located within 40 km).

Table 1: Sky Blockage for various single and multiple STRAPS scenarios

STRAPS Deployment Scenario	**STRAPS Transmit Attenuation, dB**	**Sky Blockage**	**Interference Allocation**
1 STRAPS 0 km	75	1.29%	2%
1 STRAPS 0 km	90	0.082%	2%
1 STRAPS 40 km	75	1.26%	2%
1 STRAPS 80 km	75	0.25%	2%
1 STRAPS at 100 km	75	0.02%	2%
1 STRAPS at 120 km	75	0.01%	2%
1 STRAPS at 200 km	75	0.003%	2%
1 STRAP at 40 km, 1 at 80 km	75	1.51%	5%
1 STRAP at 40 km, 1 at 80 km, 1 at 120 km	75	1.52%	5%
1 STRAPS at 40 km, 15 STRAPS at 80 km	75	5.0%	5%
1 STRAPS at 40 km, 550 STRAPS at 120 km	75	5.0%	5%
25 STRAPS at 40 km	90	2.0%	5%
63 STRAPS at 40 km	90	5.0%	5%

The analysis in Exhibit 4 also addresses higher elevation RAS sites. Higher RAS antenna altitude would result in fewer STRAPS above the 5% RAS elevation angle and therefore the aggregate interference level and Sky Blockage would be lower.[155] For example, for the LBO VLBA telescopes in Mauna Kea at ~13000 feet altitude (4 km), although the theoretically maximum possible number of visible STRAPS would be 1260, only 60 of the STRAPS would be above a 5-degree elevation angle. This compares to the nominal assumed scenario of the RAS

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[154] As detailed in Exhibit 4, performance characteristics of RAS sensors are based on Recommendation ITU-R RA.769. Single and total system interference allocation are both based on Recommendation ITU-R RA.1513. *See id.*, pp. 4.2-4.3.

[155] *See id.*, p. 4.9.

location at ground elevation, in which case 90 of the theoretical maximum number of visible STRAPS (672) are above a 5-degree elevation angle.

NRAO also raises a question regarding the possibility of STRAPS downlink in-band transmissions exceeding the RAS damage power level threshold.[156] Figure 1 shows that in-band received power is significantly less than the 5 mW damage level in Recommendation ITU-R.2188 for a single STRAPS for all RAS station separation distances.[157]

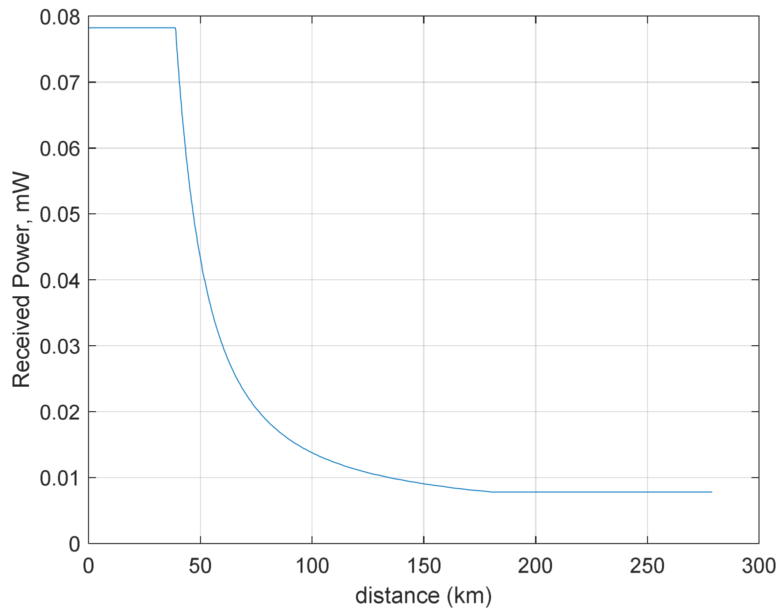

Figure 1: In-Band received power from a single STRAPS

As detailed in Exhibit 4, translating the results onto a multi-STRAPS case reveals that it would take 62 co-channel STRAPS at 40 km distance from the RAS site to exceed the RAS damage levels, a number which is well beyond realistic *worst-case* situations even where there are multiple SBCS providers. Multiple providers would result in, at most, just a few STRAPS

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[156] *See NRAO Comments* at 3 (referencing ITU-R Report RA. 2188).

[157] *See also* discussion in Exhibit 4, p. 4.11.

within 40 km, and even within distances of several hundred kilometers from a RAS station there would almost certainly be only a fraction of sixty-two STRAPS within view.[158]

Moreover, further enhancing compatibility, and quelling any residual concerns that NRAO may have, if radio astronomers require knowledge of the solid angle over which interference from a single STRAPS's downlink may exceed the protection criteria, the small variability in a STRAPS location while station keeping can be well understood. Elefante Group envisions that the station and real-time location of each STRAPS will be published in near real-time to comply with FAA requirements. This information could also be made available to the RAS stations so that any observations can account for shifts in Sky Blockage that might occur at the margin.

Finally, NRAO raised concerns that, in practice, the "orbit" of a STRAPS could increase the amount of Sky Blockage and data loss seen by a radio telescope.[159] As shown in Exhibit 4, any STRAPS location variability during station keeping will have a minor impact on Sky Blockage even if STRAPS location information is not utilized by the RAS station.[160]

Elefante Group welcomes the opportunity to work with NRAO to address any remaining concerns which it may have regarding the SBCS proposed in the *Petition*. Elefante Group remains committed to compatible operations and intends to ensure the survivability of any potentially affected co-primary radio astronomy operations.

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158 *See id.*, pp. 9-10.

159 *See NRAO Comments* at 2-3.

160 *See* Exhibit 4, p. 4.11.

2. The 26 GHz Band Is Essential for Realizing SBCS and Does Not Create Unique Opportunities for Commercial Mobile to Justify Precluding SBCS from Access

While Elefante Group anticipates that potential, future commercial mobile access to the 26 GHz Band issues will be addressed more fully in the *Spectrum Frontiers* proceeding, it wishes to address briefly the claims that CTIA and T-Mobile made in their comments that the 26 GHz Band somehow presents a unique prospect for the mobile industry.[161] Leaving aside any challenges of mobile's spectrum compatibility with federal incumbents in the band that would first have to be overcome,[162] 26 GHz does not offer irreplaceable opportunities for the mobile industry for several reasons.

First, the Commission has made already 5.5 gigahertz of mmW spectrum available for UMFUS in the First and Second Report and Order and associated decisions in *Spectrum Frontiers*.[163] Further, the Commission currently has another 4.3 gigahertz under consideration for UMFUS in the proceeding, apart from 26 GHz, by virtue of the July 2016 Further Notice and June 2018 *Third FNPRM*, which has the support of the commercial industry.[164]

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161 *CTIA Opposition* at 2; *T-Mobile Opposition* at 4-6.

162 As demonstrated in the *Petition*, and its accompanying compatibility analyses, SBCS are capable of compatible operation with incumbent federal users in the 26 GHz Band. *See Petition* at 72-74, Appendices J-L, Q, S.

163 *See First Spectrum Frontiers Order* at ¶¶ 19-72, 101-124; *Second Spectrum Frontiers Order* at ¶¶ 15-59.

164 *See First Spectrum Frontiers Further Notice* at ¶¶ 386-403, 418-423; *Third FNPRM* at ¶¶ 47-57; *see also* Comments of CTIA, GN Docket No. 14-177, *et al.*, at 6-8 (Jan. 23, 2018) (advocating the designation of the 31.8-33.4 GHz, 42.0-42.5 GHz, and 50.4-52.6 GHz bands for flexible terrestrial use) ("*January 2018 CTIA Comments*"); Comments of T-Mobile USA, Inc., GN Docket No. 14-177, *et al.*, 11 (Jan. 23, 2018) (same); Comments of AT&T Services, Inc., GN Docket No. 14-177, *et al.*, 4-5 (Jan. 23, 2018) (same). Moreover, the commercial mobile advocates urge the Commission to make the remaining Local Multipoint Distribution Service spectrum available for UMFUS, yet another 450 megahertz of spectrum (namely, 29.1-29.25 GHz and 31-31.3 GHz). *See, e.g.*, *January 2018 CTIA Comments* at 2, 5-6.

Second, any claimed advantage of the prospect for almost four gigahertz of contiguous spectrum in the 24.75-28.35 GHz band for UMFUS is largely illusory.[165] There is no guarantee or even inherent likelihood that single licensees would have use of the contiguous spectrum, made up of multiple sub-bands within the 24 and 28 GHz spectrum now set for auction and multiple different smaller ranges that will be awarded separately through competitive bidding. Moreover, carrier aggregation technologies increasingly minimize the importance of contiguous spectrum.

Third, CTIA and T-Mobile's claims that designation of the 26 GHz Band for mobile is advantageous for international harmonization of this band are exaggerated.[166] The availability of the 24 and 28 GHz Bands in the United States for next-generation ground-based networks already, as a result of tuning range compatibility, ensures harmonization with equipment deployed in other countries in parts or all of the 24.25-27.5 GHz range. The specific allocation of the 26 GHz Band for UMFUS is not necessary to achieve the objectives of international harmonization, economies of scale, or international roaming.

On the other hand, the 26 GHz Band will play an essential role in ensuring that the benefits of high-capacity, low-latency SBCS can become a reality. As explained at length in the *Petition*, after analyzing spectrum options throughout the 17-43.5 GHz range, Elefante Group and Lockheed Martin concluded that the candidates set out in the *Petition* for SBCS spectrum were, as practical matter, far and away the most suitable candidate for SBCS.[167] Consequently,

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165 *CTIA Opposition* at 5.

166 *See id.*; *T-Mobile Opposition* at 5-6.

167 *Petition* at 55-85.

to the extent the 26 GHz Band presents a unique opportunity, it is for the realization of SBCS in this country.[168]

C. 70/80 GHz Bands[169]

1. SBCS Can Operate Compatibly with Fixed Services in the 70-80 GHz Bands under the Current Regulatory Framework

In its comments, the FWCC indicated a desire for additional demonstration regarding the compatibility of SBCS Feeder links operating in the 70/80 GHz Bands with conventional ground-based fixed services links ("Conventional E-Band Links") that are being deployed under the Commission's "light licensing framework" in these bands.[170] SBCS feeder links are fully compatible with and present no technical challenges to Conventional E-Band Links). This is detailed more fully in Exhibits 6 and 7, appended hereto, which examine compatibility of SBCS 81-86 GHz Feeder uplinks and SBCS 71-76 GHz Feeder downlinks, respectively, with Conventional E-Band Links.[171]

In summary:

- SBCS Feeder *uplink* transmitters present only backlobes towards the receivers used in Conventional E-Band Links ("Conventional E-Band Receivers") in all azimuth directions, and thus SBCS Feeder uplinks present even fewer coordination challenges for operators of Conventional E-Band Links than do transmitters in Conventional E-Band Links ("Conventional E-Band Transmitters").

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168 That said, as noted above, Elefante Group continues to analyze prospects of SBCS and mobile having access to the 26 GHz Band on a shared basis and welcomes a good faith exploration of such issues with the mobile industry.

169 After filing the *Petition*, Elefante Group and Lockheed Martin conducted a specific analysis of the compatibility of STRAPS Feeder uplinks in the 80 GHz Band with Earth Exploration Satellite Service ("EESS") passive sensing operations in the 86-92 GHz bands. *See* Exhibit 5. The analysis showed that the SBCS feeder uplinks can be operated compatibly with EESS. Elefante Group and Lockheed Martin have shared the results of this analysis with the National Oceanic and Atmospheric Administration.

170 *FWCC Comments* at 6.

171 *See infra* Exhibits 6-7.

- SBCS Feeder *downlinks* transmit from a STRAPS to the ground from such a high elevation angle that only a handful of registered Conventional E-Band Links could possibly be affected by any single SBCS Feeder downlink; in the *worst case* geometry a Conventional E-Band Link must exceed 39.5 degrees elevation in a narrow range of azimuth directions to experience interference from a STRAPS downlink, and in all other cases the required elevation of the Conventional E-Band Link is higher. Therefore SBCS Feeder downlinks will effectively present no coordination challenge to the installation of new Conventional E-Band Links.

For similar reasons, SBCS Feeder links are unlikely to be victims of harmful interference from Conventional E-Band Links. Whereas Conventional E-Band Receivers present high gain over a very narrow range of azimuth, high elevation angle SBCS Feeder downlink receivers (*i.e.*, approximately 42 degrees and above) will *not* present high gain toward Conventional E-Band Transmitters (seen at low elevation angles far from the direction of peak gain) in *any* azimuth direction. SBCS Feeder uplink receivers, located on STRAPS, can only receive interference from very high elevation angle Conventional E-Band Transmitters (again, 42 degrees and above) aimed in an aligning azimuth direction and located within a kilometer or so of the SBCS Feeder terminal on the ground (assuming conservative worst-case situation).[172] Consequently, SBCS Feeder links in both directions and Conventional E-Band Links in both directions will have virtually no interaction with each other and coordination analyses should generally be *pro forma*, with no actions required.

By way of further explanation how SBCS Feeder links and Conventional E-Band Links will co-exist in practice, Elefante Group takes this opportunity to outline its vision for registration of SBCS Feeder links. Elefante Group submits that SBCS Feeder links can be readily registered using the current system applicable to Conventional E-Band Links with no changes. The only additional data necessary for new SBCS Feeder links to conduct the

[172] *See* Exhibit 6, pp. 6.3, 6.6; Exhibit 7, pp. 7.3, 7.6.

coordination analysis that must be included when they are registered are the dimensions of the control volume of the STRAPS around its nominal station. This information can be made available by using the unique identifier of the STRAPS as it appears in the STRAPS registry for the location name of the STRAPS node, permitting cross-reference to the necessary data for Fixed Services operators.[173]

2. SBCS Feeder Links Can Operate Compatibly with Proposed Fixed Satellite Services

SES raises the prospect for compatibility issues between SBCS and future FSS in the 70/80 GHz Bands, *i.e.*, the E-Band.[174] Elefante Group proposes that SBCS Feeder links use the same convention of 81-86 GHz uplink and 71-76 GHz downlink described in the FSS E-Band allocations.[175] Compatibility between SBCS Feeder links and FSS links will be quite similar to compatibility between such links among FSS operators alone, relying heavily on the extremely narrow beam width of transmissions to achieve spatial isolation. In general, narrow E-Band beams enjoy significant isolation as long as their boresights are not directed within a few degrees of each other, and the compatibility and subsequent coordination challenge is chiefly characterized by ensuring sufficient separation between nodes to prevent close pointing. But compatibility will also be dependent on the system characteristics of the potential interferer and potential victim.

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[173] The location description might also be designated as "STRAPS" and, if the field length permits, could even include the control volume dimensions, eliminating the need to even cross-reference the STRAPS registry when conducting E-Band coordination.

[174] *SES Americom/O3b Comments* at 2.

[175] *Petition* at 81-85; *see also* 47 C.F.R. § 2.106

SES, in its comments, identifies one application for FSS in the E-Band, the OneWeb application which went on public notice on June 6, 2018.[176] A detailed analysis of SBCS compatibility with the proposed OneWeb constellation use of E-Band feeders was appended by Elefante Group to its August 6, 2018, comments on OneWeb's application.[177] A copy of that analysis is attached hereto as Exhibit 8.

Lockheed Martin considered the four primary potential interference paths between the two systems: 1) OneWeb gateway uplinks into STRAPS receivers; 2) SBCS Feeder uplinks into OneWeb NGSO satellite receivers; 3) OneWeb gateway downlinks into SBCS gateway receivers; and 4) STRAPS downlinks into OneWeb gateway earth station receivers. The analysis concluded that the two types of systems, OneWeb and SBCS, are indeed compatible in all four scenarios, particularly given that OneWeb plans only a small handful of gateway earth stations located in remote geographic areas.[178] The analysis, using very conservative assumptions, calculated reasonable separation distances for complete prevention of harmful interference, based on OneWeb's approach to place feeders with 20 degree minimum elevation angles in remote locations.[179] These distances are likely to be reduced with further analysis adopting more real-world assumptions.[180] Furthermore, the study finds that separation distances could be reduced dramatically if mitigation approaches such as those described as OneWeb capabilities

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176 *SES Americom/O3b Comments* at 3 (citing *WorldVu Satellites Limited*, File No. SAT-AMD-20180104-00004).

177 Comments of Elefante Group, Inc., File No. SAT-AMD-20180104-00004 (Aug. 6, 2018) ("*Elefante OneWeb Comments*").

178 *Id.* at 4-9.

179 *See* Exhibit 8.

180 *Elefante OneWeb Comments* at 6.

(small, calculated avoidance angles around certain directions where alignment of narrow E-Band beams can occur) are employed.[181]

Compatibility with other FSS systems in the E-Band should generally be similar to the OneWeb results, assuming the uplink and downlink EIRP densities are similar and, more importantly, that the FSS Feeder and NGSO or GSO beam widths are not significantly larger. In the case of FSS GSO links, coordination is simplified because the range of FSS feeder pointing angles, even for GSOs with non-zero inclination angle, are significantly smaller than feeders tracking NGSOs. In this case, compatibility requires not so much of a minimum separation distance as identifying specific ground locations where earth stations of either service could interfere with the other, and coordinating to avoid them.

3. SBCS Use of the 70/80 GHz Bands in General Should Be Compatible with Other Proposed Airborne and Satellite Services

Several commenters, while not opposed to SBCS or the *Petition*, raised more general concerns that any action taken to enable SBCS as Elefante Group proposes not preclude other uses of the 70/80 GHz Bands. The concerns of AeroNet[182] and Loon[183] that the proposed SBCS rules for E-Band feeder links (designed for compatibility with Conventional E-Band Links, the

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181 See *WorldVu Satellites Limited Amendment to Petition for Declaratory Ruling Granting Access to the U.S. Market for the OneWeb V-Band System*, File No. SAT-AMD-20180104-00004 (Jan. 4, 2018), Technical Information to Supplement Schedule S, at Sections A.8.1, A.8.2, A.8.3.

182 Comments of AeroNet Global Communications Inc., RM-11809, 4 (July 11, 2018). AeroNet does not specifically object, but rather comments generally that the Commission should proceed with caution, as there are multiple providers that seek to offer services in the band, and "the Commission must be careful not to take any action that would either harm incumbent users or foreclose innovative uses by new entrants." *Id.*

183 *Loon Comments* at 3-5.

only currently authorized use of the band) might inhibit their and possibly other, future airborne applications are generalized and difficult to comment on as a result.[184]

Without reference operational parameters and performance characteristics of a new service type, it is impossible to quantify compatibility with proposed new services.[185] There were no specific reasons raised by these commenters that SBCS would generally preclude other overhead applications. Nonetheless, Elefante Group wishes to reiterate its expectation that SBCS, as proposed in the *Petition*, will be compatible with a variety of airborne and satellite applications that, like Elefante Group's SBCS, seek to design for compatibility at the start.

The analyses described in the previous two subsections discussed SBCS' compatibility regarding both Conventional E-Band Links and the OneWeb gateway link proposal[186] and serve as a reference and point of departure for compatibility for SBCS and other possible future E-Band applications or for others to investigate their E-Band operational compatibility.

As an initial matter, in addition to the discussion in the previous subsection about basic compatibility with OneWeb's FSS proposal, the *Petition* explains that multiple SBCS solutions can be compatible and, with some basic coordination, serve large overlapping areas in the same

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184 Neither AeroNet nor Loon appear to contend that their applications would qualify as SBCS. Based on their descriptions of their contemplated services, it would appear neither of them plan to operate nominally-fixed airborne stations and their platforms would not meet the definition of STRAPS.

185 Elefante Group reserves the right to comment at an appropriate time as to whether the applications envisioned by AeroNet and Loon fall under the Mobile Service, Fixed Service, or some other category.

186 *See supra* Sections IV.C.1-2, Exhibits 6-8.

spectrum at the same time.[187] As detailed in Section II above and in the *Petition*, the proposed rules would support a variety of SBCS solutions.[188]

In its objection, Loon maintains that the *Petition*'s proposed elevation-based threshold on EIRP density for overhead links "would not be wise," and that "[t]he current absence of restrictions based on elevation angle provides systems such as Loon important flexibility to operate standardized feeder links to aerial platforms, whether they are located directly above a ground station (with a near-vertical link) or at some horizontal distance from the nearest ground station (resulting in a lower elevation angle)."[189] While Elefante Group would enjoy the lack of any EIRP density limit on overhead links, as a practical matter, to be compatible, such a measure is a near necessity. In short, Elefante Group proposes the measure as an approach needed to protect and operate compatibly with widespread existing Conventional E-Band Links already deployed on the E-Band. On the other hand, without such a limit, if an operator's feeder station minimum elevation angle were low enough and beamwidth wide enough, higher EIRP density projected toward ground-based locations could (potentially in any azimuth direction) present interference that would unduly inhibit growth of new Conventional E-Band Links.

The *Petition* proposes that, regardless of the specific SBCS design, some regulatory limits on SBCS feeder EIRP density as a function of elevation angle are necessary to guarantee protection of incumbent Fixed Services.[190] Elefante Group is open to consider any proposed alternative regulatory approaches that would still ensure protection for terrestrial links but not impede Loon's or others' planned airborne operations as well as the *Petition*'s proposal.

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187 *Petition* at 79-81.

188 *See supra Section* II; *Petition* at 79-81.

189 *Loon Comments* at 5.

190 *Petition* at 85.

Loon's comment brings up concerns regarding compatibility of SBCS Feeder links with E-Band *cross-links* between its contemplated mobile stratospheric stations.[191] Without Loon's performance characteristics, which it has not provided, one can still extrapolate from Elefante Group's previous studies discussed in Sections IV.C.1-2 above to develop a sense of whether there will be compatibility. Presuming the putative Loon cross-links are between stations at nearly the same altitude and thus within a range of effectively small elevation angles relative to the earth's surface, then by analogy with low-elevation angle ground-based geometries, high-elevation angle links like SBCS, FSS, and other similar deployments will be largely compatible. But given the dynamic nature of cross-links between mobile stratospheric stations, like Loon's, that are moving with the wind over a range of altitudes and directions and pass by station-keeping STRAPS, geometries resulting in interference into SBCS are certainly possible. So, the issue is not whether SBCS would preclude services such as Loon's but whether, in the end, Loon's contemplated service is compatible with other services. Elefante Group's SBCS proposal is highly compatible, and should Loon make a proposal, its compatibility should be assessed at that time.

4. SBCS Feeder Links Can Adequately Protect Radio Astronomy Adjacent to the 71-76 GHz Band

NRAO indicated concerns that SBCS downlinks in the 70 GHz Band might cause harmful interference with radio astronomical observations in the 76-81 GHz band, and that the matter was not addressed in the *Petition*.[192] In response, Elefante Group engaged Lockheed Martin to conduct a compatibility analysis to assess the potential of out-of-band transmissions from SBCS Feeder downlinks at 71-76 GHz to interfere with Radio Astronomy Service Ground

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[191] *See Loon Comments* at 4.

[192] *NRAO Comments* at 2-3.

Radio Receivers authorized to operate in the adjacent 76-81 GHz band.[193] Consistent with the studies that accompanied the *Petition*, worst-case operating conditions and interference geometry were utilized, including the worst-case location and maximum quantity of SBCS feeder terminals (in the Elefante Group reference design). The analysis also assumed minimum STRAPS transmit rejection and the minimum RAS receiver interference threshold across various RAS observation types. Finally, the analysis made the assumption that RAS observations could be made up to the edge of the band at 76 GHz. In assessing whether any interference received would be harmful interference, Lockheed Martin used an IPC from Recommendation ITU-R RA.1513 and RAS band-specific characteristics as well as interference thresholds from Recommendation ITU-R RA.314-0.[194]

The compatibility study results illustrate[195] the percentage Sky Blockage parametrically as a function of separation distance and concludes that a single STRAPS can operate (including +/- 10 km drift) nearly adjacent to the RAS station and still meet the IPC. As a practical example, a RAS station located only 40 km from the center of a STRAPS coverage area results in less than 0.04% Sky Blockage relative to the 2% Single System Interference Allocation from Recommendation ITU-R RA.1513.

A multiple-STRAPS analysis was also performed under highly conservative and extreme theoretical conditions. That analysis again shows parametric results as a function of separation distance[196] and indicates a worst-case possible Sky Blockage of 0.67% relative to the 5% Total Interference Allocation. Additionally, the maximum in-band interference with multiple STRAPS

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193 *See* Exhibit 9.

194 *Id.* at 9.2.

195 *Id.* at Figures 3-4.

196 *Id.* at Figures 7-8.

was compared to the RAS station damage levels assuming a minimum 40 km separation distance and indicates significant positive margin.[197]

As a result of these studies, Elefante Group is confident that SBCS Feeder downlinks in the 71-76 GHz band can operate compatibly with RAS stations making observations in the adjacent band, including accounting for multiple STRAPS deployments.

5. Contrary to T-Mobile's Assertions, the FCC has not yet Considered Elefante Group's Proposal in the 70/80 GHz Bands.

Curiously, T-Mobile claims that the Commission has already considered and rejected Elefante Group's proposal to use the 70/80 GHz Bands for SBCS feeder links in the *Second Spectrum Frontiers Order*.[198] T-Mobile's misinterpretation of the *Second Spectrum Frontiers Order* is difficult to understand, as the Commission was quite clear in that decision that it was not addressing Elefante Group's plans to use the 70/80 GHz Bands for feeder links on the merits.[199] Indeed, the Commission procedurally may not have been able to do so in any event given that the Commission's July 2016 FNPRM did not propose use of the band for that purpose. Now that Elefante Group has filed its *Petition* and a comprehensive spectrum proposal, changing the landscape concerning these issues considerably, the Commission, using its broad procedural authority under Section 4(i), may unquestionably determine to consolidate consideration of SBCS into the *Spectrum Frontiers* proceeding, as Elefante Group urged above.[200]

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[197] *See id.* at p. 9.10.

[198] *T-Mobile Opposition* at 7 (citing *Second Spectrum Frontiers Order* at ¶¶ 200-201).

[199] *Second Spectrum Frontiers Order* at ¶ 201 (stating that Elefante Group and others "have proposed different uses for these bands which neither fit the traditional mobile broadband nor fixed link models").

[200] 47 U.S.C. § 154(i).

By contrast, what the Commission unmistakably did determine in the *Second Spectrum Frontiers Order* was to forego further consideration, at this time, of introducing flexible mobile use into the 70/80 GHz Bands.[201] This issue was squarely before the Commission as a result of the July 2016 *Spectrum Frontiers* FNPRM, and the Commission ultimately decided the public interest weighed against adopting rules to permit mobile operations in the band, in part because of issues raised by flexible mobile deployments concerning compatibility with incumbent fixed services uses.[202] In short, the Commission instead opted to encourage continued deployment of fixed services in the 70/80 GHz Bands.[203] Elefante Group's *Petition*, demonstrating a high degree of compatibility with fixed and other services in and near the 70/80 GHz Bands, which is amplified above, is wholly in keeping with the Commission's decision in that proceeding.

V. NONE OF THE COMMENTS CHALLENGE THE COMMISSION'S TREATMENT OF THE *PETITION* UNDER SECTION 7

In the *Petition*, Elefante Group demonstrated that SBCS includes new technologies and services – with tremendous public interest benefits – that merit treatment under Section 7 of the Communications Act.[204] None of the comments offer any challenges to this claim. However, T-Mobile asserts that qualifying for Section 7 treatment should not compel the Commission to supersede consideration of ongoing matters.[205] Elefante Group did not and has not asserted that Section 7 requires the Commission to act favorably on its request to the exclusion of other considerations, but rather that the Commission should act in a timely fashion on its request,

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201 *Second Spectrum Frontiers Order* at ¶ 200 ("We decline to authorize mobile use in the 70 GHz and 80 GHz Bands.").

202 *Id.*

203 *Id*. See also discussion in *supra* Section III.

204 *Petition* at 103-112 (citing 47 U.S.C. § 157).

205 *T-Mobile Opposition* at 7-8.

which is what Section 7 mandates and even T-Mobile has no choice but to acknowledge.[206] Elefante Group's views regarding Section 7 as a general matter are laid out more fully in its reply comments in the Commission's Section 7 rulemaking.[207]

Nevertheless, Elefante Group does submit that, in the present context, action on the *Petition*'s proposals should be consolidated with other possible changes concerning the 26 GHz Band in the *Spectrum Frontiers* proceeding. Sound spectrum management does not counsel that the Commission consider possible new uses of 26 GHz *seriatim*, as T-Mobile suggests at one point.[208] Moreover, the Commission has already raised issues regarding SBCS access to 26 GHz in the *Third FNPRM* in the *Spectrum Frontiers* proceeding, albeit in a way that might be construed to preclude, without a further notice, the adoption of SBCS rules depending on the Commission's public interest findings.[209] For this reason, Elefante Group asks the Commission out of an abundance of caution to shore up the existing procedural situation where consideration of the future of the 26 GHz Band is taking place on two tracks and formally consolidate consideration of the request for SBCS rules with the *Spectrum Frontiers* proceeding.

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206 *See id.* at 8 (stating that Section 7 "requires expedited Commission action" on requests).

207 *See* Reply Comments of Elefante Group, Inc., GN Docket No. 18-22 (June 20, 2018).

208 *T-Mobile Opposition* at 8 (indicating the Commission should "leav[e] open the potential to reevaluate the [Elefante Group] Petition once the *Spectrum Frontiers* proceeding is complete").

209 *Third FNPRM* at ¶¶ 86-87.

VI. CONCLUSION

For the reasons set forth herein, the Commission should swiftly - and in any event within one year - initiate a rulemaking to adopt a regulatory framework to give SBCS systems access on a non-exclusive basis to spectrum in the 21.5-23.6, 25.25-27.5, 71-76, and 81-86 GHz Bands.

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August 15, 2018

Exhibit 1
Elefante Group Stratospheric Platform Station
Technical Specifications

August 15, 2018 Update to the Technical Specifications appended to the Elefante Group Petition for Rulemaking (PFR), RM-118089, filed May 31, 2018 (Appendix A).

The technical specifications of the Stratospheric Platform Station (STRAPS) that have been used in compatibility analyses are provided below.

Changes from PFR, Appendix A

The previous version of the Technical Specifications was originally submitted as Appendix A to the PFR. The primary change in this version is to update the number of feeder beams to match current business planning.[1]

System Specifications

The following table summarizes primary system specifications of the Elefante Group STRAPS and nominal operating area.

Item	Units	System Design
User Uplink Band	GHz	21.5-23.6
User Downlink Band	GHz	25.25-27.5
Feeder Uplink Band	GHz	81-86
Feeder Downlink Band	GHz	71-76
Platform Type		Lighter Than Air
Nominal Platform Service Radius	km	70
Min Platform Altitude	km	18.3
Max Platform Altitude	km	21.3
Max Platform Flight Radius	km	10
# User Beams		Over 100
# Feeder Beams		10-20
UT Density	UT/km^2	Dependent on business case. For compatibility analyses, the worst-case scenario was always evaluated as described in the appropriate analysis Appendix.
Deployment environment		Urban, suburban, rural

[1] This document also changes all references from CPE to UTs, updates User Terminal antenna patterns (with supplemental notes on use of the patterns) in the User Terminal Table, and clarifies height of the STRAPS platform in multiple tables.

User Terminals

Elefante Group will utilize two different User Terminals (UTs). Enterprise UTs will utilize the full bandwidth of 450 MHz. Consumer UTs will utilize small bandwidth within the entire beam channel size of 450 MHz. Commercially, Consumer UTs may be appropriate for use in small to medium sized businesses despite the name.

Item	Units	System Design	
Category		Consumer (Narrowband)	Enterprise (Fullband)
TX Band	GHz	21.5-24	21.5-25
RX Band	GHz	25.25-27.5	25.25-27.6
Bandwidth	MHz	5 to 20	450
Aperture Diameter	m	0.45	1
Boresite Gain	dBi	34	40.7
3dB Beamwidth	deg	3.35	1.6
Pattern		ITU-R F.1245 (1)	ITU-R F.1245 (1)
Polarization		RHCP/LHCP	RHCP/LHCP
Clear sky EIRP spectral density	dB(W/MHz)	12	20
Hardware Max EIRP spectral density	dB(W/MHz)	26.4	25.6
Power control		Yes	Yes
Max Elevation Angle	deg	90	90
Min Elevation Angle	deg	12.5-16.6	12.5-16.6
Height above ground	m	10 typical	10 typical
Receiver Noise Density	dB(W/MHz)	-141.7	-141.7
Protection Criteria (I/N)	dB	-6	-6

(1) Custom Pattern (defined in table below) were utilized for PFR Appendices T and U. They are also used in the Fixed Service analysis Exhibit for consistency with previous analyses and to effectively present isotropic backlobes in all azimuth directions toward terrestrial targets.

User Beams

Different beam sizes will be used across the coverage area. Design values for center beams and outer beams are provided in the table below.

Item	**Units**	**System Design**	
Category		User (Center)	User (Outer)
TX Band	GHz	25.25-27.5	25.25-27.6
RX Band	GHz	21.5-24	21.5-25
Bandwidth	MHz	450	450
Aperture Diameter	m	0.05	0.17
Boresite Gain (bottom of band)	dBi	22	32
6dB Beamwidth	deg	13	5
Pattern		Custom (bound with ITU-R F.1245)	Custom (bound with ITU-R F.1245)
Polarization		RHCP/LHCP	RHCP/LHCP
Clear sky EIRP density	dB(W/MHz)	EIRP density adjusted to not exceed ground PFD vs elevation mask. Adopting FSS limits from 25.208 (c)	EIRP density adjusted to not exceed ground PFD vs elevation mask. Adopting FSS limits from 25.208 (c)
Hardware Max EIRP density	dB(W/MHz)	PFD limit + TBD weather margin	PFD limit + TBD weather margin
Power control		Yes	Yes
Max Elevation Angle	deg	90	20
Min Elevation Angle	deg	12.5	12.5
Height above ground	km	18.3-21.3	18.3-21.3
Receiver Noise Density	dB(W/MHz)	-141.7	-141.7
Protection Criteria (I/N)	dB	-6	-6

Feeder Links

Item	**Units**	**System Design**	
Category		Gateway	STRAPS
TX Band	GHz	81-86	71-76
RX Band	GHz	71-76	81-86
Bandwidth	MHz	5000	5000
Aperture Diameter	m	1	0.5
Boresight Gain	dBi	56.4	50.4
3dB Beamwidth	deg	0.22	0.44
Pattern		ITU-R F.1245	ITU-R F.1245
Polarization		RHCP/LHCP	RHCP/LHCP
Clear sky EIRP spectral density	dB(W/MHz)	5	-10.7
Hardware Max EIRP spectral density	dB(W/MHz)	24	14.3
Power control		Yes	Yes
Max Elevation Angle	deg	90	90
Min Elevation Angle	deg	45	45
Height above ground	m	10 typical	18,300 to 21,300
Receiver Noise Density	dB(W/MHz)	-136.4	-136.4
Protection Criteria (I/N)	dB	-6	-6

Custom Antenna Patterns

Enterprise (Full Band) User Terminal Antenna **1 m SOR** **Boresite gain: 40.66 dBi** **3 dB Beamwidth: 1.6 deg**	
Theta deg	**Gain Envelope dBi**
0	40.66
0.5	40.2
0.8	37.66
1	37.1
1.5	34.6
2	24.6
2.5	10
3	-5
3.5	-8.6
4	-11
4.5	-11.9
5	-14.3
5.5	-15
6	-15.5
6.5	-16.5
7	-17.6
7.5	-18.5
8	-19
8.5	-20
180	-20

Consumer (Narrow Band) User Terminal Antenna **0.45 m SOR** **Boresite gain: 34 dBi** **3 dB Beamwidth: 3.4 deg**	
Theta deg	**Gain Envelope dBi**
0	34
1	33
1.5	32
1.67	31
2	30
3	28
4	23
5	13
6	0
7	-10
8	-12.5
9	-13
10	-15
11	-16.5
12	-17
13	-18
14	-20
180	-20

Exhibit 2
Technical Analysis:
Separation Required Between Co-Channel SBCS User Terminals and Conventional FS Receivers in the 21.5-23.6 GHz Band
(Prepared by Lockheed Martin Corporation for Elefante Group, Inc.)

This analysis addresses the question of whether high elevation angle uplinks in Stratospheric-Based Communications Service (SBCS) from fixed User Terminals (UTs) transmitting to Stratospheric Platform Stations (STRAPS) can operate compatibly in close proximity to conventional Fixed Service (FS) receivers. As discussed below, compatible operation is possible with small separation distances, even with conservative assumptions.

Key to compatibility between overhead and terrestrial geometries in the FS is the spatial isolation providing antenna discrimination between high and low elevation angle links, the use of ATPC for coordination advantage where qualifying criteria are met. These factors permit conventional FS receivers to operate closer to SBCS UTs (in both separation distance and angle discrimination) than to conventional FS transmitters.

From the custom antenna patterns[1] presented in the Elefante Group Petition, Appendix A,[2] both Enterprise and Consumer terminals, when aimed at 15 degrees or higher, present no more than -20 dBi gain horizontally toward terrestrial receivers. This represents a 60.6 dB and 54 dB rolloff from boresight gain, respectively, simplifying the EIRP density each presents to -40.6 dB(W/MHz) and -42 dB(W/MHz) at nominal non-faded power in all azimuth directions, and a hardware maximum of -35 dB(W/MHz) and -27.6 dB(W/MHz) that could be exercised to overcome weather. This can be contrasted to the dramatically higher EIRP densities necessarily presented in azimuth near the transmitting direction from licensed FS transmitters (ranging, for example, from 15 to 50 dB(W/MHz) in the San Francisco Bay area as shown in Figure 1). FS receivers and SBCS UTs may operate successfully at close distances in any direction from a SBCS UT.

1 These patterns have significantly higher roll-off than the FCC regulatory mask described in Directional antennas 47 C.F.R. § 101.115.

2 *Petition to Modify Parts 2 and 101 of the Commission's Rules to Enable Timely Deployment of Fixed Stratospheric-Based Communications Services in the 21.5-23.6, 25.25-27.5, 71-76, and 81-86 GHz Bands*, Petition for Rulemaking, RM-11809 (May 31, 2018) ("*Petition*").

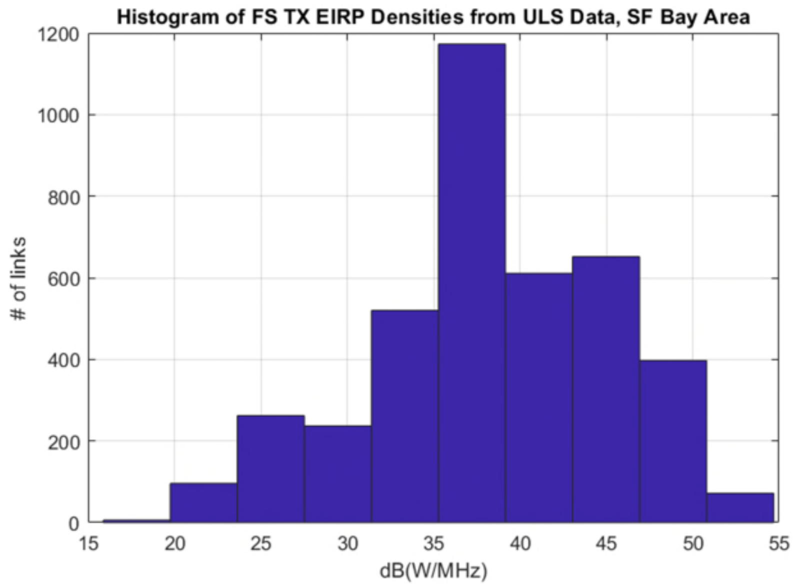

Figure 1: Spread of EIRP density permitted by licensed FS links in the San Francisco Bay Area, indicating a range from15 to 55 dB(W/MHz) with an average value near 40.

Practically, this can be used to illustrate the separation distance and angle required for a new co-channel receiver from a registered SBCS UT. Clearly there is a minimum separation required to prevent (in the absence of shielding or ground clutter) backlobe to backlobe interference. As separation is increased, the azimuth angle the receiver must be aimed away from the UT decreases. At some separation distance, the receiver can be aimed directly at the UT. The figures below illustrate, for three different size receivers, the relationship between minimum separation angle and separation distance in several scenarios. For this illustration, three gains (33.5, 40.4, and 43.8 dBi) are used for the FS RX. ITU-R F.1245, which fits the §101.115 attenuation mask for the 33.5 dBi antenna, is used to bound their patterns. Noise density is assumed as -139 dB(W/MHz). Polarization mismatch loss is assumed to be 1.5 dB, and an I/N protection criteria of -6 dB is used.

As shown in Figure 2, the middle size aperture can aim anywhere outside +/- 48 deg from the Enterprise UT once it is separated by 40 m when the UT is transmitting at nominal unfaded power, and 80 m if the UT transmits at maximum power to overcome weather loss. It is prevented from pointing within +/- 10 deg of the Enterprise UT when the latter is transmitting at nominal unfaded power and separation is 290 m or maximum hardware power and 570 m.

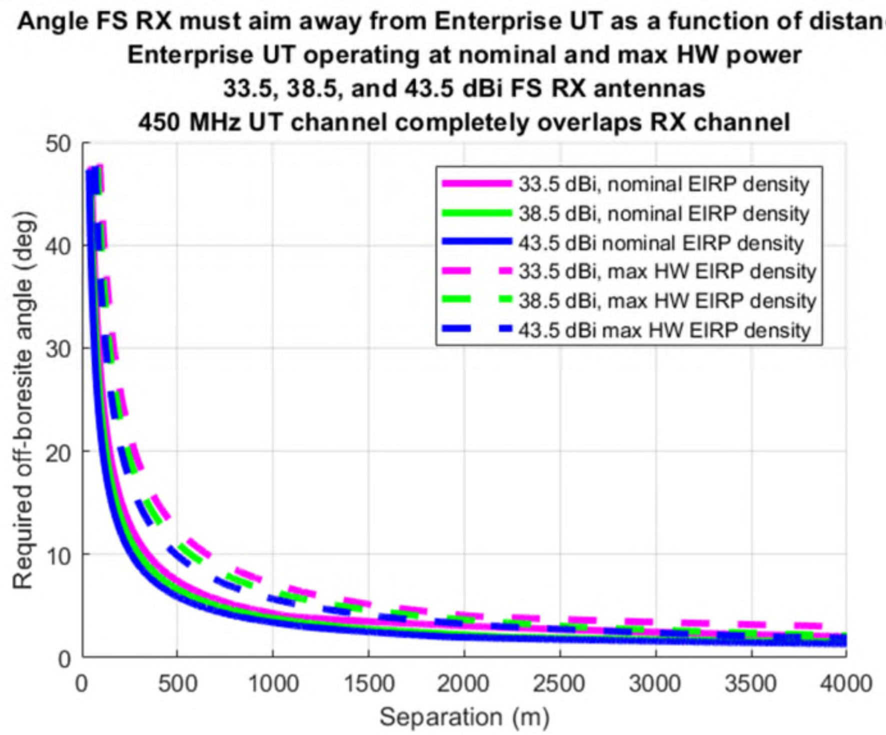

Figure 2: Minimum off-boresight angle for three FS receive antenna sizes as a function of separation distance from Enterprise UT

Figure 3 illustrates the same analysis for the Consumer UT when the 5 MHz channel falls completely within a 50 MHz channel used by the FS RX, the minimum interference when both channels overlap each other. Figure 4 shows the worst case when the UT channel *exactly* overlaps an FS RX channel (e.g. 5 MHz UT channel overlaps a 5 MHz FS RX channel), the maximum interference possible. For the Consumer UT, it should be noted that these cases become highly statistical in nature, and would include the probability of the UT channel overlapping the FS RX channels as well as the probability that weather would prompt the UT to increase transmit power. In some situations, the maximum power must be used. However, in many situations (dependent on relative geometry of the interferer and victim paths and fade margins) ATPC on the UT should qualify it to justify up to a 10 dB lower coordinated power

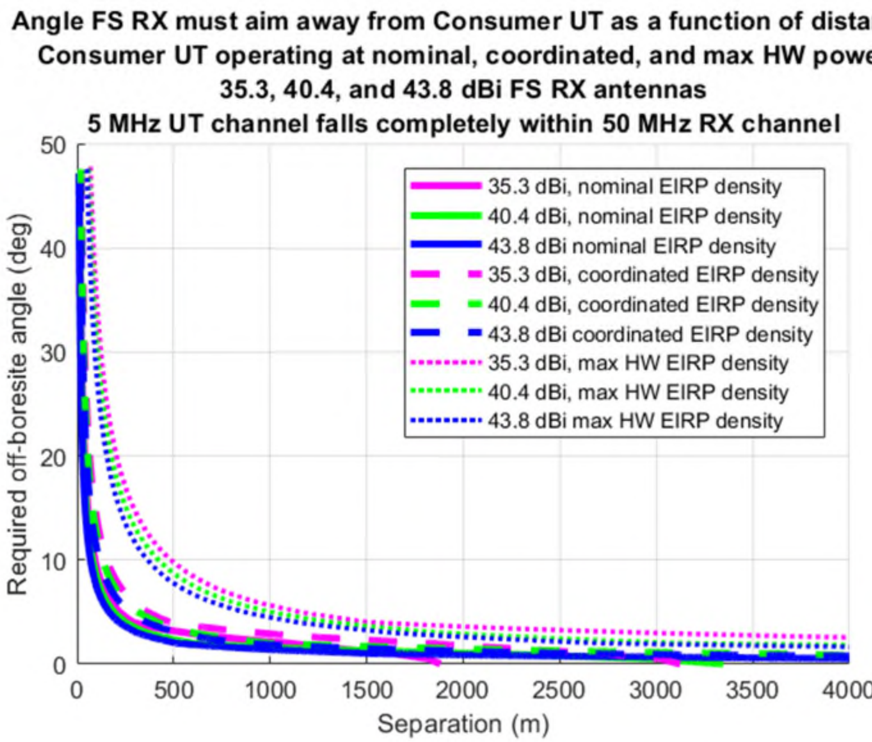

Figure 3: Minimum off-boresight angle for three FS receive antenna sizes as a function of separation distance from Consumer UT

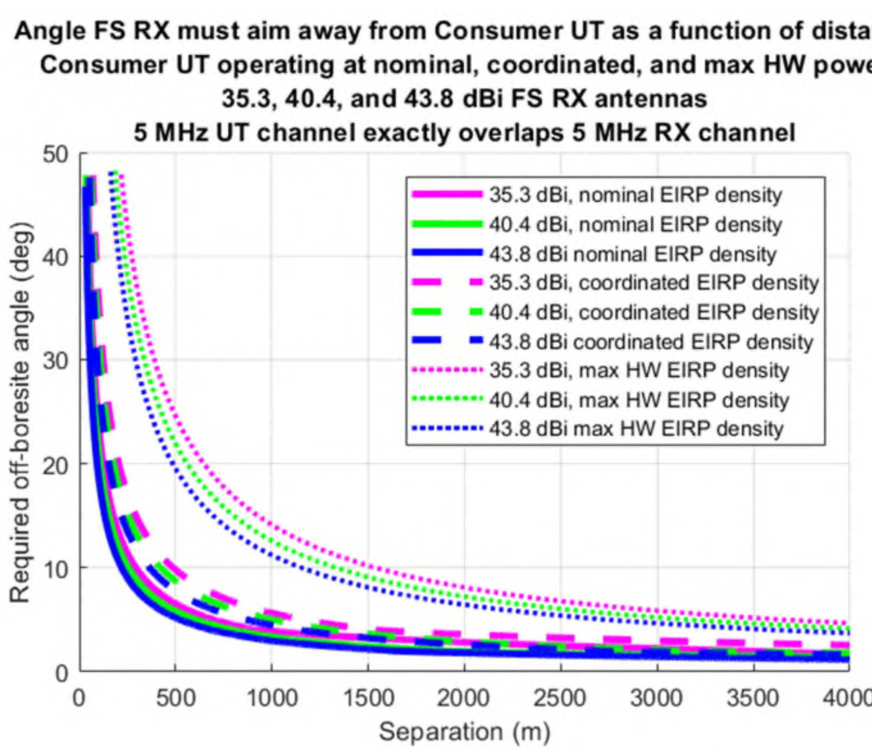

Figure 4: Minimum off-boresight angle for three FS receive antenna sizes as a function of separation distance from Consumer UT

This angle vs distance relationship represents a small difference in the placement of the receiver and/or transmitter. For example, in the worst case overlap and weather for the middle size aperture and the Enterprise UT, shifting the RX location ~100m perpendicular to the desired pointing direction eliminates the interference entirely. This is not practical or feasible for all links (e.g. when antennas are restricted to roofs of two small buildings or when a relay node is not viable), but there is a degree of freedom available to work around installed UT links that, due to the extremely low horizontally directed EIRP density, is even less restrictive than working around the pointing direction of conventional FS transmitters.

Importantly, the above analysis is generally conservative in that it does not account for any ground clutter loss between the UT and FS RX that may come from buildings or topography. Note that where multipath is an important concern for low elevation ground-based links, the overhead directed UT beams do not experience the same phenomena leading to multipath toward ground receivers. Only multipath of emissions from sidelobes far off the UT beam peak are geometrically aligned for such interference.

Exhibit 3
Compatibility Analysis:
SBCS User Terminal Uplink Interference into
NGSO Return Link (LEO-to-MEO) Inter-Satellite Service Link in the
22.55 – 23.55 GHz Band
(Prepared by Lockheed Martin Corporation for Elefante Group, Inc.)

August 15, 2018 Update to the Compatibility Analysis appended to
the Elefante Group Petition for Rulemaking (PFR), RM-118089,
filed May 31, 2018 (Appendix D)

CHANGES FROM PFR, APPENDIX D

The previous version of this analysis, "Compatibility Analysis: STRAPS User Uplink Interference into NGSO Return Link (LEO-to-MEO) Inter-Satellite Service Link in the 22.55 - 23.55 GHz Band," was originally submitted as Appendix D to the PFR. The primary change in this version is the inclusion (on pp. 9-13) of a new risk based statistical study to quantify the maximum possible duration of interference into the medium earth orbit (MEO) Inter-Satellite Service (ISS) satellite.[1]

SUMMARY

- Elefante Group is proposing to access the 22.55–23.55 GHz band for User uplink communications from User Terminals (UTs) to Stratospheric Platform Stations (STRAPS) as part of the Stratospheric-Based Communications Services (SBCS) on a co-Primary basis.

- This study assesses the compatibility of User Terminal uplinks with NGSO Return Link (LEO-to-MEO) Inter-Satellite Service (ISS) which are authorized to operate in the 22.55-23.18 and 23.38-23.55 GHz band.

- Worst-case operating conditions are utilized for a bounding analysis: 1) all UTs simultaneously active and transmitting at power levels which achieve the highest data rates, and 2) maximum number of UTs operating to ensure that the entire 22.55-23.55 GHz band is fully occupied to guarantee overlap with the LEO-to-MEO ISS channels.

- Bounding compatibility study results show that the worst-case geometry and operating conditions are unlikely and would be a transient condition, justifying a statistical analysis and/or coordination to ensure that the LEO-to-MEO ISS service is not impacted.

- Results of a risk-based statistical analysis assuming a typical polar orbit satellite, as a proxy for the Audacy Base service user satellite, also demonstrates that percentage time of interference is well below the ISS protection criterion even under worst-case assumptions.

[1] This document also updates references to NGSO receive antenna patterns, corrects a figure reference number (under "Study Scenarios"), corrects Table 2 where User Terminal types were inadvertently mislabeled, and clarifies references to "STRAPS User uplinks" as "User uplinks" (i.e., uplinks from UTs, not from STRAPS).

PURPOSE OF THE STUDY

Elefante Group is proposing that the 22.55–23.55 GHz band be made available for Stratospheric-Based Communications Services (SBCS), operating as a Fixed service, in the uplink direction. (While not the purpose of this study or a primary tenet of its proposal, Elefante Group proposes that the 22.55–23.55 GHz band also be considered for use in the downlink direction). All or part of this band is allocated in the federal allocation to Fixed, Mobile, Space Research (earth-to-space), and Inter-Satellite Service. Audacy Corporation's application for a non-Federal ISS license in the 23 GHz band was authorized on June 6, 2018. Most of the band will be used to crosslink Audacy's customer's LEO User Satellites with Audacy's MEO Relay satellites. Since the Audacy application file, and other public sources, contain insufficient information regarding the anticipated LEO User satellite characteristics, this study is limited to potential interference into the MEO Relay satellites.

This study assesses the compatibility with LEO-to-MEO ISS links of uplink transmissions from ground-based UTs to a multi-beam stratospheric platform.

This study assesses the potential for interference into NGSO MEO satellite receivers to exceed the -10 dB DRS ISS I/N Protection Criterion which has been assumed to apply to Audacy's LEO-to-MEO return link to determine if mitigation measures are necessary.

OPERATIONAL CHARACTERISTICS OF NGSO ISS MEO RECEIVERS

Operational characteristics of the NGSO ISS MEO receivers utilized for this study are based on Audacy Corporation's FCC Application SAT-LOA-20161115-00117 and shown in Table 1 with the satellite constellation geometry illustrated in Figure 1 and Base service area illustrated in .

Table 1: NGSO ISS Link Receive Characteristics

Parameter	Value	Notes
Number of Satellite Planes	1	
Number of Satellites Per Plane	3	
Nominal Altitude	13,890 km	
Orbital Inclination	25.0 deg	
Frequency Range	22.550 – 22.950 GHz	LHCP & RHCP
Channel Bandwidth	50-100 MHz Base User 150-250 Mhz Advanced User	
LEO User Altitude	<1,500 km	160 km minimum satellite altitude assumed
Total Bandwidth	400 MHz	
Rx Antenna Peak Gain	36.2 dBi Base User 43.5 dBi Advanced User	BRL1, BRR1 ARL2, ARR2

Rx Antenna 3dB Beamwidth	2.6 deg Base User 1.1 deg Advanced User	
Rx Antenna Polarization	RHCP, LHCP	45 deg relative to Equatorial Plane
Rx Antenna Pattern	ITU-R S.672	Assumed typical based on other ISS links referenced in ITU-R S.1591 and ITU-R SA.1414-2
G/T at Max Gain Point	10.0 dB/K Base User 18.0 dB/K Advanced User	
Satellite Receiver Noise Density	-142.4 dBW/MHz Base User -143.1 dBW/MHz Adv User	Calculated from G/T
Protection Criterion	I/N < -10 dB Exceedance <0.1% of visible time	ITU-R SA.1155 assumed to apply to Audacy's LEO-to-MEO return link

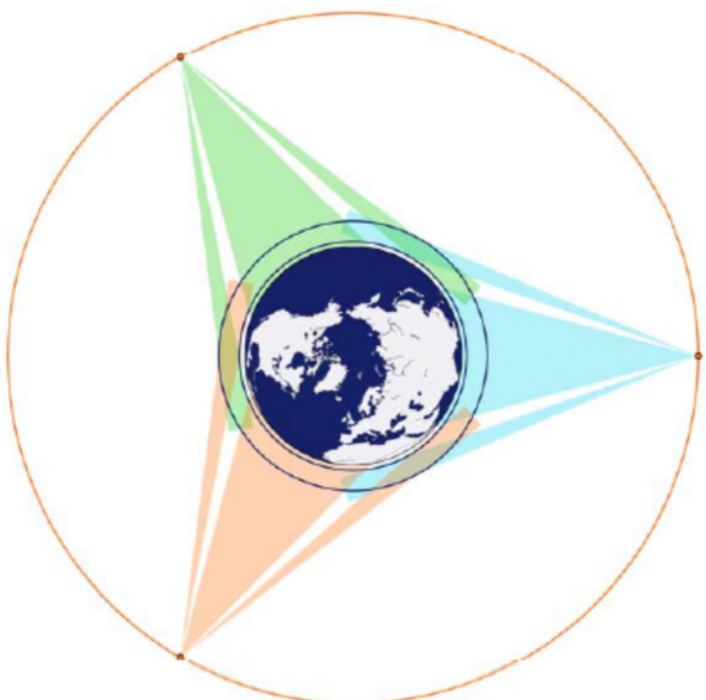

Figure 1: Top-down view of NGSO (Audacy) Base Service Area Geometry
Ref: FCC File Number SAT-LOA-20161115-00117

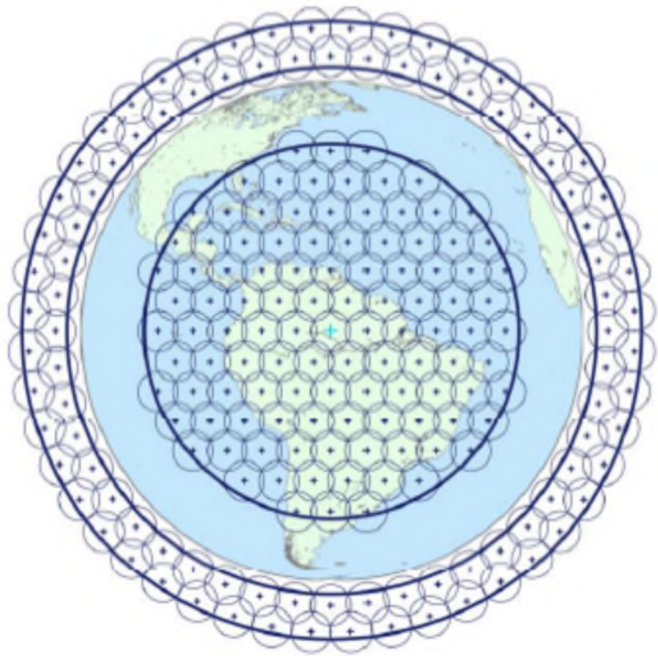

Figure 2: NGSO (Audacy) Single Relay Base Service Area
Ref: FCC File Number SAT-LOA-20161115-00117

OPERATIONAL CHARACTERISTICS OF SBCS

The SBCS will utilize STRAPS, UTs, and Gateway terminals to provide fixed services over a specific service area. Transmit characteristics of the Elefante Group STRAPS user uplink, used in this study, are given in Exhibit 1.

For this study, worst-case operating and geometric conditions are utilized for a bounding analysis prior to considering, if appropriate, risk-based interference assessment using probability and statistical methods:

1) All UTs simultaneously active and transmitting at power levels which achieve the highest data rates, i.e. EIRP Density of 20 dBW/MHz for Enterprise UTs and 12 dBW/MHz for Consumer UTs.

2) Maximum number of UTs operating to ensure that the entire 22.55-23.55 GHz band is fully occupied to guarantee overlap with Audacy's narrower LEO-to-MEO ISS Base user and Advanced user channels.

3) Worst-case geometric alignment between MEO ISS receiver, STRAPS service area and an UT.

STUDY SCENARIOS

Figure 3 illustrates the interference geometry applicable to this study.

- UTs located across the coverage area transmit User Uplink signals to the associated STRAPS.
- Audacy LEO User satellite transmits the desired LEO-to-MEO ISS return link signal to the Audacy MEO Relay satellite.
- As the LEO User satellite and the MEO Relay satellite transverses through their respective orbits, there will be instances of time during which the worst-case alignment for interference will occur when the MEO ISS receiver is pointed directly down towards the STRAPS at the center of the coverage area.
- A UT located at the center of the STRAPS coverage area having the highest elevation angle and shortest distance to the MEO ISS receiver will have the highest potential for interference when its boresight is co-aligned with the MEO ISS receiver.
- A single-entry compatibility study is performed for each type of UT assuming the interference from the boresight pointed UT will dominate since this UT is assumed to transmit across the full STRAPS channel and the inter-beam spacing results in adequate isolation from the next closest UT.
- A risk based statistical study using conservative SBCS system assumptions is also performed to quantify the maximum possible duration of interference into the MEO Relay satellite and the percentage of time I/N Protection Criterion is exceeded. This study is performed for the Audacy Base service since in its Narrative Exhibit, Audacy states that "The orbital distribution of Users in each Relay's field of view means that the Advanced spot beams will rarely intersect the Earth, eliminating potential interference with terrestrial users of the same spectrum". Unlike the Base service, the Advanced Services doesn't have separate inner and outer beam coverage areas towards User Satellites which avoids low elevation angle fixed service.

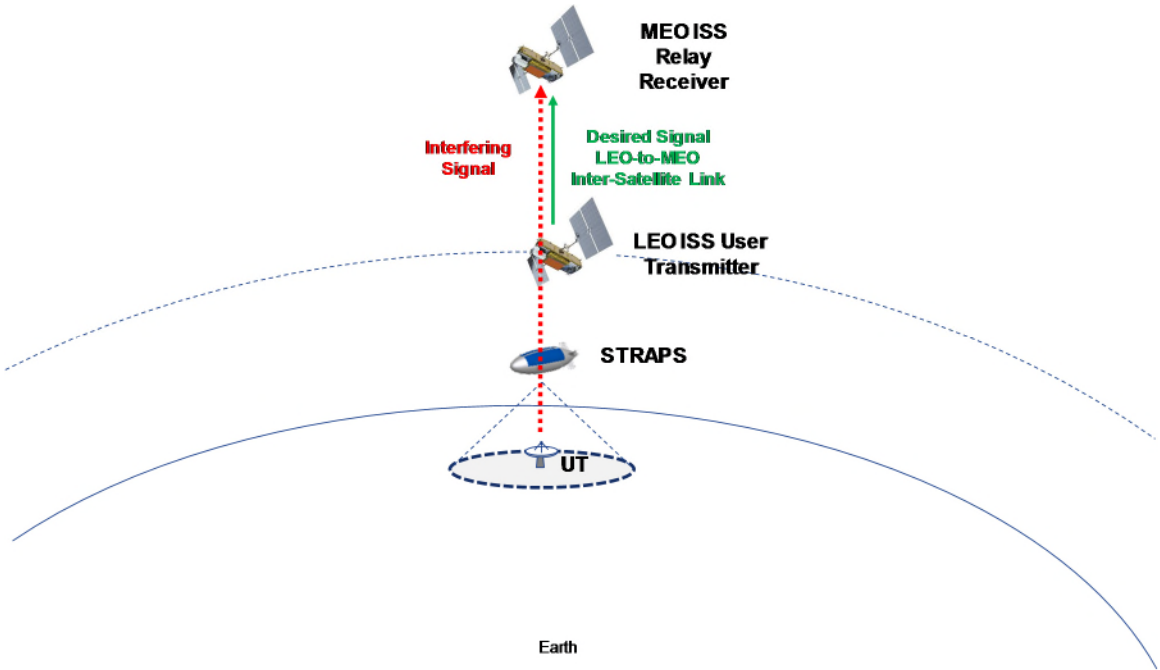

Figure 3: Worst-Case Interference Geometry

STUDY METHODOLOGY – Bounding Single Entry Analysis

As illustrated in **Error! Reference source not found.**, the worst-case static interference geometry is setup as follows:

Interfering UT elevation angle = 90 degrees (boresight pointed directly at MEO receiver)

Range from Interfering UT to MEO satellite = 13,890 km

MEO satellite boresight angle towards UT = 0 deg

Therefore, the interference level from the UT into the MEO ISS receiver is:

$$Io\ \left(\frac{dBW}{MHz}\right) = \ EIRP\ Density\ (\delta) - FSL - Gr\ (\beta)$$

where:

δ = Angle off UT (Interferer) boresight towards the MEO ISS receiver = 0 degrees

$Gr\ (\beta)$ = $Gr\ (0\ deg)$ = MEO ISS (Victim) receive antenna peak boresight gain towards UT

FSL = Free Space Loss between the UT and MEO ISS receiver

Therefore,

$$I/_N\ Margin\,(dB) = I/_N\ Threshold - (I_o - N_o)$$

where $I/_N\ Threshold$ is the DRS ISS Protection Criterion of -10 dB which is assumed to be applicable to the LEO-to-MEO ISS link.

STUDY RESULTS – Bounding Single-Entry Analysis

Results of the worst-case single-entry compatibility study are summarized in Table 2.

Table 2: Worst-case Single-Entry Compatibility Study Results

UT Type	Audacy User Service	Worst-Case I/N Margin
Enterprise	Base	-6.2 dB
Enterprise	Advanced	-14.2 dB
Consumer	Base	+1.8 dB
Consumer	Advanced	-6.2 dB

Not surprisingly, during the instance of worst-case alignment of the UT transmitting directly into the MEO receiver boresight at the minimum range, the worst-case I/N Margins are generally negative.

Taking the worst-case scenarios with Advanced Audacy User service, Figure 4 and Figure 5 illustrate that the negative I/N margins occur for a very small range of UT and MEO off-boresight antenna angles where the yellow areas indicate regions of positive I/N margin therefore even a small offset in these angles as the MEO and user satellites move through their orbits, will significantly reduce the interference level.

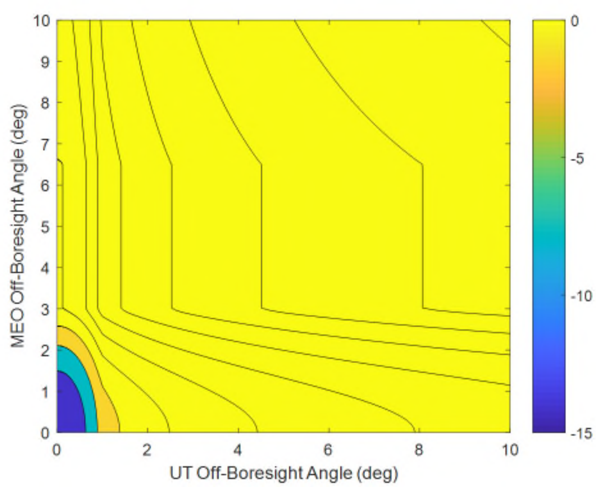

Figure 4: I/N Margin versus UT and MEO Boresight Angles – Enterprise UTs

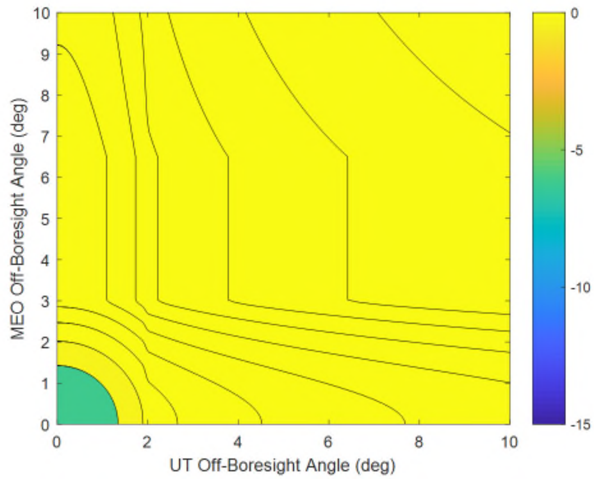

Figure 5: I/N Margin versus UT and MEO Boresight Angles – Consumer UTs

A more realistic scenario which takes into account the short duration transient nature of such worst-case alignment requires additional knowledge of the Audacy's user systems in order to perform a risk-based statistical compatibility analysis. Given the lack of additional information and drawing from information in the Relay to NGSO interference scenario cited in Audacy's Narrative Exhibit, a risk based statistical analysis was performed assuming a typical polar orbiting User satellite as shown in the next section.

The following are excerpts from the Audacy's ex-parte dated 13 October 2017 which support the unlikely and transient likelihood of such worst-case alignment:

- Relays will not continuously radiate Earth's surface
- Statistically, most Network user satellites are at the poles and around the edge of the Earth: most Relay-User beams will not intersect Earth (see Figure 6)
- Relay beams only transmit/receive when User present
- Relay signals will not interfere with Fixed/Mobile systems: In-line geometries are rare and extremely transient

It should be noted that the likelihood of interference is also a function of the worst-case combination of the following:

- Overlap in bandwidth between SBCS system and Audacy's user system
- Geographic extend of the interference geometry; i.e. the intersection of STRAPS coverage area with the Audacy's MEO satellite beams
- The transient overlap in time between the Audacy user transmitting and UTs transmitting at the maximum power. It should be noted that the contact time for Audacy's over-the-horizon beams should be a lot longer than the corresponding time over Earth pointing beams

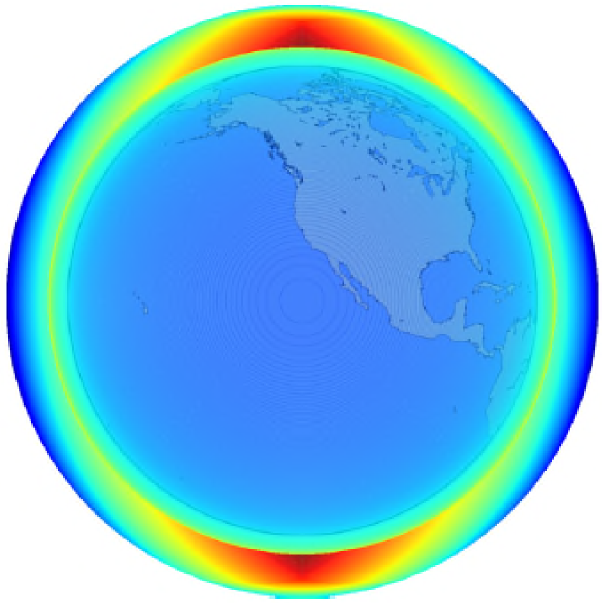

Figure 6: Audacy Heatmap Showing User Statistical Distribution
Ref: Audacy Ex Parte dated 13 October 2017

STUDY METHODOLOGY AND RESULTS – Risk Based Statistical Analysis

A risk-based statistical analysis was performed for Elefante Group Enterprise UTs to examine the duration and frequency of the worst-case scenario from the single-entry results shown in Table 2 with I/N margin of -6.2 dB which corresponds to a UT pointing directly into the boresight of Audacy Relay satellite receive antenna. From the Audacy Relay satellite antenna perspective, this means that positive I/N margin would be achieved if the Relay satellite receive antenna gain towards the UT is 6.2 dB lower than its peak. This corresponds to a 3.75 degree off-boresight angle using the ITU-R S.672 antenna pattern as explained in Table 1. The 3.75 degree off-boresight angle can be mapped into a projected area on the ground from which interference from a UT, exceeding the I/N Protection Criteria, is possible under worst-case alignment and UT pointing conditions.

Further constraining the possible geometry for interference is that only UTs with an elevation angle greater than 41.1 degrees can possibly aim directly into an Audacy Relay satellite; these will correspond to UTs located within 22.6 km radius of the STRAPS representing 10% of the total service area.

Note that UTs with elevation angles lower than 31.4 degrees (down to the minimum 15 degrees) would have sufficient off-boresight angle rejection on their own to result in positive I/N margin; these will correspond to UTs located outside a 33.2 km radius of the STRAPS nominally fixed position. This means that UTs in 79% of the STRAPS service area could never present harmful interference to the Relay satellite.

To further examine the geometry and the worst-case duration for such interference, a case-study is examined with the STRAPS centered above Miami, FL where an Audacy Relay satellite is visible twice per day. Results of the analysis are shown in Figure 7 which illustrates that there are small alignment zones consisting of 0.507% of the STRAPS service area from where the geometric alignment can occur to permit such interference. Each point within these alignment zones represents where a UT could be deployed and pointed towards the Relay satellite and the full alignment zone is representative of all such UT locations as the Relay satellite progresses in its orbit.

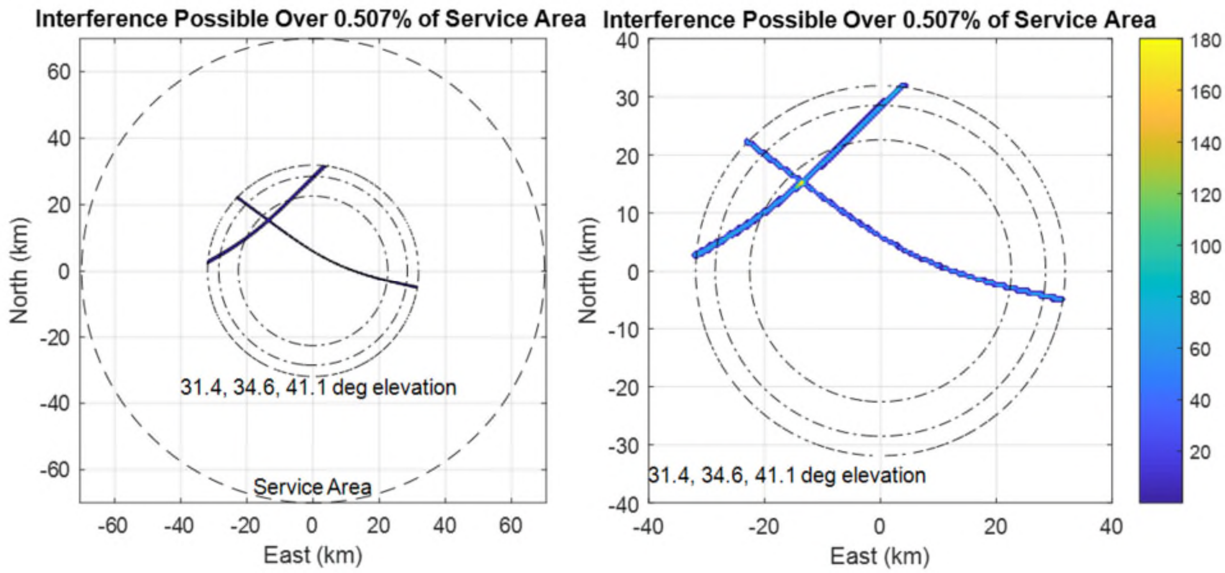

Figure 7: STRAPS coverage area where geometric alignment creates potential for interference
Left figure shows full 70 km radius STRAPS coverage area
Right figure indicates of possible alignment zones and corresponding maximum durations

Note that above results are a conservative over-estimation since the geometric conditions have assumed the need to compensate for the full 6.2 dB negative I/N margin everywhere while in the real case, the negative margin tapers between the 22.6 and 32.2 km radii represented by the inner and outer circles in Figure 7. As in the case of the single-entry bounding analysis, the UTs are assumed to be transmitting at maximum EIRP density in clear sky conditions while in the real case, Enterprise UTs would employ Automatic Transmit Power Control (ATPC) which limits the EIRP to that necessary for the modulation being used which is dependent on time-varying data rates from each site.

Making an absolute worst-case assumption of the entire STRAPS user bandwidth across all beams being occupied by the maximum number of 540 possible Enterprise UTs and none allocated to Consumer UTs, there is a 1 out of 8 probability that an interfering UT would be operating in the same band and polarization which could interfere with the Audacy return link based on the planned 4-color beam laydown in each STRAPS service area.

Therefore, based on Figure 7 and assuming that UTs are randomly distributed, the probability of an Enterprise UT aligned to cause interference from a STRAPS service area and in the same frequency band and polarization is 540 / 8 x 0.0507% = 34.2%.

To determine the probability of interference and therefore the percentage of time over the Audacy User-to-Relay satellite return link is impacted by such interference, time dynamics of the interference geometry must be considered.

Using the above described geometric alignment analysis, the probability of the maximum interference duration for UTs which are within the alignment zones is illustrated in Figure 8. Results demonstrate that a 100 sec duration can be safely utilized as a bounding geometric assumption to determine the percentage of time interference into the Audacy Relay satellite return link can occur. Note that these results only represent bounding durations based only on geometric alignment of STRAPS and Relay satellite and actual duration for interference will be much shorter and will be limited by the number and density of UTs within the alignment zones.

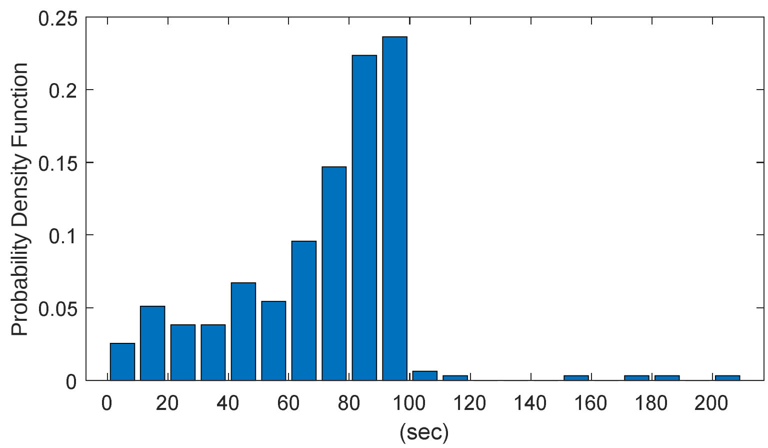

Figure 8: Probability distribution of maximum interference duration for UTs in 0.5% of STRAPS coverage area which have possible geometric alignment to cause interference

With regards to time alignment of the User satellite, interference into an Audacy return link can only occur if the User satellite happens to be in the alignment zone during the times when the Relay satellite, STRAPS and UT are co-aligned.

First, the probability statistics of a typical polar (User) satellite with a retrograde orbit and inclination angle of 81.3 degrees are determined. The longitude probability density is a uniform function and the latitude probability density function is skewed towards latitudes with maxim orbital inclination angle as illustrated in Figure 9.

To simplify the problem and yet utilize worst-case assumptions, the probability that the User satellite is within the 3.75 degree off-boresight angle of the Relay satellite necessary for interference is determined noting that this angle represents the worst-case angle from the Relay satellite to STRAPS over which UT interference is possible. Results are illustrated in Figure 10 and show that the maximum probability of an interference event due to time dynamics during a single day (2 passes) over Miami is 0.52% with an average probability of 0.42%.

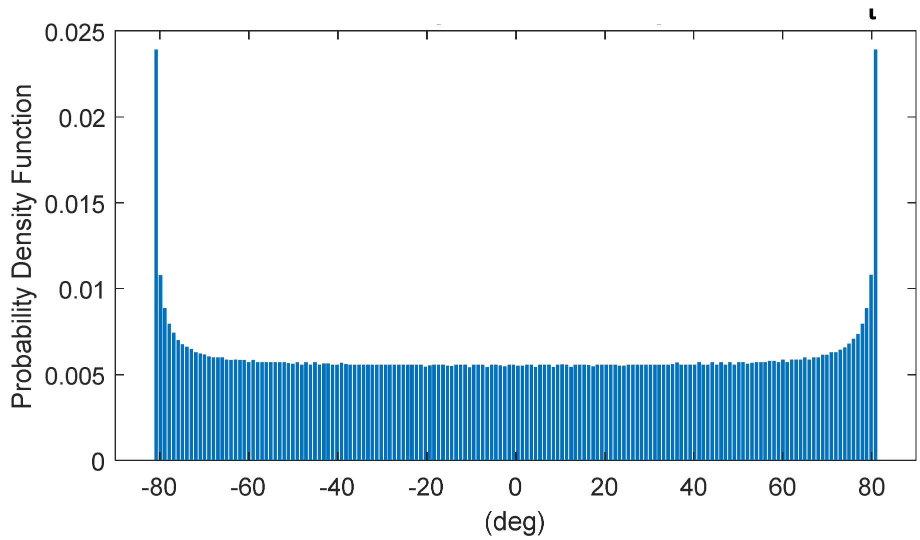

Figure 9: Probability Density Function for Latitude
Polar LEO User satellite with orbital inclination angle of 81.3 degrees

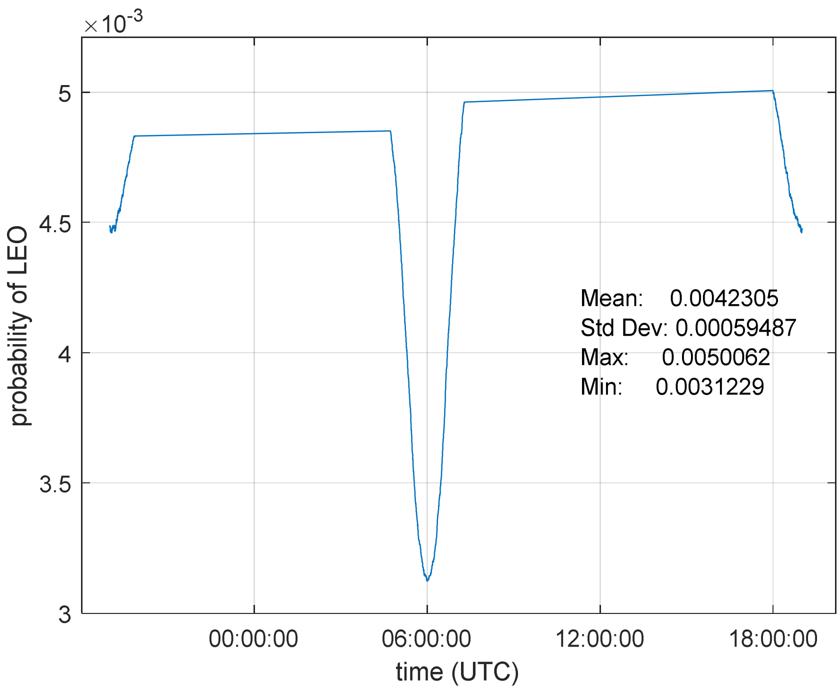

Figure 10: Probability that User Satellite is within 3.75 deg
geometric interference angle from Relay to STRAPS over a single day

Therefore, assuming the maximum interference time of 100 seconds from Figure 8 and the average probability of an interference event over a single day of 0.42% from Figure 10, the fractional time of interference from a single UT into an Audacy return link is calculated by multiplying the two values and dividing by the total number of seconds in a day:

0.0042 x 100 seconds / 86400 seconds-per-day = 0.000486%

Multiplying this figure with the 34.2% chance there is a UT aligned to cause interference from a STRAPS service area and in the same frequency band and polarization as shown in the above geometric calculation, the percentage exceedance time from a single STRAPS coverage area is:

$$0.000486\% \times 0.342 = 0.000166\%$$

The aggregate time of interference into an Audacy forward link would be dependent on the total number of STRAPS coverage areas that might be visible to an Audacy Relay satellite. Therefore, starting with the 0.1% allowable exceedance from ITU-R SA.1155, assumed to apply to Audacy's return link. This means that it would take 601 STRAPS service areas operating under the described worst-case conditions within view of the Audacy MEO satellite to cause interference that would exceed the Protection Criteria, a number that is well above the expectations even given optimistic projections on the number of STRAPS that are likely to be deployed.

As explained in the Supplemental Information section below, application of other factors such as the diversity of Audacy' s U2R Return link channels, the use of Automatic Transmit Power Control ("ATPC") by SBCS links, and Audacy's greater reliance on the outer beams than the inner beams of its system architecture will further reduce the already miniscule potential for interference into the U2R Return links.

SUPPLEMENTAL INFORMATION

Additionally, although the above described risk-based statistical analysis considers the diversity in frequency band and polarization for the Elefante Group SBCS system, it does not consider the same for the Audacy system. Specifically, the Audacy Narrative Exhibit shows the Audacy Base service beams receive 11 channels over a majority of 22.95-23.55 GHz band and 8 channels over 32.85-33 GHz. As an example, if all channels are assumed to be utilized equally, a user has an 61% chance of using a channel in the 22.95-23.55 GHz band and therefore any risk of interference from the Elefante Group SBCS system would be even less than shown in this analysis.

Additionally, although time dynamics associated with orbital alignment are considered, it is assumed that all UTs are operating at maximum power density utilizing the full bandwidth without consideration for Automatic Transmit Power Control (ATPC) which limits the EIRP to that necessary for the modulation being used which is dependent on time-varying data rates from each site. A more realistic set of operating conditions would also reduce the potential for interference.

Similarly, for harmful interference to occur, an Audacy User satellite must be actively using the beam during the time that an interferer is exceeding that beam's receiver noise threshold. How Audacy operates its system and the multiple network paths available to many User satellites is not certain, but in prior statements in the record, it has indicated that the Base service will rely much more on the outer beams than the inner beams where interference from SBCS UTs could occur. In its July 7, 2017 Opposition and Response, Audacy verified that "In a minority of cases, a User satellite will appear from the Relay satellites to be passing across the visible earth disc". They further maintained that "It is highly unlikely that the Network would have a sufficiently large number of Users, all of whom are commanding their satellites simultaneously, to necessitate the concurrent operation of all Relay transmit beams". Presuming the that the network overhead required to implement adaptive coding and modulation and beam-to-beam and relay-to-relay handovers requires some form of duplex communications, the same is assumed to be true for receive beams as well. Additionally, as shown in Figure 6, Audacy has clearly illustrated in a heat map of statistical user distributions that there will be dramatically fewer user satellites within the inner beam coverage area compared to the outer beams. Therefore, the statistical chance that a particular User satellite will be receiving in an inner beam at the same time that inner beam is receiving interference is an additional mitigating factor not accounted for in this analysis.

CONCLUSIONS

Bounding compatibility study was performed using worst-case operational and geometric assumptions including all UTs simultaneously active, transmitting at maximum power and across the entire 22.55-23.55 GHz band, thus ensuring overlap with all Audacy's LEO-to-MEO ISS Return channels.

The bounding study conducted as a static analysis also assumed worst-case geometric alignment and shortest range between the Audacy MEO receiver and the UT located at the center of the STRAPS coverage area which are unlikely and transient events and result in negative I/N margins relative to the assumed I/N Protection Criteria.

A conservative risk-based statistical analysis of the potential for interference from Enterprise UTs into MEO Relay satellites was also performed assuming a nominal Audacy User satellite operating in a polar orbit and demonstrated that even making some worst-case geometric alignment and SBCS system assumptions, the percentage time of interference into the Audacy Relay satellite receiver is much less than the 0.1% time exceedance allowable.

REFERENCES:

ITU-R S.1155: Protection Criterion related to the operation of data relay satellite systems

ITU-R S.672: Satellite antenna pattern for use as a design objective in the fixed-satellite service employing geostationary satellites

ITU-R S.1591: Sharing of inter-satellite link bands around 23, 32.5 and 64.5 GHz between non geostationary/geostationary inter-satellite links and geostationary/geostationary inter-satellite links

ITU-R SA.1414-2: Characteristics of data relay satellite systems

Audacy Ex Parte: Notice of Ex Parte Communication – Audacy Corporation, Application for Authority to Launch and Operate a Non-Geostationary Medium Earth Orbit Satellite System in the Fixed- and Inter-Satellite Services, IBSF File No. SAT-LOA-20161115-00117 dated 13 October 2017

Exhibit 4
Compatibility Analysis:
SBCS STRAPS Downlink Interference into
Radio Astronomy Passive Sensing in the
23.6-24 GHz Band
(Prepared by Lockheed Martin Corporation for Elefante Group, Inc.)

August 15, 2018, Update to the Compatibility Analysis appended to the Elefante Group Petition for Rulemaking ("PFR"), RM-118089, filed May 31, 2018 (Appendix M)

CHANGES FROM PFR, APPENDIX M

The previous version of this analysis, "Compatibility Analysis: STRAPS User Downlink Interference into Radio Astronomy Passive Sensing in the 23.6-24 GHz Band," was originally submitted as Appendix M to the PFR. The primary change in this version is to address compatibility of multiple STRAPS located near a RAS station (on pp. 9 – 11).[1]

SUMMARY

- Elefante Group is proposing to access the 25.25–27.5 GHz band for User downlink communications from Stratospheric Platform Stations (STRAPS) to User Terminals (UTs) as part of the Stratospheric-Based Communications Services (SBCS) on a co-Primary basis.

- This study assesses the compatibility of STRAPS downlink out-of-band emissions with the Radio Astronomy Service (RAS), which has allocation to operate on a protected basis in the 23.6-24 GHz bands. The transmit and victim bands are separated by 1.25 GHz.

- Worst-case operating conditions and interference geometry are utilized for a bounding analysis which includes STRAPS transmitting at a level equal to the maximum Power Flux Density (PFD) limit as authorized for satellite downlinks into Fixed services.

- Study results show compatibility is achieved and protection criteria can be far exceeded including under extreme theoretical assumptions for multiple STRAPS located near an RAS station.

PURPOSE OF THE STUDY

Elefante Group is proposing that the 25.25–27.5 GHz band be made available for Stratospheric-Based Communications Services (SBCS), operating as a Fixed service, in the downlink direction. (While not the purpose of this study or a primary tenet of its proposal, Elefante Group proposes that the 25.25–27.5 GHz band also be considered for use in the uplink direction.) All or part of this

[1] This document also assesses the effects of STRAPS altitude and horizontal motion during station keeping to the interference level (on pp. 12) and includes a compatibility analysis to determine in-band power versus Radio Astronomy Service damage levels (on p. 11).

band is allocated for Federal Fixed, Mobile, Earth Exploration Satellite (space-to-earth), Space Research (space-to-earth), and Inter-Satellite services on a primary basis, and Space Research and Inter-Satellite service in the non-federal allocation on a secondary basis.

This study assesses the compatibility with RAS observations of out-of-band STRAPS downlink transmissions from a multi-beam stratospheric platform to ground-based UTs.

This study assesses the potential for such interference to exceed the I/N and percentage data Protection Criteria to determine if mitigation measures are necessary.

PERFORMANCE CHARACTERISTICS OF RAS SENSORS

Table 1 presents general characteristics for RAS common to all frequency observation bands. Table 2 presents performance characteristics of RAS sensors utilized in this study based on ITU-R RA 769-2 and specific PFD thresholds for interference when the RAS antenna presents 0 dBi gain to the interferer.

The continuum observation centered on 23.8 GHz is the most sensitive to interference. RAS also makes observations within other bands that are not allocated or protected, which will be addressed in the results section.

Table 1: General RAS characteristics for interference analysis

Parameter	Value	Source
Rx Antenna Gain	88 dBi	Utilizing typical gain from ITU-RA.1631 which correlates with a 100m diameter antenna
Rx Antenna Beam Width	0.8 deg	Derived assuming 70% efficient antenna (1)
Rx Antenna Pattern	ITU-R SA.509-3	ITU-R SA.509-3
Min. Elevation Angle	5 deg	ITU-R RA.1513
Polarization	Co-polarized with interferer	Worst case
Total interference allocation	5%	ITU-R RA.1513
Single system interference allocation	2%	ITU-R RA.1513
RAS Damage Power Level	10 mW	ITU-RA.2188 Assuming typical 100m RAS antenna diameter

Table 2: Band Specific Characteristics

Type	Center (GHz)	Bandwidth (MHz)	Threshold PFD dB(W/m^2/MHz)
Line	22.2	250	-156
Line	23.7	250	-155
Continuum	22.355	290	-171
Continuum	23.8	400	-173
VLBI	23.8		-123

OPERATIONAL CHARACTERISTICS OF SBCS

The SBCS will utilize STRAPS, UTs, and Gateway terminals to provide fixed services over a specific service area. Transmit characteristics of the Elefante Group STRAPS user downlink utilized in this study are given in Exhibit 1.

For this study, worst-case operating conditions and alignments are utilized for a bounding analysis prior to considering, if appropriate, risk-based interference assessment using probability and statistical methods:

1) STRAPS located at a minimum altitude of 18.3 km and transmitting at the maximum PFD limit as authorized for satellite downlinks in this band to protect interference into Fixed Services per CFR Title 47 25.208(c) over the STRAPS 70 km radius coverage area. The STRAPS downlink power is the maximum from the total power range provided by Automatic Transmit Power Control (ATPC).

2) Multiple STRAPS downlink channels operating simultaneously to encompass the full user downlink band (not considering that coverage is provided by multiple channels “colors” which are spread across hundreds of beams and that the nearest RAS station may not be making observations at 23.6 GHz).

3) Conservative RAS station including an 100m antenna making observations in the most sensitive Continuum band down to 23.6 GHz to a minimum elevation angle of 5 degrees.

STUDY SCENARIO

Figure 1 illustrates the interference geometry applicable to this study.

- STRAPS transmits downlink signals to the associated service area.
- RAS observations conducted down to 5 deg minimum elevation angle over a 1.83 pi steradian solid angle.

- If PFD threshold is exceeded, RAS experiences interference when aimed within some angle of the STRAPS. This solid angle of interference (SAI) determines the percent of RAS field of regard that would be unavailable for observations, “Sky Blockage,” satisfying protection criteria threshold.

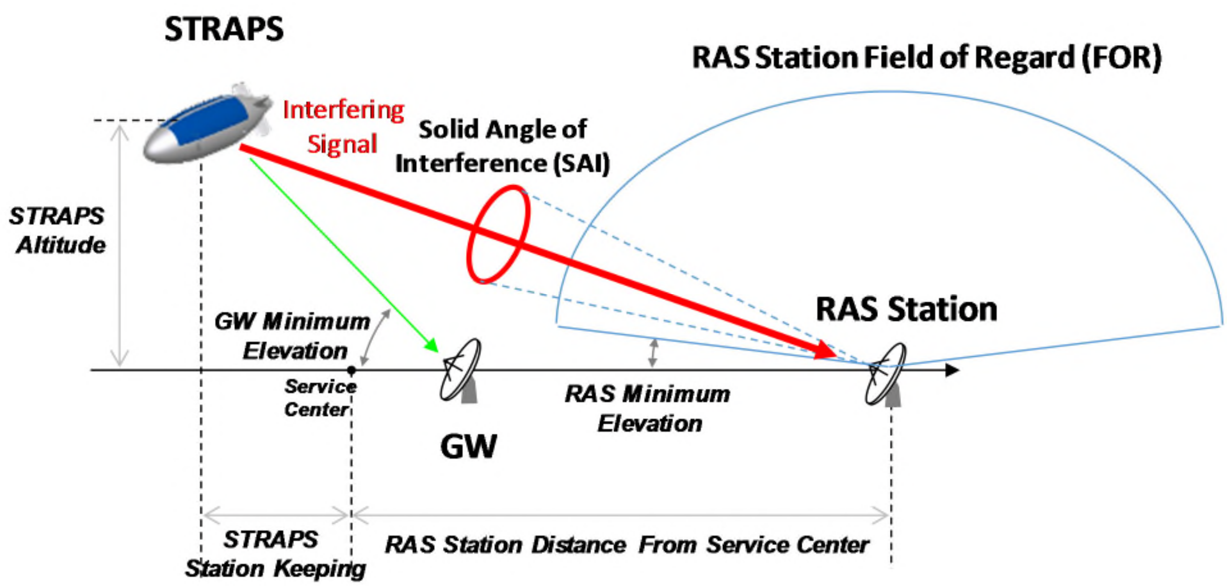

Figure 1: Interference Geometry

STUDY METHODOLOGY

The study starts by assuming the STRAPS is transmitting at a level equal to the PFD limit that is proposed by Elefante Group, namely that authorized for satellite downlinks in the adjacent 23 GHz band to protect interference into Fixed services per CFR Title 47 25.208(c). The assumption is that the STRAPS service area is defined by a 70 km radius coverage area centered on the point below the STRAPS fixed position as described below and illustrated in Figure 2 and Figure 3.

$$PFD\left(\frac{dBW}{m^2 * MHz}\right) = \begin{cases} -115 & 0 \le \delta < 5 \\ -115 + 0.5 * (\delta - 5) & 5 \le \delta < 25 \\ -105 & 25 \le \delta \le 90 \end{cases}$$

Where δ is the angle of arrival (in degrees) above the horizontal plane (elevation angle)

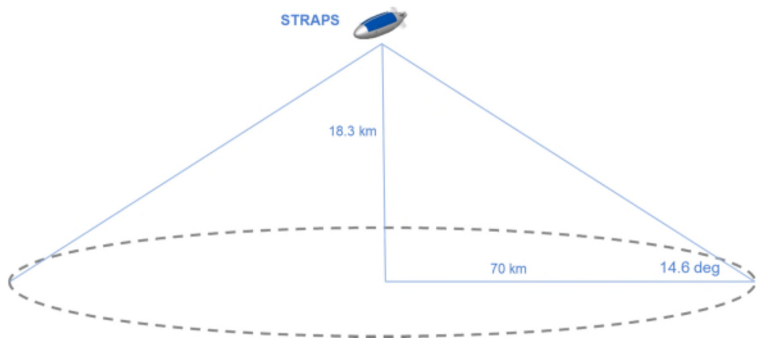

Figure 2: STRAPS Service Area Geometry

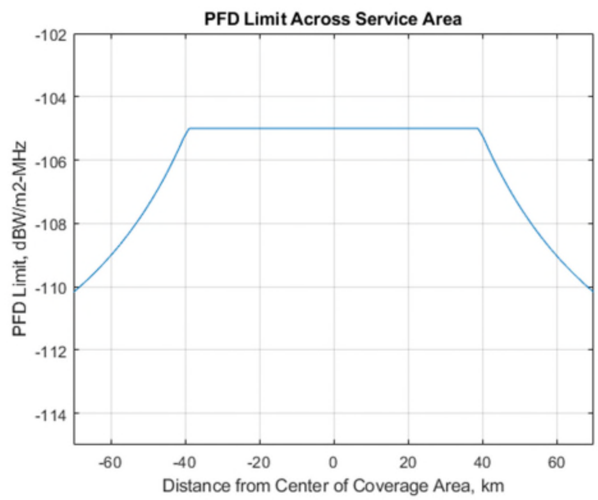

Figure 3: PFD Limit Across Service Area

PFD outside of the coverage area is calculated by starting with the PFD limit and rolling it off using the ITU-R F.1245 antenna pattern with peak antenna gain of 32.7 dB at the edge of coverage.

The corresponding STRAPS (Interferer) EIRP Density as a function of transmit antenna boresight angle is calculated as follows and illustrated in Figure 4.

$$EIRP\ Density\ \left(\frac{dBW}{MHz}\right) = PFD - 10 * \log(4 * \pi * r^2)$$

Where r is the distance from STRAPS to the ground distance away from the center of the coverage area

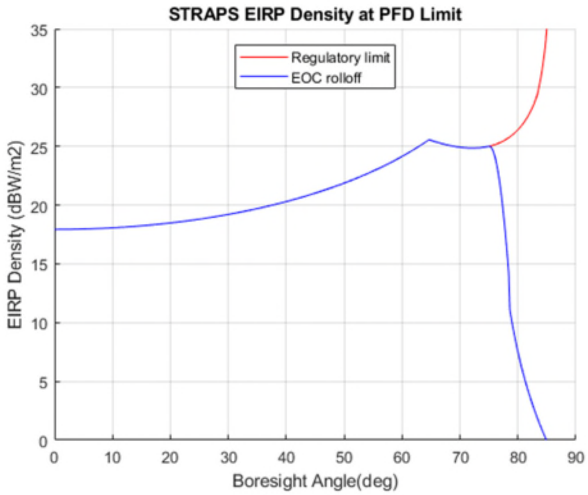

Figure 4: STRAPS EIRP Density at PFD Limit. Rather than generating EIRP sufficient to maintain the PFD limit outside the STRAPS service area (red), the EIRP tapers with the antenna pattern roll-off of the STRAPS beam directed toward the edge of the coverage area (blue).

The incident PFD is compared to the threshold PFD of -173 dB(W/MHz) for 23.6-24 GHz RAS observations. This threshold applies to the case of 0 dBi presented by the RAS sensor, whereas actual gain presented can be as high as the RAS boresight gain of 88 dBi. Therefore, the interference margin is calculated as

Margin = Threshold PFD - Incident PFD – RAS gain

This relationship is used in two ways:

<u>Bounding analysis</u>: In a bounding analysis, the worst-case RAS gain is assumed and the out-of-band attenuation necessary to achieve 0 dB margin is determined as a function of RAS separation distance from the service area center.

- At separations where the STRAPS appears above the minimum 5 deg elevation, the gain presented is the boresite gain.
- At greater separations, the gain presented is the minimum off-boresight gain presented when the RAS is aimed at 5 deg elevation and in azimuth toward the STRAPS.

<u>Interference Criteria analysis</u>: This analysis assesses the percent data loss due to observations with negative interference margin.

- Because RAS gain is a function of angle off boresight, the margin relationship is used to determine the angle the RAS sensor must maintain off the STRAPS to achieve positive margin given an incident PFD.
- In turn, as shown in Figure 1, the required angle is used to calculate the solid angle of interference, which is compared to the RAS field of regard solid angle to determine the percentage of observing area where margin would be exceeded. Assuming an equal weighting of observations over the entire field of regard, this serves as a proxy for the percentage of data with negative interference margin, aka “Sky Blockage.”

- By surveying separation distance and incident PFD attenuation values, contours of percent data with negative margin can be determined.

STUDY RESULTS

Although results for the bounding analysis indicate extreme attenuation is necessary to enable RAS observations directly toward the STRAPS, the narrow, pencil beam of the RAS sensor allows the percent data loss criteria to be met with significant margin.

Figure 5 depicts the bounding analysis results. Because of the high sensitivity and gain of the RAS sensor, over 150 dB attenuation would be necessary if the STRAPS operated directly above the RAS at 0 km separation. The degree of attenuation follows the downlink PFD limit as it rolls off to the 70 km service area edge, then rolls off more rapidly with the roll-off of the outermost beam until the RAS station has 200 km separation, where the STRAPS is observed at 5 deg elevation. Beyond 200 km, the roll-off follows the RAS gain pattern, benefiting slightly from increased range loss as well, until the RAS station passes below the horizon of the STRAPS at ~525 km separation.

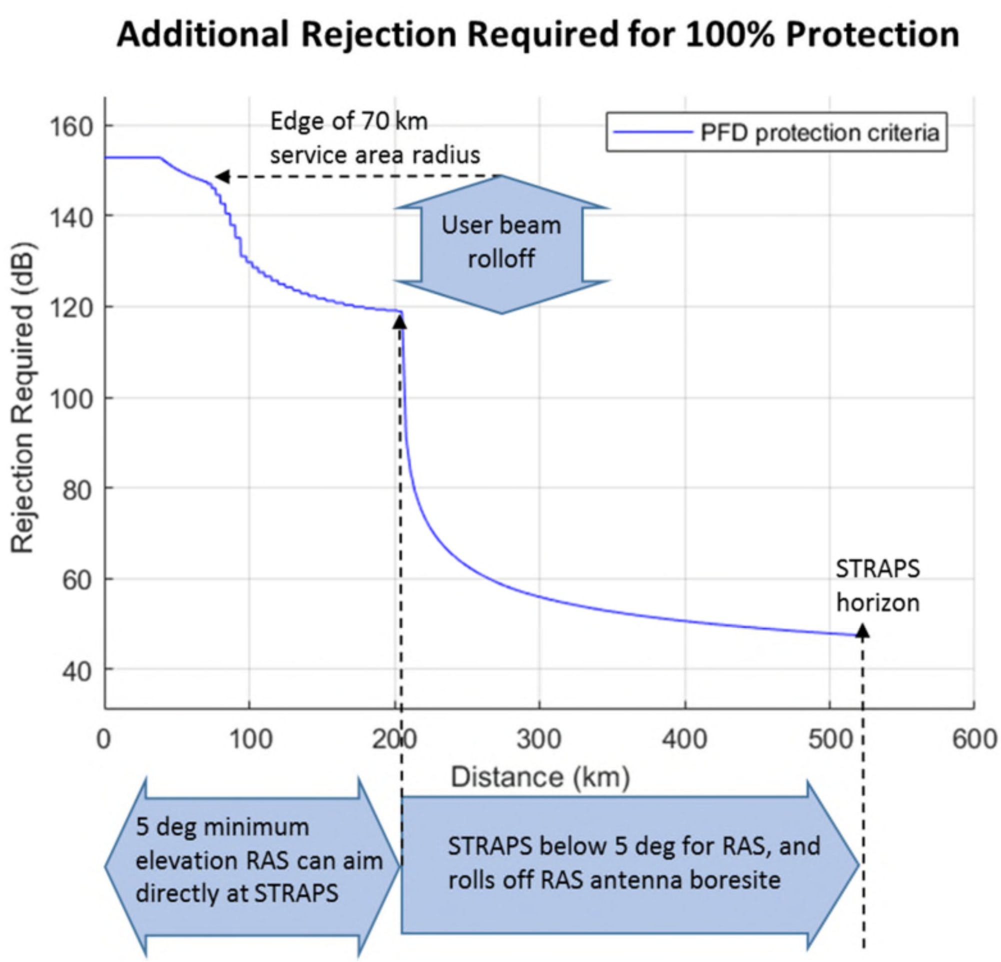

Figure 5: Additional out-of-band attenuation necessary to enable RAS observations at closest boresight angle to STRAPS

Figure 6 depicts the bounding analysis results. This analysis determines the solid angle where observations would receive interference exceeding the threshold and demonstrates how important the narrow, high gain RAS beam is to limiting the extent of that solid angle. Because the beam is so narrow, the RAS gain presented to an interferer drops dramatically at only small angles off its boresight.

Results indicate that even at a separation distance of 0 km (the STRAPS directly over the RAS station) at the worst-case minimum altitude of 18.3 km, out-of-band emissions 75 dB lower than in-band would be sufficient to interfere with only 1.29% of observation data vs the 2% allocation for a single system. For STRAPS downlink out-of-band emissions into 23.6-24.0 GHz band, 75 dB rejection is easily met due to nominal signal roll off and filtering, and rejection up 90 dB could be achieved, if necessary.

Similarly, a STRAPS located near a RAS station with a conservative separation distance of 40 km, the resultant Sky Blockage is 1.26%, which falls below the Single System Interference Allocation of 2%. Changing the separation distance to a more typical of 100 – 150 km, reduces the Sky Blockage to 0.003 – 0.02%.

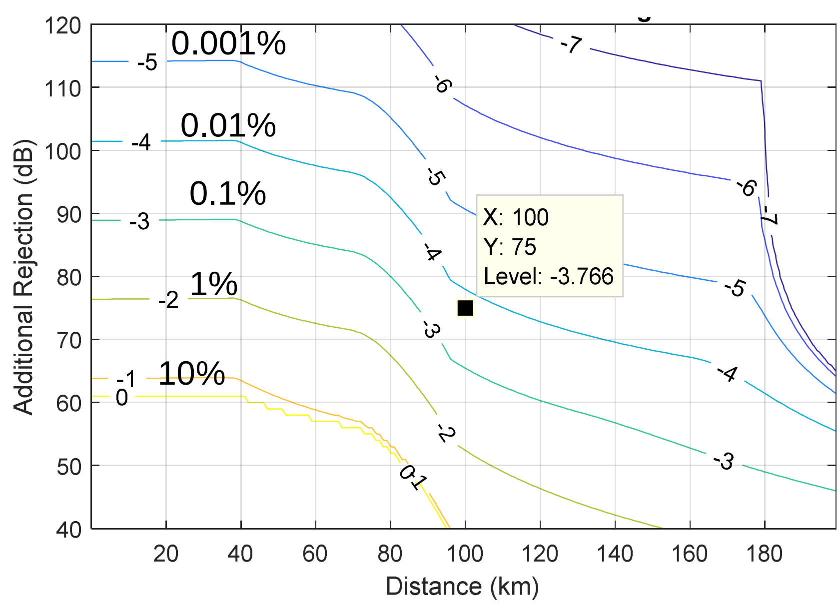

Figure 6: Contours of % RAS data loss (Sky Blockage) as a function of separation distance and STRAPS transmit attenuation of the out-of-band downlink signal at 23.6-24.0 GHz

Considering that a majority of RAS stations are intentionally located away from major urban centers, it is unlikely that more than one STRAPS will be close enough to cause interference into the RAS station.[2] However, in certain instances, it is feasible that a few STRAPS may be

[2] Evaluation of current Federal and Non-Federal RAS stations, not considering associated radio telescope operational frequencies, indicates that RAS stations are generally located away from major urban population centers. Typical distances from RAS stations to urban centers are 120-230 km with Haystack Observatory in Westford, MA located 45 km from Boston, MA and SRI International Antenna Facility in Palo Alto, CA which is within the San

positioned to serve large metropolitan areas such as Greater Los Angeles and RAS stations may be deployed with radio telescopes operating in the 23.6-24.0 GHz band. In this situation, one STRAPS may be close to the RAS and the others would be further away.

To evaluate the impact of total interference from multiple STRAPS into the RAS station, the single STRAPS compatibility study results shown in Figure 6 can be used to derive the cumulative Sky Blockage by summing the contribution from each STRAPS.

Various scenarios for single and multiple STRAPS deployments are summarized in Table 3, primarily to illustrate the flexibility that exists in STRAPS deployments while ensuring that the RAS Protection Criteria are met, including under extreme, indeed wholly unrealistic assumptions for multiple STRAPS deployments in the vicinity of an RAS site (*e.g.*, 63 straps located within 40 km).

Table 3: Sky Blockage for Various Single and Multiple STRAPS Scenarios

STRAPS Deployment Scenario	STRAPS Transmit Attenuation, dB	Sky Blockage	Interference Allocation
1 STRAPS 0 km	75	1.29%	2%
1 STRAPS 0 km	90	0.082%	2%
1 STRAPS 40 km	75	1.26%	2%
1 STRAPS 80 km	75	0.25%	2%
1 STRAPS at 100 km	75	0.02%	2%
1 STRAPS at 120 km	75	0.01%	2%
1 STRAPS at 200 km	75	0.003%	2%
1 STRAP at 40 km, 1 at 80 km	75	1.51%	5%
1 STRAP at 40 km, 1 at 80 km, 1 at 120 km	75	1.52%	5%
1 STRAPS at 40 km, 15 STRAPS at 80 km	75	5.0%	5%
1 STRAPS at 40 km, 550 STRAPS at 120 km	75	5.0%	5%
25 STRAPS at 40 km	90	2.0%	5%
63 STRAPS at 40 km	90	5.0%	5%

As these examples illustrate there is significant available margin so that even assuming unrealizable theoretical conditions such as 25-60 STRAPS at 40 km or 550 STRAPS at 120 km, the Total Interference Allocation would be met.

It should be noted that a higher RAS altitude would result in fewer STRAPS above the 5% RAS elevation angle and therefore the aggregate interference level and Sky Blockage would be lower. For example, assuming a grid of STRAPS with a worst-case 40 km separation as illustrated in Figure 7, for the LBO VLBA telescopes in Mauna Kea at ~13000 feet altitude (4 km), although the possible number of visible STRAPS would be 1260, only 60 of the STRAPS would be above 5-degree elevation angle. This compares to the nominal assumed scenario of the RAS location at

Francisco Bay Area. For the purposes of this compatibility study, although results are presented for varying RAS station distances, 40 km distance was considered as a bounding minimum case with the idea that any exceptions are unlikely, and any necessary interference mitigation would be considered on a case-by-case basis.

ground elevation in which case 90 of the visible 672 STRAPS are above 5-degree elevation angle[3]. Of course, this example is for illustrative purposes only since it's unlikely that multiple STRAPS would be deployed for Hawaii coverage.

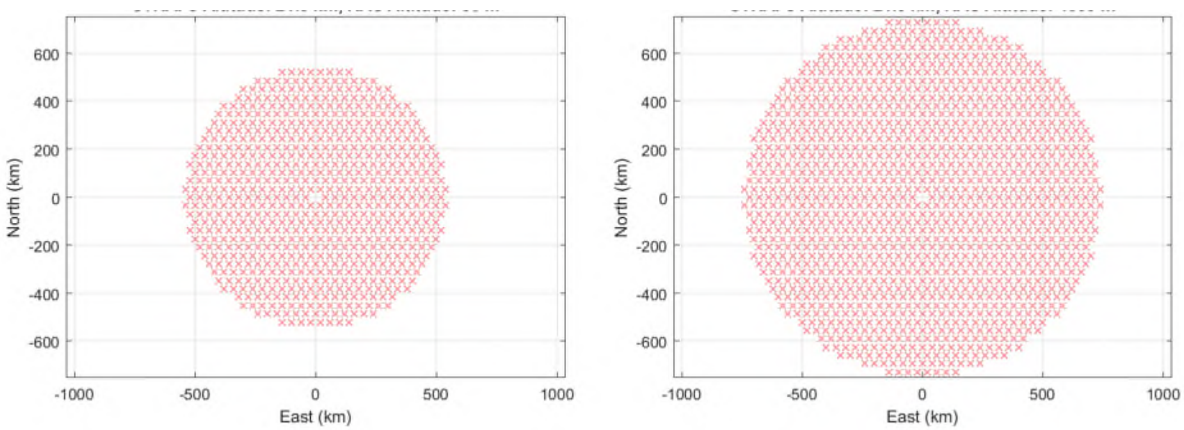

Figure 7: STRAPS constellation using 21.3 km altitude and 40 km worst-case separation
Left Hand Figure: 50m RAS altitude, Right Hand Figure: 4km RAS altitude

In addition to compatibility analysis related to RAS Protection Criteria, the maximum in-band power received at the RAS station was evaluated and compared to the RAS Damage Power Level in ITU-R.2188. Figure 8 shows that in-band received power is significantly less than the 5 mW damage level for a single STRAPS for all RAS station to STRAPS separation distances. For these calculations, the received power is calculated by integrating over the 450 MHz user link channel bandwidth since any given STRAPS will be transmitting one channel worth of power in a given beam. Also note that the calculated in-band power is worst-case since it is based on the maximum recommended PFD limits from STRAPS transmissions including any effects from power control.

Translating the results of Figure 8 into a multi-STRAPS case means that even under an unlikely assumption of STRAPS located 40 km away, it would take 62 STRAPS to exceed the RAS damage levels which is well beyond realistic worst-cases situations of a few STRAPS typically located at distances of 100-200 km away from RAS stations with possibly a single STRAPS at a shorter distance.

3 *See* Exhibit 9, pp. 7-10 for additional details of a multiple STRAPS scenario.

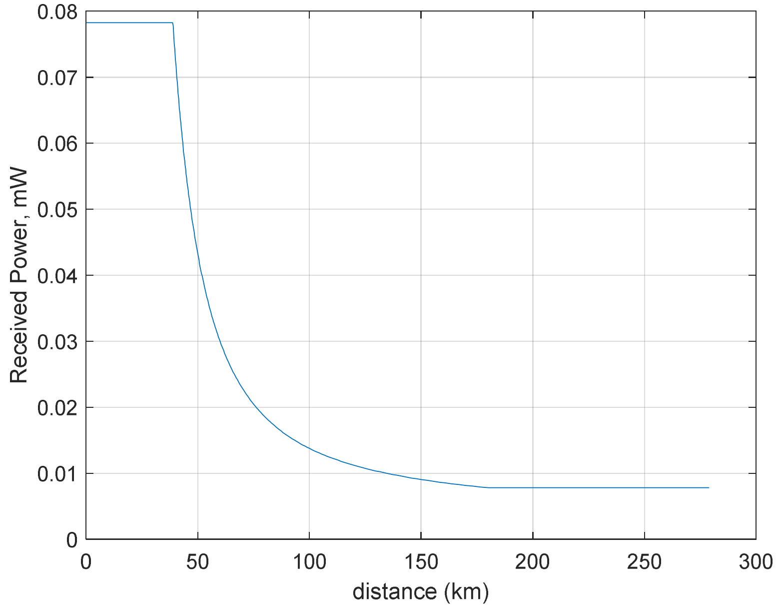

Figure 8: In-Band received power from a single STRAPS

STRAPS STATION KEEPING

If Radio Telescope observations require knowledge of the solid angle over which interference may exceed the protection criteria, the variability in the STRAPS location within station-keeping limits needs to be understood. Each STRAPS location may be published in near real-time to comply with FAA requirements and could also be made available to the RAS station so that any observations can account for shifts in Sky Blockage.

To better assess the effect of STRAPS location variability on the RAS station viewpoint, an analysis was performed assuming STRAPS altitude change of +/- 1.5 km and horizontal motion of +/- 10 km during normal station keeping. The results, as shown in Figure 9, indicate that STRAPS location variability has a minor impact on Sky Blockage even if STRAPS location information is not utilized by the RAS station.

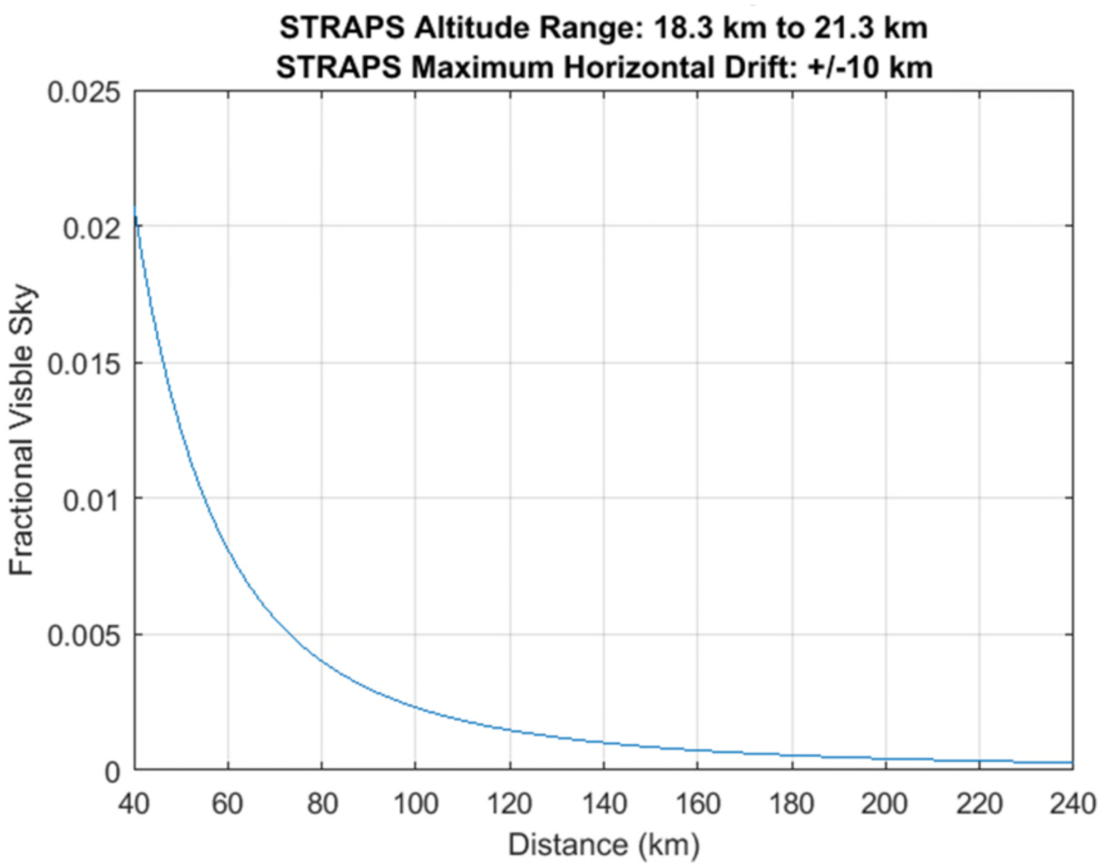

Figure 9: RAS Sky Blockage variability due to STRAPS location variability

CONCLUSIONS

This analysis demonstrates compatibility between the proposed STRAPS downlink and RAS, with the protection criteria met (and far exceeded under example deployment scenarios) including under extreme theoretical multiple STRAPS conditions. This analysis also demonstrates that RAS Interference Protection Criteria are met even under worst-case RAS deployment scenarios.

As previously noted, RAS observations are not limited to the bands allocated and protected for RAS. For observatories to protect sensitive RAS receivers from unexpectedly high power when observing within or close to the 25.25-27.5 STRAPS downlink band, it is important to know the maximum PFD that could be incident on them and the direction of its source to plan observations. The database of registered STRAPS will include the service area, STRAPS location and the control volume around it where downlink is authorized. STRAPS deployed within the coordination radius of RAS stations will already be engaged in coordination as described in the analysis on compatibility with RAS in the SBCS user uplink band.

REFERENCES:

ITU-R RA.769-2: Protection criteria used for radio astronomical measurements

ITU-R RA.1513-2: Levels of data loss to radio astronomy observations and percentage-of-time criteria resulting from degradation by interference for frequency bands allocated to the radio astronomy service on a primary basis

ITU-R RA.314-0: Preferred frequency bands for radio astronomical measurements

ITU-R SA.509-3: Space research earth station and radio astronomy reference antenna radiation pattern for use in interference calculations, including coordination procedures, for frequencies less than 30 GHz

ITU RA.1631: Reference radio astronomy antenna pattern to be used for compatibility analyses between non-GSO systems and radio astronomy service stations based on the epfd concept

ITU-R RA.2188: Power flux-density and e.i.r.p. levels potentially damaging to radio astronomy receivers

Exhibit 5
Compatibility Analysis:
STRAPS Feeder Uplink Interference into
EESS Passive Sensing in the 86-92 GHz Bands
(Prepared by Lockheed Martin Corporation for Elefante Group, Inc.)

SUMMARY

- Elefante Group is proposing to access the 81-86 GHz band for feeder uplink communications from feeder terminals located at network gateways (GW) to Stratospheric Platform Stations (STRAPS) on a co-Primary basis.

- This study assesses the compatibility of STRAPS Feeder uplinks with EESS Passive which have allocations to operate in the 86-92[1] GHz band.

- Worst-case operating conditions are utilized for a bounding analysis, in which all GWs are simultaneously active and transmitting at the maximum permitted EIRP density across their maximum bandwidth. Worst-case geometry is analyzed for a single STRAPS, and an unrealistically extreme bounding case is considered with worst-case geometry from thousands of STRAPS.

- Bounding compatibility study results show that conservative regulatory bounds on EIRP in the EESS bands can be developed that still permit practical GW design, and that it is reasonable to permit with a showing that the statistical protection criteria are met for specific SBCS implementations.

PURPOSE OF THE STUDY

Elefante Group is proposing that the 81-86 GHz band be made available for Stratospheric-Based Communications Services (SBCS), operating as a Fixed service, in the uplink direction. (While not the purpose of this study, Elefante Group proposes that the 81-86 GHz band also be considered for use in the downlink direction.[2]) All or part of this band is allocated in the federal and non-federal allocation to Fixed, Fixed Satellite, Mobile, Mobile Satellite, Radio Astronomy, and (on a secondary basis) Space Research (space-to-earth).

This study assesses the compatibility with EESS passive sensing of uplink transmissions from ground-based UTs to a multi-beam stratospheric platform.

This study assesses the potential for interference into EESS passive sensing to exceed the I/N Protection Criterion to determine if mitigation measures are necessary.

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1 Elefante Group is evaluating the prospect for GW uplinks in the 71-76 GHz band. Although such links are beyond the scope of the present compatibility study and discussion, Elefante Group believes a similar analysis and conclusions would largely apply to compatibility with FS links in that band.

2 Only in locations where radio astronomy observatories would not be affected.

PERFORMANCE AND OPERATIONAL CHARACTERISTICS OF EESS SENSORS

Operational characteristics of the EESS sensors utilized for this study are based on ITU-R RS.1861 and reproduced here for convenience. Table 1 presents characteristics of sensors in the 86-92 GHz band,

Table 1: 86-92 GHz EESS sensor operational and performance characteristics for interference analysis

Sensor Type		L1	L2	L3	L4	L5	L6	L7	L8
		Conical Scan	Conical Scan	Conical Scan	Cross-Track Scan	Cross-Track Scan	Cross-Track Scan	Conical Scan	Conical Scan
Altitude	km	867	705	833	833	833	824	835	700
Freq Min	GHz	87.65	87.5	86	86	87.6	86	86	87.5
Freq Max	GHz	90.35	90.5	92	92	90.4	92	92	90.5
Channel BW	MHz	2700	3000	6000	6000	2800	2000	2000	3000
Max Boresite Gain	dBi	50	60.5	56	34.4	44.8	37.9	54	62.4
3 dB Beamwidth	deg	0.43	0.18	0.39	3.3	1.1	2.2	0.4	0.15
Max off-nadir angle	deg	44.5	47.5	46.98	48.33	49.4	52.73	46.41[3]	47.5
Min off-nadir angle	deg	44.5	47.5	46.98	0	0	0	46.41	47.5
Pattern	ITU-R	Unspecified – Applied ITU-R RS.1813 as default pattern							
Polarization		HV	HV	HV	QV	QV	QV	HV	HV
Reference BW	MHz	100	100	100	100	100	100	100	100
Max Interferer Power over Reference BW	dBW	-169	-169	-169	-169	-169	-169	-169	-169

Protection criteria for these sensors is -169 dBW max interference power over a 100 MHz reference bandwidth for sensors, not to be exceeded over more than 0.01% of the time or observation area.

[3] Sensor L7 provides "N/A" for conical scan off-nadir angle. Off-nadir angle calculated from 35 deg incidence angle at Earth.

OPERATIONAL CHARACTERISTICS OF SBCS

The SBCS will utilize STRAPS, User Terminals, and Gateway terminals to provide fixed services over a specific service area. Transmit characteristics of the Elefante Group STRAPS user uplink used in this study, are given in Exhibit 1.

For this study, worst-case operating and geometric conditions are utilized for a bounding analysis prior to considering, if appropriate, risk-based interference assessment using probability and statistical methods:

1) All GWs simultaneously active and transmitting at power levels which achieve the highest data rates, i.e. effective EIRP density of 5 dBW/MHz (as seen through weather) is maintained through ATPC.
2) Worst-case geometric alignment between EESS sensor, STRAPS service area, and GW.

STUDY SCENARIO

Figure 1 illustrates the interference geometry applicable to this study.

- GWs located within a 10 km radius around the center of the STRAPS service area transmit Feeder Uplink signals to the associated STRAPS.
- EESS sensors are located on satellites with different orbital parameters. Sensors have beams that differ in gain and beamwidth depending on application. Beams have different scanning characteristics, including conical scans at a fixed off-nadir angle and cross-track scanning.
- As the EESS sensors move through their respective orbits, there will be instances of time during which the worst-case alignment for interference will occur when the receive beam is pointed toward the center of the STRAPS coverage area and aligned exactly along the boresight of a transmitting GW.
- A single-entry compatibility study is initially performed for the highest EIRP density GW assuming the interference from the boresight pointed GW will dominate. Results are subsequently expanded to multi-entry cases to account from the aggregate interference from all GWs.

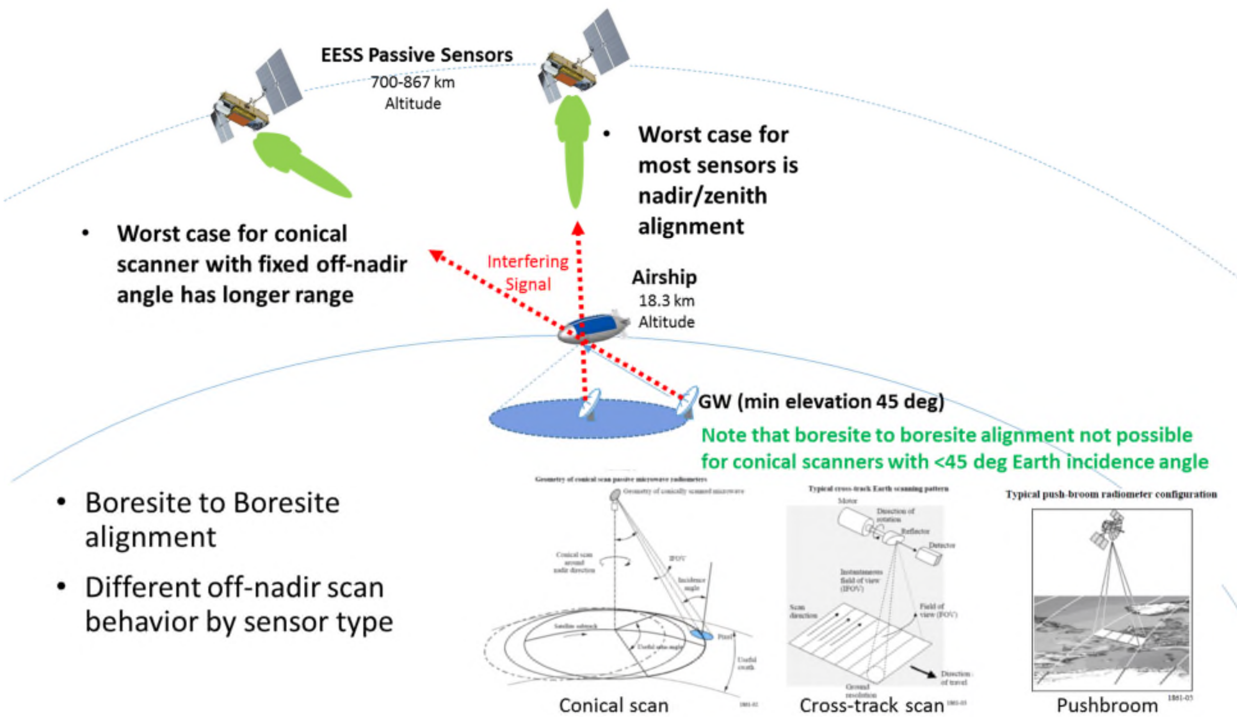

Figure 1: Interference geometry for UT and EESS orbital passive sensor systems

Three scenarios are considered for each sensor:

- Worst case geometry for single entry GW to sensor. This case occurs when the boresight of the EESS sensor is aligned exactly with the boresight of a GW transmitter. Level of interference into the sensor is a function of the off-nadir angle the sensor is pointed when the alignment occurs.
- Worst case multi-entry from additional GWs serving a single STRAPS. Assuming the worst case single entry interference already exists, additional interference from additional GWs beyond the worst aligned one is calculated.
- Unrealistic bounding case of multi-entry from multiple STRAPS within the sensor field of regard.

STUDY METHODOLOGY

Analysis of these scenarios using the 5 dB(W/MHz) EIRP density limit proposed for the Elefante Group SBCS reference system for GW uplinks determines a required attenuation as a function of off-nadir angle at which the sensor beam is pointing[4]. This attenuation can be subtracted from the EIRP density and generalized to a maximum EIRP permitted over the EESS reference bands within

[4] For the single entry case, interference and therefore required attenuation decrease with increasing off-nadir angle due to increasing range. In the multiple entry case, interference will decrease for a sufficiently high gain beam, which will roll off in gain rapidly and only include a few STRAPS locations in the mainlobe. If the beam has a large enough beamwidth, the spread of the mainlobe projected to the ground will expand with off-nadir angle to include more STRAPS with increasing off-nadir angle, overcoming the benefit of increasing range.

their allocations; a design constraint that can be imposed through regulation on SBCS to ensure compatibility by rule.

Importantly, this analysis is for 100% satisfaction of the maximum interference criteria, and does not account for the statistical nature of the protection criteria that only required 99.99% satisfaction.

Figure 2 summarizes the approach and anticipated results of the analyses.

- The blue line represents the static worst case alignment, which will require less attenuation with increasing sensor off-nadir angle due to increasing range on the interference path, and thus permit a higher GW EIRP density at lower elevation angles.
- The magenta line represents interference from additional STRAPS, each with a GW aimed at the sensor. At nadir it will certainly require more attenuation than the single STRAPS case, and may require even more reduction with increasing off-nadir angle as the tilted incidence angle with the Earth can cause more STRAPS to be within the mainlobe of the sensor beam.
- The green line represents the notional result of a time dynamic analysis. In a time dynamic analysis, orbital motion of the sensor satellites, a realistic deployment scenario for STRAPS, and pointing and activity of GWs can all be considered to extract statistics on the likelihood of the worst case alignments and of multiple simultaneous worst case alignments. In many cases this will permit operation of GWs emitting a higher EIRP density in the EESS band.

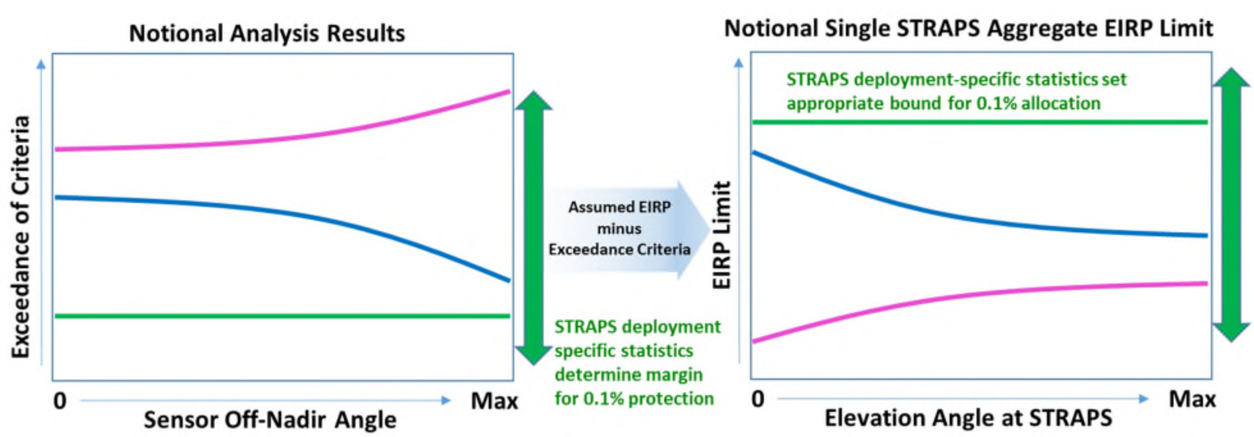

Figure 2: Notional results for studies. Exceedance of interference thresholds by GWs at maximum EIRP density determines maximum not to exceed EIRP density. Static worst case (blue) will require less attenuation with increasing sensor off-nadir angle and thus permit a higher GW EIRP density at lower elevation angles. Multiple entry STRAPS (magenta) may require more attenuation with increasing off-nadir angle. A time dynamic analysis (green) may determine the protection at a relaxed threshold.

Worst Case Geometry for Single Entry GW to Sensor

For this case a simple link calculation determines the interference power density at the sensor receiver, based on the maximum GW EIRP density, free space loss due to range, and the boresight gain of the sensor. Range as a function of sensor off-nadir angle is calculated based on the satellite altitude.

$$Io\left(\frac{dBW}{MHz}\right) = EIRP\ Density\ - FSL - Gr\ - 3dB\ polarization\ loss^{5}$$

This is added to the decibel reference bandwidth (e.g. 20 dB(MHz) for the 100 MHz bandwidth) to obtain interference power for comparison to the threshold.

Multiple Interfering GW from One STRAPS

Efficient STRAPS implementations will seek to reuse spectrum by using multiple beams to spatially separate reuse of parts or all of the uplink band, allowing multiple GWs to transmit on the same frequency. If they are to reuse the same channel adjacent to the EESS band, they will need to be spatially separated enough to not interfere with each other, resulting in different elevation angles to the STRAPS and therefore different GW off-boresight angles presented to the orbital EESS sensor (i.e. two GWs cannot both present maximum gain to the sensor simultaneously).

Figure 3 illustrates the situation described above using sensor L4 as an example. Because the range from the GW to the sensor is much larger than the range from the GW to the STRAPS, the angular separation between closest GWs seen from the STRAPS is approximately the same as the off-boresight angle the closest GW will present to the sensor.

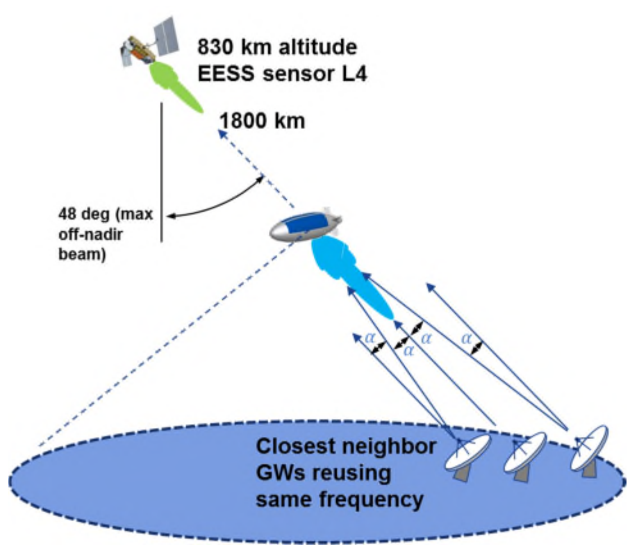

Figure 3 - Additional same channel GW interferers from single STRAPS location have minimum off-boresight angles from minimum separation for frequency reuse

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[5] In this analysis, the STRAPS GWs are assumed to use circular polarization, whereas the sensors use linear polarization. Because directional beams will have good axial ratios on their boresights, polarization mismatch loss is 3 dB in the single entry interference analysis. In the multi-entry interference analysis, where sensors will receive GW interference through their sidelobes and backlobes where axial ratio is not well controlled, mismatch loss is assumed to average 1.5 dB.

To protect EESS sensors from multiple GWs associated with a single STRAPS, the regulatory limit for emissions in each EESS band sets the maximum *aggregate* EIRP density the SBCS system can emit as a function of elevation angle. It is up to the system designer to meet the requirement regardless of the SBCS architecture adopted or specifics of the implementation.

Practically, the aggregate requirement will have little impact on the SBCS system design. SBCS GWs will be regulatorily required to not exceed an EIRP density mask vs off-boresight angle, which ensures roll-off is sufficient for compatibility with other services and non-exclusive coverage from STRAPS (multiple STRAPS can serve the same market). The example used in this analysis has the 5 dB(W/MHz) peak roll-off to -29 dB(W/MHz) at 1.4 deg. Using the example EIRP density mask, if 19 additional GWs were active, but saw the sensor 2.2 or more degrees off boresight, and no roll-off of the sensor pattern is accounted for (sensor boresight gain presented to all GWs in the STRAPS service area), the total increase in EIRP density would be 0.03 dB. Clearly, with the GWs distributed within 10 km of the center of the service area to achieve path diversity in heavy weather, separation will be much larger and the additional interference from multiple GWs will be negligible if they are sufficiently separated.

As an example of required separation: The Elefante Group reference design requires > 17 dB carrier to noise ratio to operate at the highest design data rate. Carrier power to inter-beam interference, to not be a limiting factor at all, should be > 25 dB. Thus, two simultaneous receive beams on the STRAPS reusing the same frequency would need to be pointed at least far enough apart to get 25 dB isolation between their pointing directions. The STRAPS Feeder receive beams, with 50 dBi boresight gain and the ITU-R F.1245 pattern, will require ~1.4 degrees of pointing separation to achieve 25 dB spatial isolation.

Regardless of technology improvements that might permit more directive STRAPS receive beams and thus closer spacing of co-channel GWs, a single SBCS system would still be regulatorily required to limit the aggregate EIRP density from all GWs in any particular direction.

Multiple Interfering GWs from Multiple STRAPS

Non-negligible multiple interference occurs if two or more different STRAPS platforms are physically separated but in view of an EESS sensor. If the primary interfering STRAPS location is at the boresight of the EESS sensor beam, the beam gain roll-off will determine the additional interference from the second STRAPS.

The minimum separation between the STRAPS platforms is determined by their own compatibility constraints. Required separation will vary depending primarily on each system's coverage area, but for practical systems, separation could typically be 40 km[6]. Figure 4 illustrates an example distribution of STRAPS within the field of regard of a sensor. In the single entry worst case, the sensor is aimed at nadir and has a GW aimed directly back. The worst case for multiple entry is when every other STRAPS in the field of regard also has a GW aimed directly at the sensor. The highest density of nearby STRAPS is a hexagonal array with 40 km centers.

[6] *See Petition to Modify Parts 2 and 101 of the Commission's Rules to Enable Timely Deployment of Fixed Stratospheric-Based Communications Services in the 21.5-23.6, 25.25-27.5, 71-76, and 81-86 GHz Bands,* Petition for Rulemaking, RM-11809, Appendices T-U (May 31, 2018) ("*Petition*").

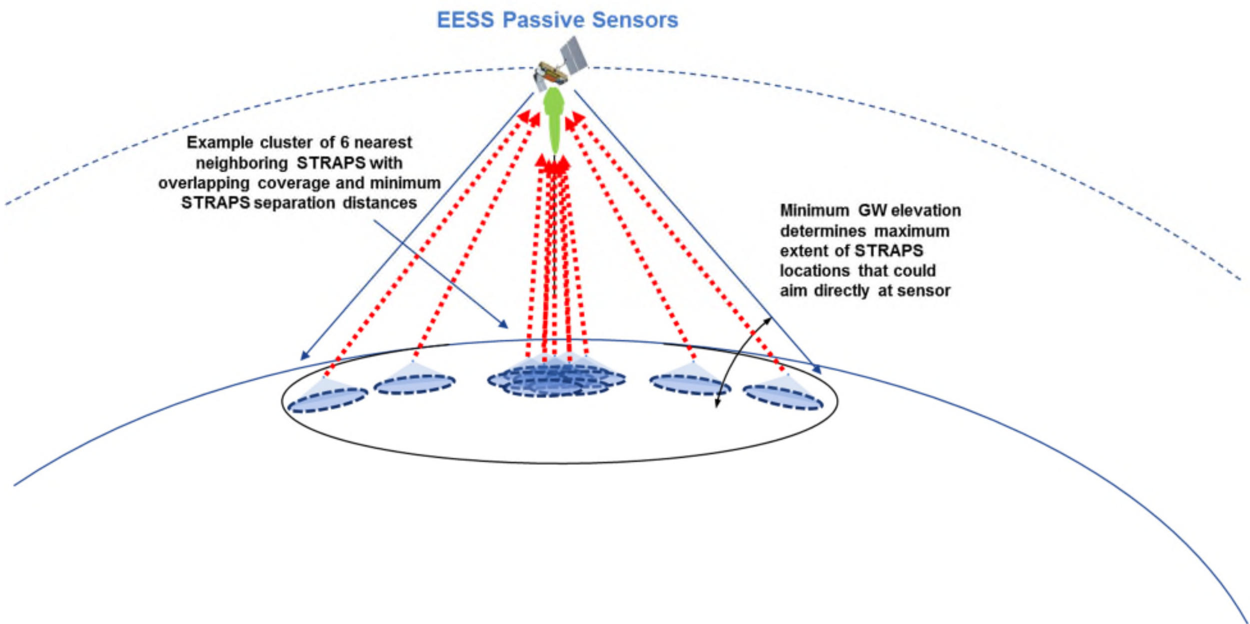

Figure 4: Multiple STRAPS deployed across area that could interfere. After single worst case interferer in sensor beam boresight, next highest interference comes from maximum of 6 nearest neighbors. Although statistically unlikely, bounding multiple interference case has GW aimed directly at sensor from every STRAPS location.

An extremely conservative analysis to bound the aggregate EIRP density for one SBCS system is to consider a grid of STRAPS separated by 40 km covering the entire Earth visible to the sensor, as shown in Figure 5. In this unrealistically extreme scenario, the worst case single entry interference is determined as before, but the interference from all other STRAPS is added to it. Thus, up to 21,000 GWs (at the highest sensor altitude considered) operating at maximum EIRP density of 5 dB(W/MHz) are aimed directly at the sensor (or as close as their minimum elevation angle allows). Despite high weather loss in the band, no atmospheric losses are considered.

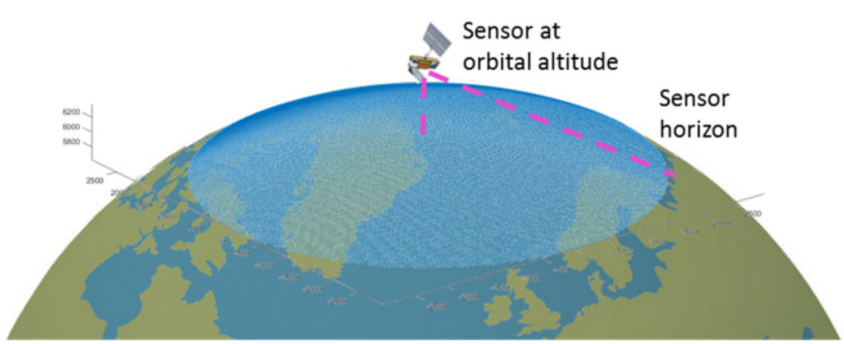

Figure 5: Grid of STRAPS locations with 40 km separation over the spherical cap of Earth visible to sensor

Figure 6 illustrates power received from the grid of SBCS systems. The analysis using the Elefante Group reference design uses a nominal 20 km altitude and 70 km service area radius setting minimum GW elevation angle at the edge of the 10 km radius GW deployment area to ~45 deg.

Thus maximum power received at the sensor falls off from GWs that see the sensor below 45 deg and cannot aim directly at it. The sensor gain pattern roll-off determines how many GWs enter the sensor mainlobe.

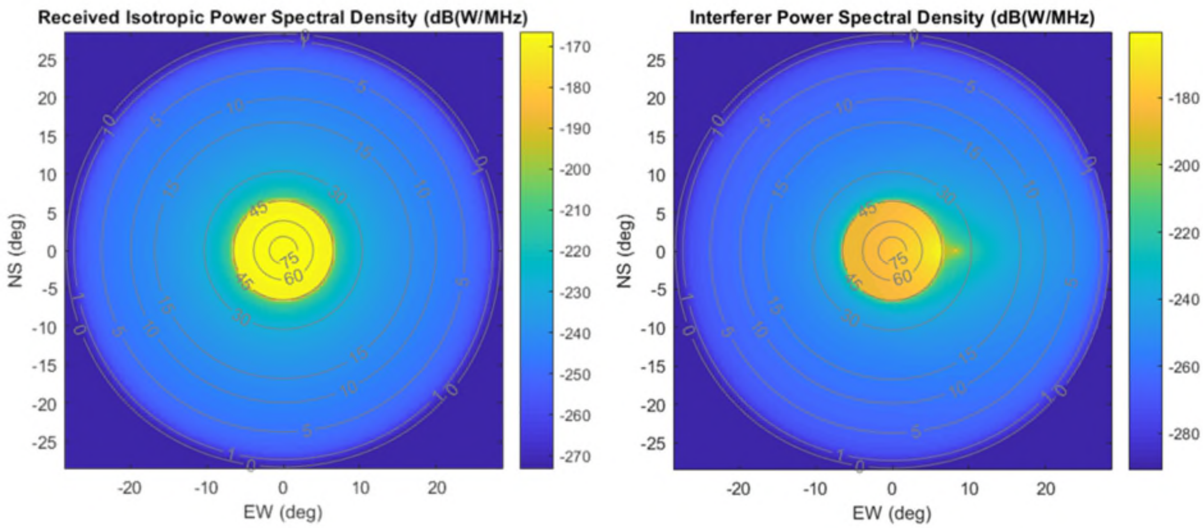

Figure 6: Power from grid of STRAPS. (left) Received power falls off rapidly at elevations below the minimum 45 deg elevation for GW pointing. (right) Sensor gain pattern amplifies signals differently based on location the boresight intersects the Earth.

STUDY RESULTS

Within each 86-92 GHz band, all sensor types are considered and the attenuation necessary for a nominal 5 dB(W/MHz) GW to meet the interference threshold criterion is determined for the single entry and the unrealistic bounding case. This attenuation can be subtracted from the nominal EIRP density to determine the maximum EIRP density a GW can emit in the EESS band to never exceed the interference threshold.

Figure 7 illustrates results for sensors L1-L8, and shows how attenuation from this unrealistic bounding case does not exceed the single entry case by more than about 10 dB.

In the case of the cross-track scanning sensors, the solid lines show required attenuation for single entry, boresight-to-boresight interference out to the maximum off-nadir scan angle (even if the GW minimum elevation angle would not allow it). The dashed lines show the unrealistic bounding case and include the minimum elevation angle constraint on the GW. All three show that required attenuation drops significantly when the sensor beams off-nadir angle exceeds ~39 degrees, which corresponds to the minimum elevation angle of the GW. Beyond this angle, no GW boresight can align with the sensor boresight.

- Sensor L5 has a narrower beam and higher gain. Rapid gain roll-off means that contributions from additional STRAPS are less significant. Although the beam footprint expands at larger off-nadir angles to include more STRAPS closer to the center of the beam, the effect is not sufficient to overcome the increasing range loss.
- Sensors L4 and L6 have broader beams and lower gain. Although the single interferer interference is lower due to the lower gain, the shallower roll-off means that contributions

from additional STRAPS off-boresight are more significant relative to the STRAPS at the center. Thus, at nadir the increase in necessary attenuation is greater. As the off-nadir angle increases and the beam footprint expands, contributions from multiple STRAPS increase at a rate greater than reduction from range loss.

In the case of the conical scanning sensors, required attenuation is low because their scan angles are all large enough that the incident angle at the ground is lower than the minimum elevation angle for the GWs. The solid circles indicate the attenuation that would have been required if boresight to boresight alignment had been possible, and the open circles show how much lower the actual attenuation required is based on the closest angle to boresight the GW can present to the sensor.

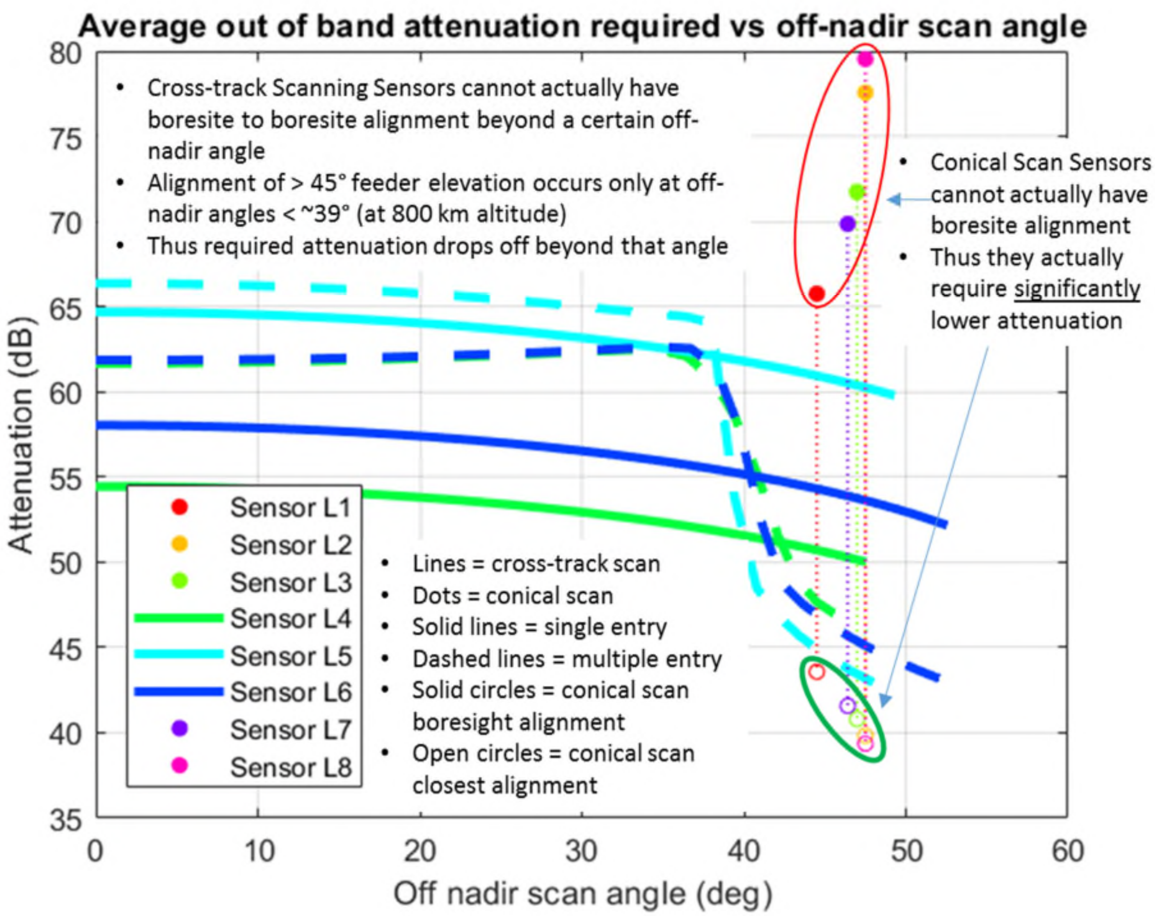

Figure 7: Results for sensors in the 21.2-21.4 GHz band. Single entry results (solid line) and unrealistically conservative multiple entry results (dashed line).

It should be further noted that only sensors L3, L4, L6, and L7 utilize the full 86-92 GHz band, and the other sensors have at least 1.5 GHz of additional margin from the 81-86 GHz SBCS uplink band.

As noted before, the attenuation required for a specific design can be converted to an absolute level required for protection against which multiple designs can be evaluated. In the case of the Elefante Group baseline design for GWs, the out of band emissions in the EESS passive sensor bands will be low enough to protect them 100% time (vs 99.99% time required by ITU-R RS.2017) against the unrealistic bounding scenarios of tens of thousands of STRAPS, all with GW's aimed directly at the sensor. Figure 8 illustrates an example roll-off using a 140 MHz guard band compared to the emission masks, depicted relative to the peak in-band power of this GW design.

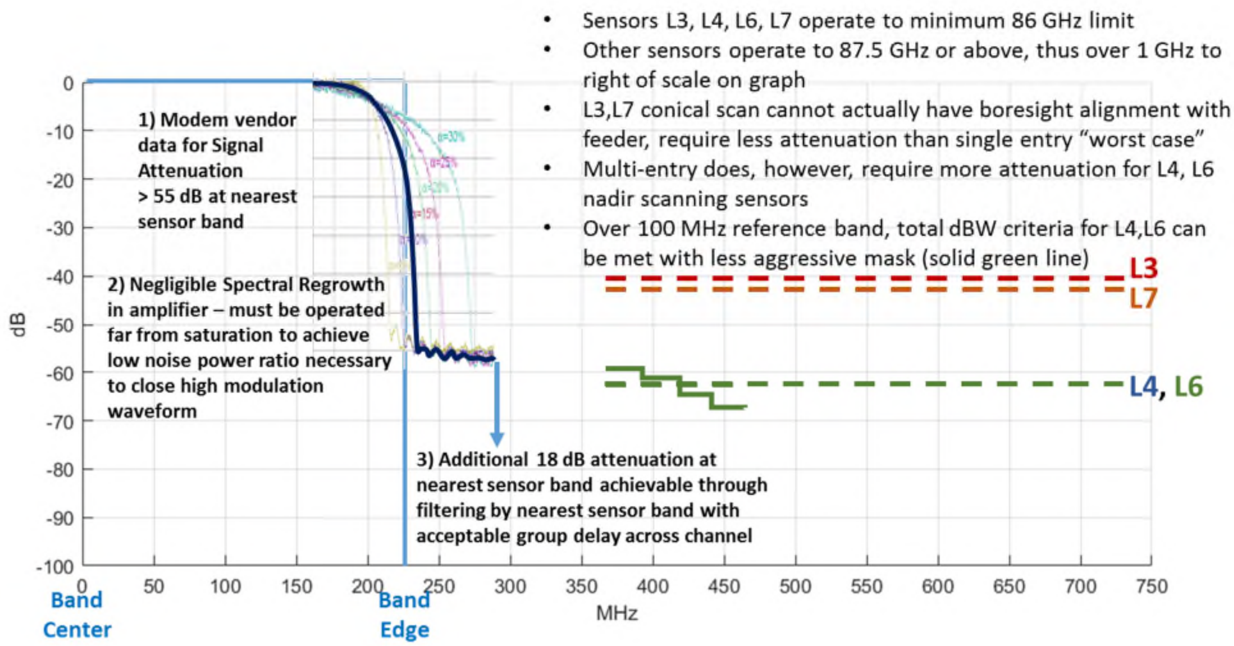

Figure 8: Out of band emission roll-off of example design compared to emission masks derived from unrealistic bounding case for 100% time protection criteria. EESS protection easily achievable with realistic GW designs

CONCLUSIONS

A compatibility study was performed using worst-case operational and geometric assumptions for single entry interference, including all GWs simultaneously active and transmitting at maximum power. In addition, an extremely unrealistic deployment of SBCS systems blanketing the Earth at minimum separation distance was used to demonstrate a bound on the increase in interference from multiple SBCS systems.

Emission limits toward sensors were derived that can be used to regulate aggregate 81-86 GHz emissions from an SBCS system. As described previously (in Figure 2), these limits are generalized but conservative. They can be refined to incorporate variation in the limit with elevation angle if desired. Importantly, as a 100% protection approach exceeding the 99.99% requirement, they represent a point of departure for more sophisticated time dynamic and statistical analyses that can be applied to specific SBCS designs and incorporate the % time aspect of the protection criteria; e.g. a system that meets these limits 100% of the time should be deemed acceptable, and a system that exceeds them may generate a statistical showing based on more detailed modeling and simulation that the 99.99% criteria is met.

Casting these results as a limit on PFD received at EESS sensors in the 86-92 GHz band (rather than on GW EIRP, which an SBCS system might adjust through ATPC to compensate for weather losses while maintaining the same max PFD at the sensor) is a superior approach to achieve regulatory protection than detailed regulatory prescription of SBCS channel and guard band sizes, filter parameters, etc. This method specifies the metric that matters, and enables development of creative designs and different system architectures and implementations to compete in the marketplace, rather than mandating design details and a single solution or approach.

REFERENCES:

ITU-R RS.2017: Performance and interference criteria for satellite passive remote sensing

ITU-R RS.1861: Typical technical and operational characteristics of Earth exploration-satellite service (passive) systems using allocations between 1.4 and 275 GHz

ITU-R RS.1813: Reference antenna pattern for passive sensors operating in the Earth exploration satellite service (passive) to be used in compatibility analyses in the frequency range 1.4-100 GHz

Exhibit 6
Compatibility Analysis:
SBCS Feeder Uplink Interference into
Fixed Service in the
81 - 86 GHz Band
(Prepared by Lockheed Martin Corporation for Elefante Group, Inc.)

SUMMARY

- Elefante Group is proposing to access the 81-86 GHz band for Stratospheric-Based Communications Services (SBCS) feeder uplink communications from feeder terminals located at network gateways (GW) to Stratospheric Platform Stations (STRAPS) on a co-Primary basis.

- This study assesses the compatibility of SBCS Feeder uplinks with Fixed Service (FS) point to point microwave links which are authorized to operate in the 81-86[1] GHz band.

- Worst-case operating conditions are utilized for a bounding analysis: GWs are at maximum EIRP, and no atmospheric propagation or ground clutter losses are considered.

- The spatial isolation enjoyed between the overhead geometry of GWs and terrestrial geometry of conventional FS links combined with the narrow beamwidth of beams at this frequency make these links easily compatible.

- GWs can be coordinated using the same national license and link registration scheme currently in place for FS in this band.

PURPOSE OF THE STUDY

Elefante Group is proposing that the 81-86 GHz band be made available for SBCS, operating as a Fixed service, in the uplink direction. (While not the purpose of this study, Elefante Group proposes that the 81-86 GHz band also be considered for use in the downlink direction.[2]) All or part of this band is allocated in the federal and non-federal allocation to Fixed, Fixed Satellite, Mobile, Mobile Satellite, Radio Astronomy, and (on a secondary basis) Space Research (space-to-earth).

This study assesses the compatibility with other Fixed Service links with uplink transmissions from ground-based GWs to a multi-beam stratospheric platform, and assesses the potential for interference into conventional FS point to point microwave links to exceed the I/N Protection Criterion to determine if mitigation measures are necessary.

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1 Elefante Group is also looking at the prospect for GW uplinks in the 71-76 GHz band. Although such links are beyond the scope of the present compatibility study and discussion, Elefante Group believes a similar analysis and conclusions would largely apply to compatibility with FS links in that band.

2 Only in locations where radio astronomy observatories would not be affected.

The proposed approach for coordinating with existing conventional FS receivers from GW FS transmitters is to follow the existing coordination procedures as described in 47 C.F.R. Part 101 Subpart Q. The registration information may be expanded to describe the geometry of the control volume the STRAPS can operate within, or simply reference the STRAPS registry where that information is available.

OPERATIONAL CHARACTERISTICS OF TERRESTRIAL FS RECEIVERS

FS link receiver data was gathered from one of the three third-party registry databases where E-band links are registered by licensees. The database contains sufficient information on both transmit and receive locations on a path to determine all relevant receiver geometry (latitude, longitude, altitude, azimuth, and elevation) and spectrum use for a specific link, and statistics for links in general.

Although boresight gain and 3 dB beamwidth are recorded, full receive gain patterns as a function of angle off boresight require manufacturer data and will vary by manufacturer as well, so a more general bounding pattern is sought. Per §101.115, the minimum antenna boresight gain is 43 dBi, which is used here because it represents the widest mainlobe that would be most sensitive to off-axis interference. Although ITU-R F.699 was updated earlier this year to model patterns > 70 GHz, for a 43 dBi antenna the model exceeds the off-axis attenuation rules in §101.115. Therefore the §101.115 transmit mask, assuming reciprocity, is used for the worst case receive pattern. Figure 1 shows a comparison of receive gain patterns from the above references.

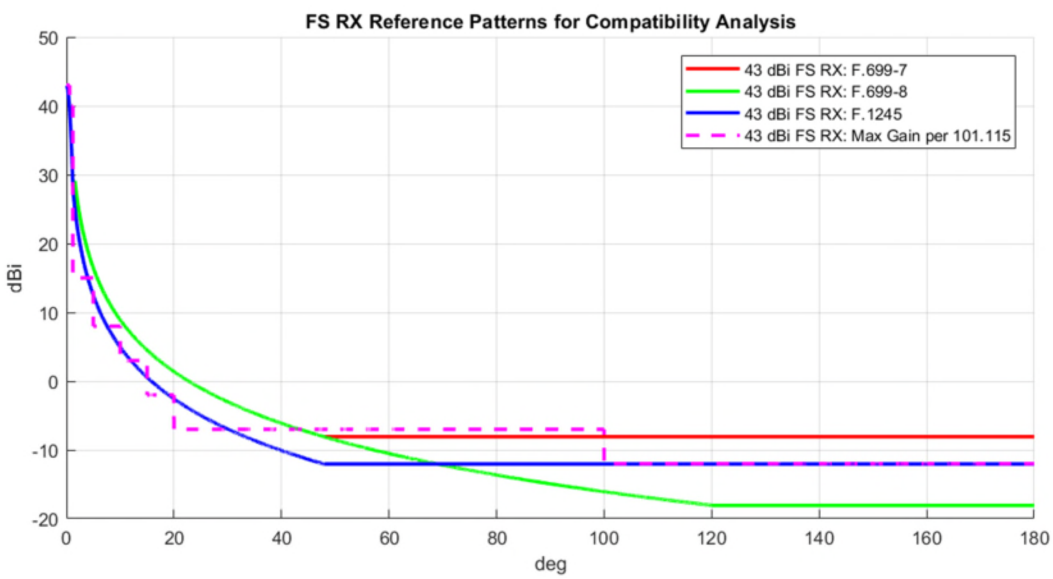

Figure 1: Comparison of antenna gain pattern options for FS RX antenna

Data from the registry indicates the majority of receiver noise figures are 7 dB up to 14 dB, with only very rare exceptions of lower noise figures. Thus, this analysis uses a 7 dB noise figure to derive a noise density of -137 dB(W/MHz) for the FS receiver. Rather than use specific T/I values or curves, the protection criteria used is a maximum interference to noise ratio of -6 dB (the level that would result in a 1 dB increase in receiver thermal noise).

OPERATIONAL CHARACTERISTICS OF SBCS

The SBCS will utilize STRAPS, UTs, and feeder terminals at network gateways to provide fixed services over a specific service area. Transmit characteristics of the Elefante Group SBCS Feeder uplink utilized in this study are given in Exhibit 1. In the text below, GW will refer to the feeder terminal located at the SBCS gateway.

STRAPS are only authorized to operate within their control volume, a cylindrical volume of space around a nominally fixed latitude, longitude, and altitude defined by its height and radius. In the Elefante Group reference design, the STRAPS control volume is 10 km in radius and extends from 18.3 to 21.3 km altitude, and GW links are deployed within 10 km of the nominal latitude/longitude center on the ground. Unlike the user terminals, only a small number of GWs will be required, typically up to 20.

GWs will track the STRAPS within the control volume. A GW centered within the footprint of the STRAPS control volume would track over a conical field of regard, always at above 61 degrees elevation angle. A GW 10 km from the center would track over a more complicated field of regard, with a minimum 42 degree elevation angle on the azimuth pointing to the center and a minimum 90 degree elevation angle in the azimuth opposite that.

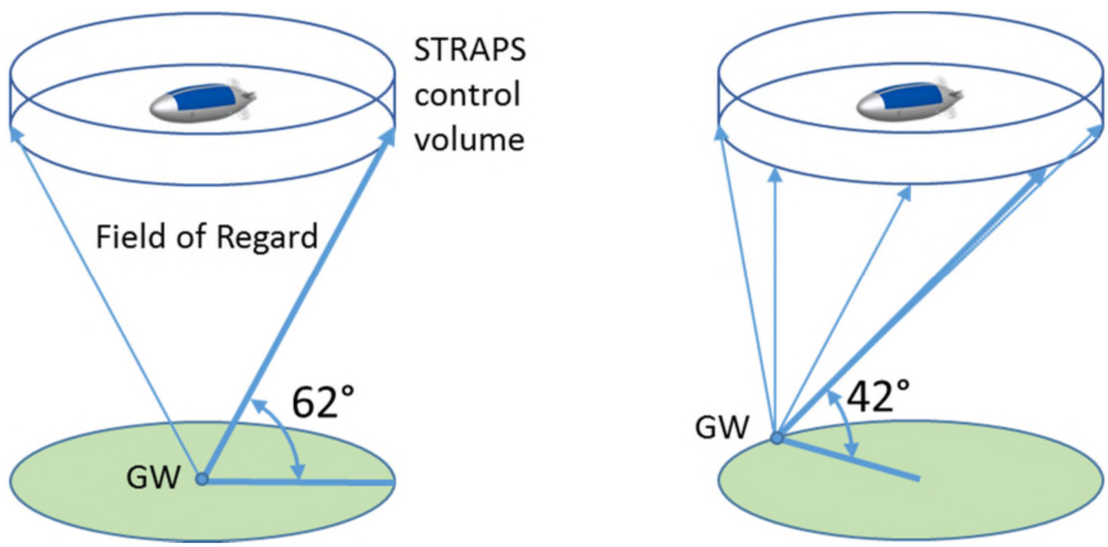

Figure 2: Geometry and minimum elevation angles for GW field of regard to track STRAPS over STRAPS control volume

It should be noted that other SBCS implementations might use a different layout of GWs resulting in different angles. The consequences for continued growth of terrestrial FS links and possible need for regulations to adequately protect continued growth of terrestrial FS links will be discussed in the conclusion.

The Elefante Group reference design gain patterns can be modeled multiple ways. Prior to the release of ITU-R F.699-8, neither F.1245 or F.699-7 extended beyond 70 GHz so, with no designated pattern for compatibility studies above 70 GHz, ITU-R F.1245 was used. The effects on this study of the differences between these ITU references are small as shown in Figure 3. For consistency with prior compatibility modeling, ITU-R F.1245 is used again here, but the results for ITU-R F.699-8 are presented for comparison. Also pictured in Figure 3 is the regulatory gain limit from §101.115. Because this limit scales from the boresight gain, it may be appropriate to adjust it for higher gain antennas like those envisioned for the Elefante Group design, and this will be discussed further in the conclusions.

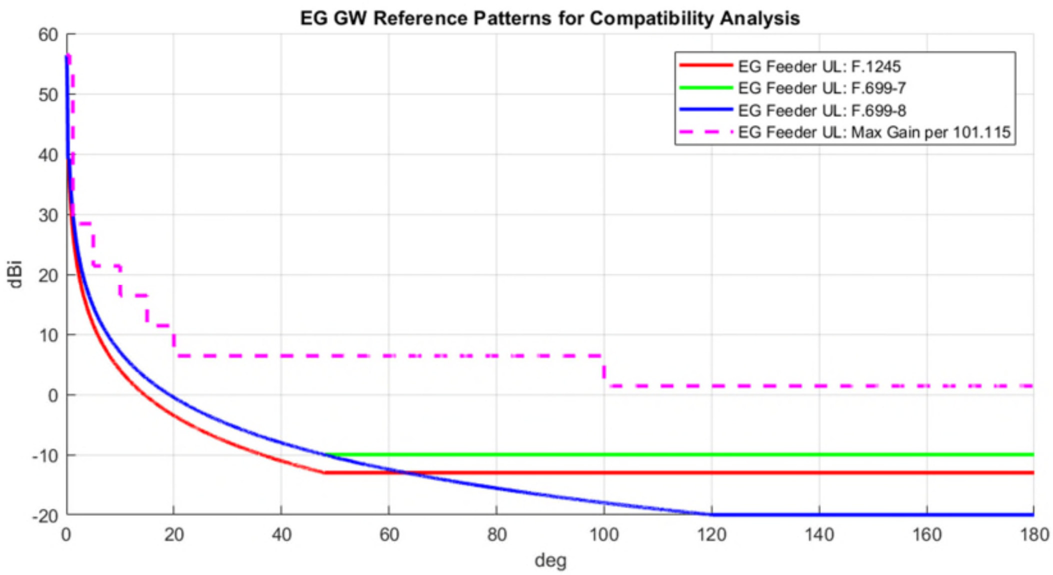

Figure 3: Comparison of antenna gain pattern options for GW antenna

For this study, worst-case operating conditions are utilized for a bounding analysis prior to considering, if appropriate, more risk-based interference assessment using probability and statistical methods:

1) GWs transmitting at the maximum power level including power control margin resulting in the maximum EIRP density, occupying the full channel bandwidth from 81-86 GHz.
2) Whereas in clear sky the EIRP density on boresight will be typically no more than 5 dB(W/MHz), the analysis will use the maximum power available to overcome weather of 24 dB(W/MHz).
3) GW antenna patterns will use the conservative bounding patterns described above (but the regulatory limits will be examined as well). Antenna patterns are evaluated at the minimum 81 GHz frequency to conservatively use the widest beamwidth.
4) STRAPS are located at a position within their control volume so as to create the worst geometry for interference with terrestrial FS link receivers.
5) Direct line of sight is assumed, with no loss from ground clutter.

STUDY SCENARIO

Figure 4 illustrates the interference geometry applicable to this study.

- FS transmitters (TX) and FS receivers (RX) are distributed across the service area and adjacent regions forming links and pointed at each other. As described in license documentation, each FS RX is located at a specified latitude and longitude, mounted at a specified height. As derivable from license documentation, it is aimed in a specific azimuth and elevation direction.

- If a candidate GW location and the STRAPS location it points to are specified, then for any FS RX the relative geometry can be calculated: range and off-boresight angle from each aperture to the other.

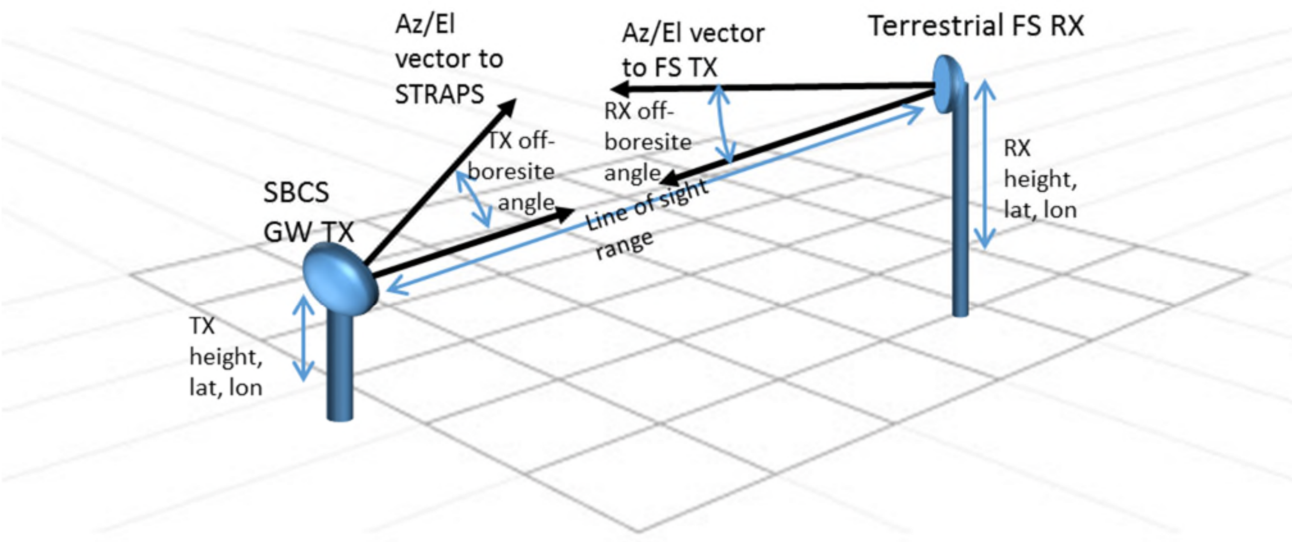

Figure 4: Geometry for high elevation SBCS GW interference transmission into terrestrial FS receiver

STUDY METHODOLOGY

This study considers the range of possible relative angular geometry between GW transmitters and FS receivers, and determines the minimum standoff distance between them across that range.

The range of angles the GW can theoretically appear off the boresight of the FS is 0 to 180 degrees, as is the range of angles the FS could theoretically appear off the boresight of the GW. This defines the two dimensions of the analysis.

Given their antenna patterns, the roll-off in gain for each antenna are determined as a function of angle off boresight. The sum of the roll-offs is the total spatial isolation for these angles.

Assuming complete overlap of the interferer and victim channels, the I/N protection criteria of -6 dB can be represented as total interference power spectral density minus receiver noise density

GW EIRP density – Free Space Loss (FSL) + FS Gain – FS Noise Density = -6

and manipulated to solve for FSL necessary to achieve protection. From the resultant FSL, the associated separation distance between the two nodes is calculated and plotted.

STUDY RESULTS

In the baseline case using the transmit gain limits of §101.115 for the FS receive pattern and ITU-R F.1245 for the GW transmit pattern, the spatial isolation at different relative antenna angles is as shown in Figure 5. The gain of the GW beam rolls off 45 dB by 5 degrees off boresight, and the FS receive beam rolls off 35 dB by 5 degrees of boresight, resulting in large degrees of isolation with only small off-pointing angles.

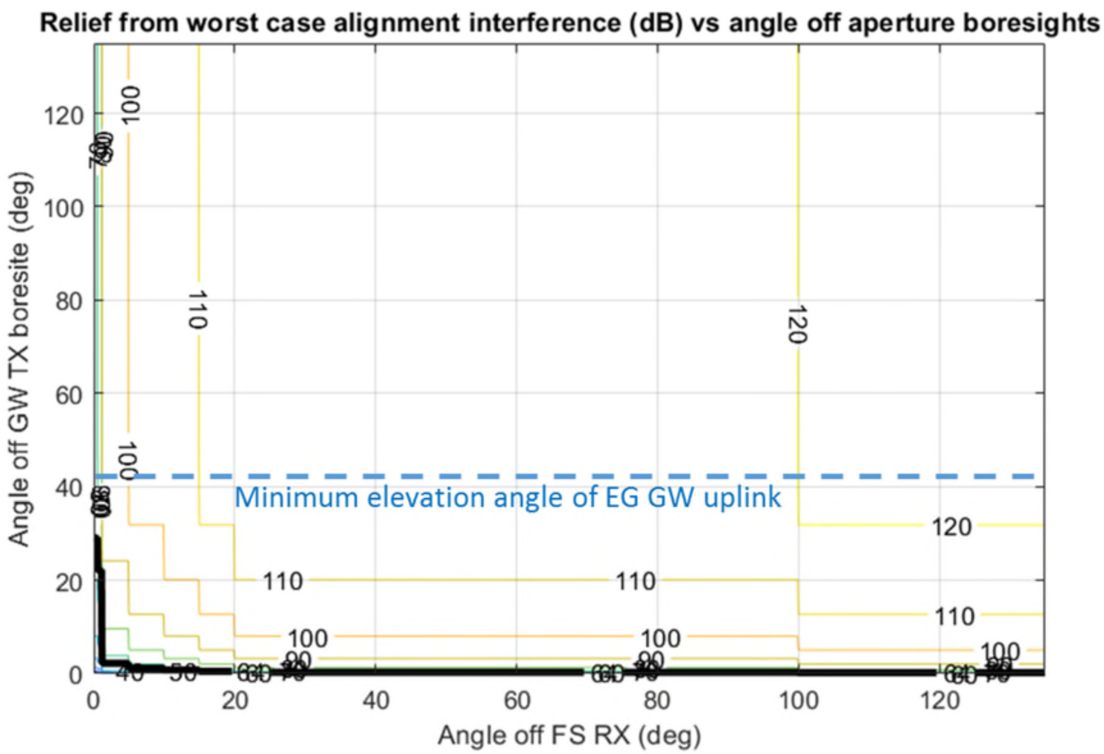

Figure 5: Spatial isolation as a function of angle off transmit and receive antennas is very large due to the rapid roll-off of the extremely narrow, high-gain E-band beams. Tracking STRAPS within control volume, GW does not point closer than 42 degrees to ground.

Very importantly, as illustrated in Figure 2, the GW beam never goes below 42 degrees elevation, a 68 dB roll-off for the beam. Only in special cases where the FS receiver is mounted much higher above the ground than the GW can the angle be smaller.

This results, as shown in Figure 6, in very small separation distances necessary between a GW and FS receiver in most circumstances. Of course, the separation is significant (~ 5km) if the RX aims *exactly* at the GW. Beyond 3 degrees off boresight, required separation is less than 200m, beyond 5 degrees it is 90m, and beyond 10 degrees it is 50m.

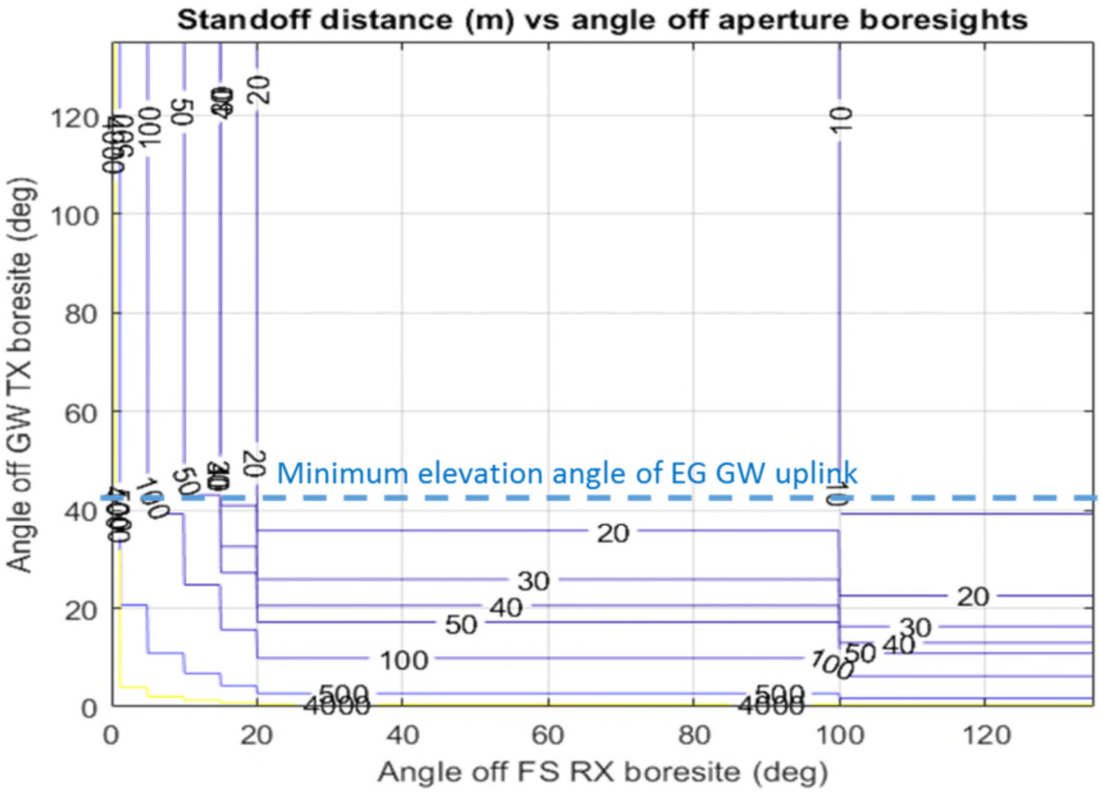

Figure 6: Required separation distance between GW and FS receiver as a function of angle off transmit and receive antennas is very small unless receiver aimed close to directly at GW.

Two other cases are illustrated for discussion.

Figure 7 shows separations when the GW is transmitting at nominal clear sky power levels, significantly backed off from the maximum EIRP capability available through ATPC for high weather loss events. In this case, modeled separations are clearly small enough that more detailed near-field analysis or modeling would be warranted to accurately assess them.

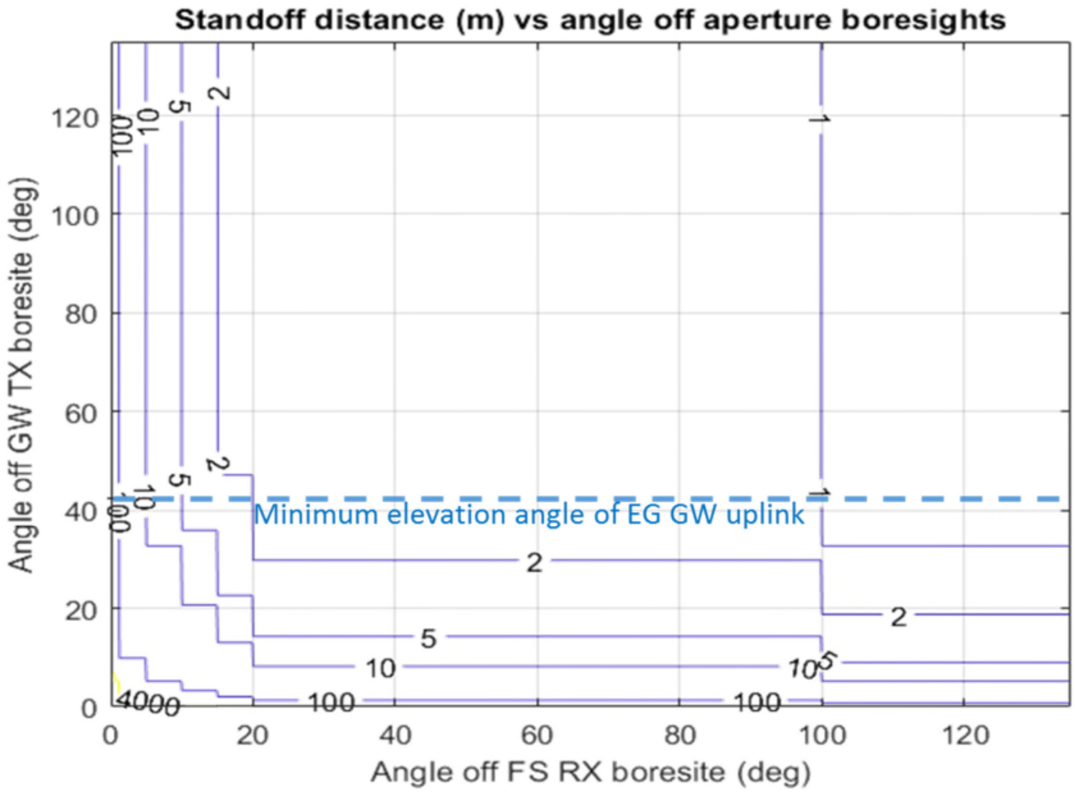

Figure 7: Required separation distance between GW and FS receiver as a function of angle off transmit and receive antennas is extremely small when GW transmitting through clear weather.

Figure 8 shows the separation result for the maximum EIRP case if the gain limit described in §101.115 were applied to a 56.4 dBi GW antenna. By using the same roll-off mask as used for the 43 dBi antenna (an unrealistic pattern), separations are significantly higher.

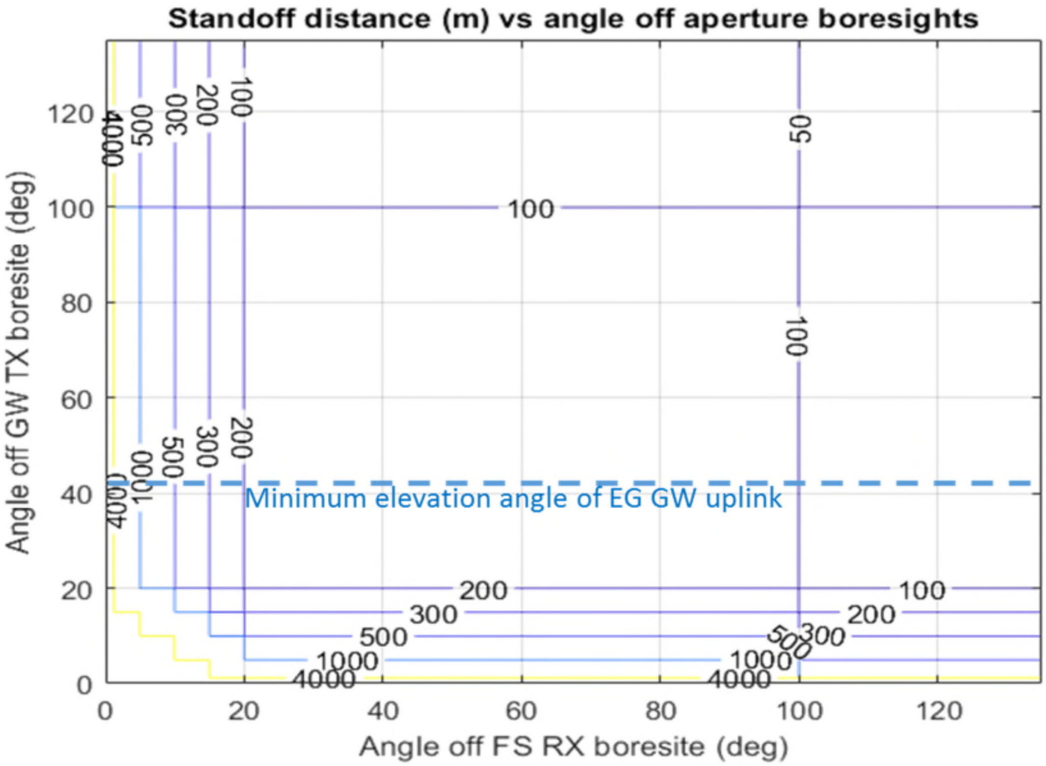

Figure 8: Required separation distance between GW and FS receiver as a function of angle off transmit and receive antennas is larger if GW antenna matched current 101.115 regulatory language.

DISCUSSION: STUDY RESULTS

The primary result of this analysis is that SBCS GWs as proposed for the Elefante Group reference design are no harder to coordinate than other FS transmitters, and in fact contribute significantly less to terrestrial congestion in the band. By virtue of their high elevation angle they present such low EIRP density in the horizontal direction that they present almost the same level in all azimuth directions as one would see in the backlobe of a horizontally aimed FS transmitter – sort of a "universal backlobe" as regards terrestrial coordination. Special cases can exist where GWs and FS receivers are to be coordinated in close proximity at different heights above the ground, but no more so than already exist in current FS coordination. It should be noted that the off-axis angle the FS receiver aims from the GW direction includes both the azimuth and elevation component. An FS receiver that is pointed 3 deg horizontally from the GW has the same isolation as one aimed 3 deg above the GW.

SBCS GWs can operate compatibly with existing and future conventional FS receivers, and neither inordinately inhibit the growth and future deployment of the other. Indeed, sharing will be enhanced further through the effects of clutter and line of sight blockage not considered in this study and, given the limited number of GWs required, might take advantage of other improvements such as shielding.

Two factors are important in generalizing the proposed rulemaking to ensure this result, and bear on the concerns of other organizations interested in innovative new applications within the band.

The first is a difference between the GW and conventional FS transmitters. The GW has a field of regard over which it tracks the STRAPS (which relays GW transmissions to a fixed user terminal at the other end of the link), whereas the FS transmitters need no articulation and have a pointing vector definable as a single azimuth and elevation. Compatibility has been demonstrated using the worst case GW elevation angle to show that, in the Elefante Group reference design, the changes in GW pointing do not present a problem to conventional FS link receivers.

The second is the difference between the Elefante Group reference design GW gain pattern and the pattern mask described in §101.115 as it applies to the higher gain of GW antennas. The mask is described as a series of minimum attenuations from the maximum gain as a function of off-boresight angle, so scales directly with the antenna gain. Clearly the mask illustrated in Figure 3, exceeding 0 dBi in all directions, does not represent a physically realizable antenna pattern, but rather a limit on sidelobes and peaks that can occur in limited directions in real designs. But were an antenna to present such a peak toward a receiver, the minimum separation distances would increase dramatically (as illustrated in Figure 8).

Without specific rules, there could be varying levels of compatibility for other SBCS designs or other services with overhead geometries. Some will be even more compatible, but some, given the two factors combined and unregulated, could result in less compatibility. For example, an overhead antenna using the minimum 43 dBi gain and operating at lower elevations would project higher EIRP density toward terrestrial receivers. If its field of regard included large azimuth shifts, it presents a very different coordination situation than the Elefante Group design. And if it was a higher gain antenna but included gain spikes up to the current regulatory limit, it could present those across a large azimuth swath as well.

This underlines the need for a regulatory framework for SBCS that maximizes the variety of possible implementations to not constrain innovation, but adequately protects the existing conventional FS infrastructure and its growth. To this end Elefante Group has proposed the general steps of:

1) Defining a maximum EIRP density that SBCS (and perhaps other services with similar overhead geometry) could radiate below some threshold elevation level. The objective is to create parity between operators where overhead directed transmitters do not present more of a coordination challenge to new conventional FS links than FS links themselves, and potentially even less of a challenge.
2) Considering an alternative definition for gain pattern masks for higher gain antennas that more realistically reflects possible antenna designs, and will not require unnecessary conservatism in compatibility analyses in the band.

In comments on the original PFR[3], several parties expressed concern that regulation related to SBCS along the lines described could hinder innovation, and particularly their own envisioned

[3] *See* Comments of Loon LLC, RM-11809, 4 (July 11, 2018); Comments of Aeronet Global Communications Inc., RM-11809, 4 (July 11, 2018); Comments of SES Americom, Inc. and O3b Limited, RM No. 11809, 2 (July 11, 2018).

operations in the band. Elefante Group welcomes constructive ideas, either through discussion or entry into the record, that can be considered as alternatives that also achieve the above objectives and support sharing in the band between new-comers and incumbent users.

DISCUSSION: PROPOSED COORDINATION APPROACH

As shown previously, SBCS gateway transmitters are compatible with conventional FS links and present less of a coordination challenge to new FS links than other conventional FS links that utilize the full band. They can be coordinated through the existing FS coordination procedures as described in Part 101 Subpart Q.

The only challenge to using the existing process is the description of STRAPS location data which, in addition to the nominal station, should include the height and radius bounds of the STRAPS control volume to enable new links to conduct the coordination analysis that must be submitted when they register. In its Petition,[4] Elefante Group has described a coordination and registration framework for STRAPS that includes a registry of STRAPS that would necessarily include this information, as well as unique STRAPS identifiers. Thus, Elefante Group suggests that E-Band links between SBCS GWs and STRAPS use exactly the same form as other FS E-Band links, but include the unique identifier of the STRAPS as its location name, and the designation "SBCS" in the location description. If the field length permits, the location description could even include the control volume dimensions.

For coordination studies, the analyst can follow a procedure similar to the methodology above but specific to the off-boresight angles with respect to the FS receivers analyzed (versus the generalized parametric analysis of angles). The analyst can readily determine the minimum elevation angle of the GW transmitter from its distance from the latitude, longitude of the STRAPS nominal station and the control volume dimensions.

CONCLUSIONS

SBCS feeder uplinks in the 81-86 GHz band are fully compatible with other FS links in the same band and can be coordinated and authorized using the existing process.

Although a regulatory approach is suggested, consideration is required to make sure it permits multiple implementations.

REFERENCES:

ITU-R F.1245-2: Mathematical model of average and related radiation patterns for line-of-sight point-to-point fixed wireless system antennas for use in certain coordination studies and interference assessment in the frequency range from 1 GHz to about 70 GHz

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4 *Petition to Modify Parts 2 and 101 of the Commission's Rules to Enable Timely Deployment of Fixed Stratospheric-Based Communications Services in the 21.5-23.6, 25.25-27.5, 71-76, and 81-86 GHz Bands*, Petition for Rulemaking, RM-11809 (May 31, 2018) ("Petition").

ITU-R F.699-7: Reference radiation patterns for fixed wireless system antennas for use in coordination studies and interference assessment in the frequency range from 100 MHz to about 70 GHz

ITU-R F.699-8: Reference radiation patterns for fixed wireless system antennas for use in coordination studies and interference assessment in the frequency range from 100 MHz to 86 GHz

Exhibit 7
Compatibility Analysis:
SBCS Feeder Downlink Interference into
Fixed Service in the
71 - 76 GHz Band
(Prepared by Lockheed Martin Corporation for Elefante Group, Inc.)

SUMMARY

- Elefante Group is proposing to access the 71-76 GHz band for Stratospheric-Based Communications Services (SBCS) downlink communications to feeder terminals located at network gateways (GW) on a co-Primary basis.

- This study assesses the compatibility of SBCS Feeder downlinks with Fixed Service (FS) point to point microwave links which are authorized to operate in the 71-76[1] GHz band.

- Worst-case operating conditions are utilized for a bounding analysis: SBCS feeder downlinks are operating at maximum EIRP, and no atmospheric propagation or ground clutter losses are considered.

- The spatial isolation enjoyed between the overhead geometry (high elevation) SBCS to GW links and the terrestrial geometry of conventional FS links combined with the narrow beamwidth of beams at this frequency make these links easily compatible.

- GWs can be coordinated using the same national license and link registration scheme currently in place for FS in this band.

PURPOSE OF THE STUDY

Elefante Group is proposing that the 71-76 GHz band be made available for SBCS, operating as a Fixed service, in the downlink direction. All or part of this band is allocated in the federal and non-federal allocation to Fixed, Fixed Satellite, Mobile, Mobile Satellite, Radio Astronomy, and (on a secondary basis) Space Research (space-to-earth). The 74-76 GHz band is also allocated to non-federal Broadcasting and Broadcasting Satellite. There are 28 military installations that have priority over all other uses for the band[2].

This study assesses the compatibility with other Fixed Service links of downlink transmissions from stratospheric platforms to ground-based GWs, and assesses the potential for interference into conventional FS point to point microwave links to exceed the I/N Protection Criterion to determine if mitigation measures are necessary.

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[1] Elefante Group is also looking at the prospect for GW uplinks in the 71-76 GHz band. Although such links are beyond the scope of the present compatibility study and discussion, Elefante Group believes a similar analysis and conclusions would largely apply to compatibility with FS links in that band.

[2] As detailed in footnote US389 in the FCC Table of Frequency Allocations.

The proposed approach for coordinating with existing conventional FS receivers from SBCS FS transmitters is to follow the existing coordination procedures as described in 47 C.F.R Part 101 Subpart Q. The registration information may be expanded to describe the geometry of the control volume the Stratospheric Platform Stations (STRAPS) can operate within, or simply reference the STRAPS registry where that information is available.

OPERATIONAL CHARACTERISTICS OF TERRESTRIAL FS RECEIVERS

FS link receiver data was gathered from one of the three third-party registry databases where E-band links are registered by licensees. The database contains sufficient information on both transmit and receive locations on a path to determine all relevant receiver geometry (latitude, longitude, altitude, azimuth, and elevation) and spectrum use for a specific link, and statistics for links in general.

Although boresight gain and 3 dB beamwidth are recorded, full receive gain patterns as a function of angle off boresight require manufacturer data and will vary by manufacturer as well, so a more general bounding pattern is sought. Per §101.115, the minimum antenna boresight gain is 43 dBi, which is used here because it represents the widest mainlobe that would be most sensitive to off-axis interference. Although ITU-R F.699 was updated earlier this year to model patterns > 70 GHz, for a 43 dBi antenna the model exceeds the off-axis attenuation rules in §101.115. Therefore the §101.115 transmit mask, assuming reciprocity, is used for the worst case receive pattern. Figure 1 shows a comparison of receive gain patterns from the above references.

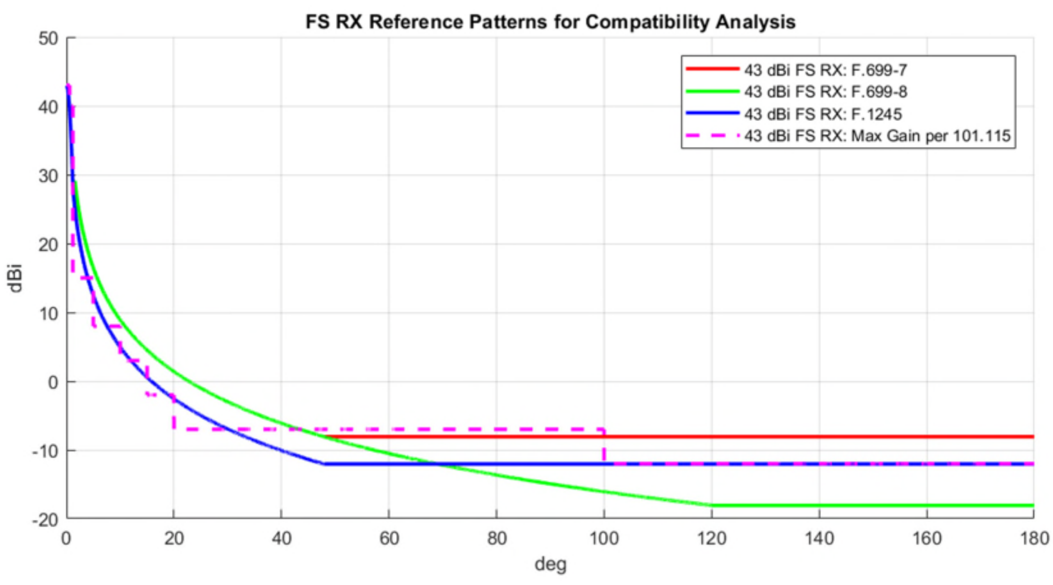

Figure 1: Comparison of antenna gain pattern options for FS RX antenna

Data from the registry indicates the majority of receiver noise figures are 7 dB up to 14 dB, with only very rare exceptions of lower noise figures. Thus, this analysis uses a 7 dB noise figure to derive a noise density of -137 dB(W/MHz) for the FS receiver. Rather than use specific T/I values or curves, the protection criteria used is a maximum interference to noise ratio of -6 dB (the level that would result in a 1 dB increase in receiver thermal noise).

Because interference can only occur when interferer and victim boresights are close to aligned, and the FS RX uses linear polarization whereas the SBCS uses circular polarization, an additional 3 dB of polarization isolation is assumed.

OPERATIONAL CHARACTERISTICS OF SBCS

The SBCS will utilize STRAPS, UTs, and feeder terminals at network gateways to provide fixed services over a specific service area. Transmit characteristics of the Elefante Group SBCS Feeder downlink utilized in this study are given in Exhibit 1. In the text below GW will refer to the feeder terminal located at the SBCS gateway.

STRAPS are only authorized to operate within their control volume, a cylindrical volume of space around a nominally fixed latitude, longitude, and altitude defined by its height and radius. In the Elefante Group reference design, the STRAPS control volume is 10 km in radius and extends from 18.3 to 21.3 km altitude, and GW links are deployed within 10 km of the nominal latitude/longitude center on the ground. Unlike the user terminals, only a small number of GWs will be required, typically up to 20.

GWs will track the STRAPS within the control volume, and the STRAPS transmitter will similarly track the GW on the ground. A GW centered within the footprint of the STRAPS control volume would track over a conical field of regard, always at above 61 degrees elevation angle. A GW 10 km from the center would track over a more complicated field of regard, with a minimum 42 degree elevation angle on the azimuth pointing to the center and a minimum 90 degree elevation angle in the azimuth opposite that.

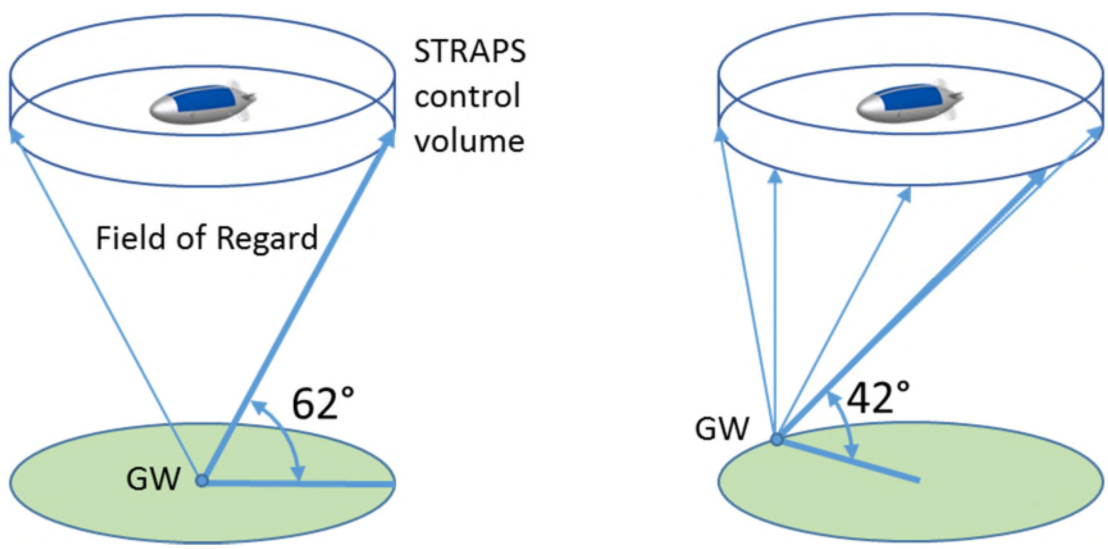

Figure 2: Geometry and minimum elevation angles for GW field of regard to track STRAPS over STRAPS control volume

It should be noted that other SBCS implementations might use a different layout of GWs resulting in different angles. The consequences for continued growth of terrestrial FS links and possible need for regulations to adequately protect continued growth of terrestrial FS links will be discussed in the conclusion.

The Elefante Group reference design gain patterns can be modeled multiple ways. Prior to the release of ITU-R F.699-8, neither F.1245 or F.699-7 extended beyond 70 GHz so, with no designated pattern for compatibility studies above 70 GHz, ITU-R F.1245 was used. The effects on this study of the differences between these ITU references are small as shone in Figure 3. For consistency with prior compatibility modeling, ITU-R F.1245 is used again here, but the results for ITU-R F.699-8 are presented for comparison. Also pictured in Figure 3 is the regulatory gain limit from §101.115. Because this limit scales from the boresight gain, it may be appropriate to adjust it for higher gain antennas like those envisioned for the Elefante Group design, and this will be discussed further in the conclusions.

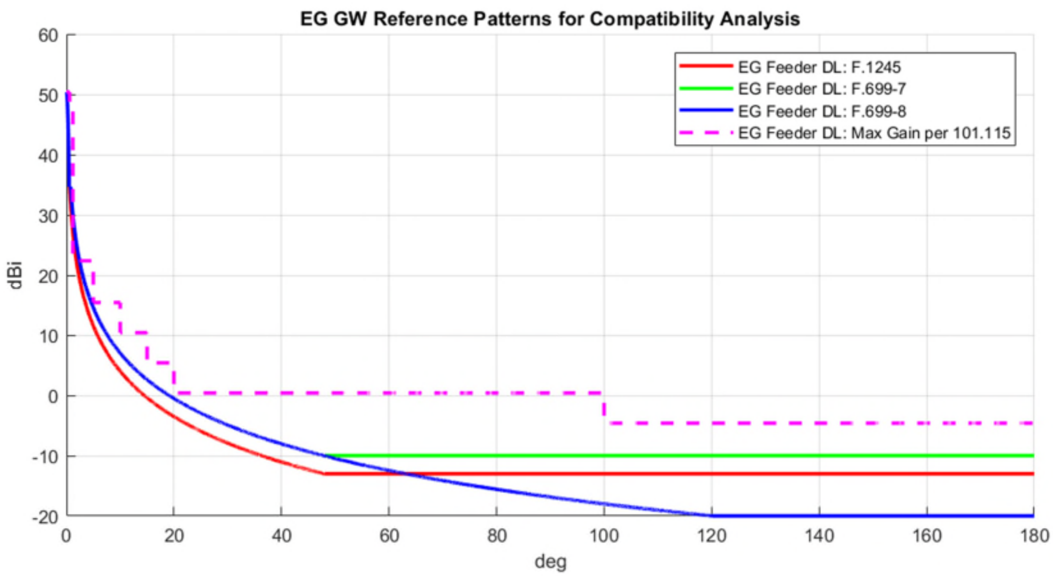

Figure 3: Comparison of antenna gain pattern options for SBCS Feeder antenna

For this study, worst-case operating conditions are utilized for a bounding analysis prior to considering, if appropriate, more risk-based interference assessment using probability and statistical methods:

1) The maximum clear sky EIRP density on SBCS Feeder boresight of -10.7 dB(W/MHz) is used (ATPC is used to maintain this EIRP density through weather) and assumed across the full 71-76 GHz bandwidth
2) SBCS Feeder antenna patterns will use the conservative bounding patterns described above (but the regulatory limits will be examined as well). Antenna patterns are evaluated at the minimum 71 GHz frequency to conservatively use the widest beamwidth.
3) STRAPS is located at a position within their control volume so as to create the worst geometry for interference with terrestrial FS link receivers. In this case it is minimum altitude and shallowest elevation angle.

4) Direct line of sight is assumed.

STUDY SCENARIO

Figure 4 illustrates the interference geometry applicable to this study.

- An SBCS GW is located somewhere within the 10 km deployment radius centered under the STRAPS nominal station.
- The STRAPS is located somewhere within the control volume centered on the station. This study uses the STRAPS at its lowest possible altitude on the opposite side of the control volume from the GW (as show on right of Figure 4) because it presents the shallowest elevation angle. The shallowest elevation angle will 1) be closest to the direction FS RXs (typically low elevation) might point and 2) generate the most extended beam footprint on the ground.
- Based on the FS RX location with respect to the GW, it will appear at some angle off the SBCS feeder downlink beam boresight, and will be illuminated by an EIRP density dependent on the SBCS feeder beam gain roll-off.
- Based on the FS RX location with respect to the GW, and on its azimuth and elevation pointing direction, the SBCS feeder will appear at some angle off the FS RX boresight and be presented a gain dependent on the FS RX beam gain roll-off.

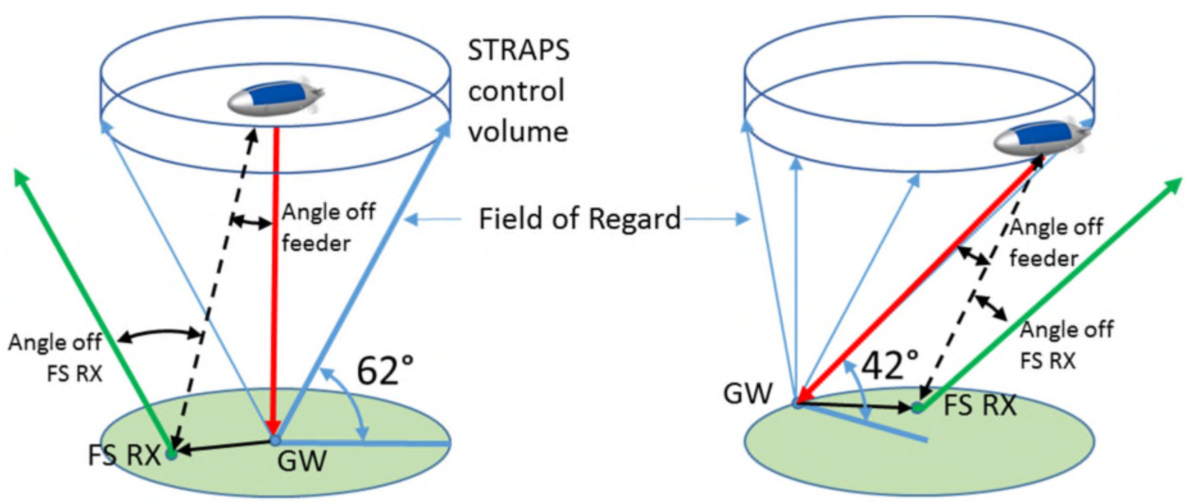

Figure 4: Geometry for high elevation SBCS Feeder interference transmission into terrestrial FS receiver. Two bounding geometries for GW at center or edge of GW area determine GW field of regard. Distance of FS RX from GW and FS RX azimuth and elevation determine off-boresight angles both apertures present to each other.

STUDY METHODOLOGY

This study considers the relative geometry between SBCS Feeder transmitters and FS receivers described above and determines the combination of minimum standoff distance between the SBCS

GW receiver and the FS receiver and minimum angle between the FS RX boresight and the SBCS Feeder to prevent harmful interference.

For the SBCS GW geometry shown on the right of

Figure 4, a grid of ground points is considered around the GW as potential locations for an FS RX. The x coordinate is positive in the direction of the STRAPS. For each grid point we calculate:

- The angle off of the SBCS feeder boresight
- The power flux density at the ground from the SBCS feeder downlink

PFD = STRAPS max EIRP density – Gain roll-off + 10*log10(1/(4*pi*Range)^2)

- The gain an FS RX would have to present in the direction of the feeder to receiver harmful interference

Max Gain = I/N threshold – (STRAPS max EIRP density – Gain roll-off – Free Space Loss – Polarization mismatch loss – FS RX noise density)

- The minimum angle off a 43 dBi FS RX boresight to not exceed that gain. This is the angle the FS RX must keep off the STRAPS direction to prevent harmful interference.

Within a certain distance from the SBCS GW, the FS RX cannot aim directly at the STRAPS without receiving harmful interference, and the STRAPS can be anywhere within the field of regard, which is defined by the angles the GW would point to track the STRAPS through its control volume. The calculated minimum off-boresight angle for the FS RX determines an additional required angular margin around this field of regard. As the separation distance between the GW and FS RX increases, the angular margin reduces and, when it becomes zero, there is no longer any direction the FS RX can point and still receive harmful interference from the STRAPS.

STUDY RESULTS

To first illustrate the results with smoothly varying antenna patterns, the case of both the SBCS feeder and FS RX using patterns derived from ITU-R F.699-8 is considered. As illustrated in Figure 5, the SBCS feeder projects a power flux density on the ground that rolls off rapidly away from the GW that it is directed at. Because the beam is projected from STRAPS seen at 42 degree elevation to the east, it is elongated in the east/west directions. To receive harmful interference, an FS RX must present significant gain toward the STRAPS, which requires its boresight to aim very close to the STRAPS direction.

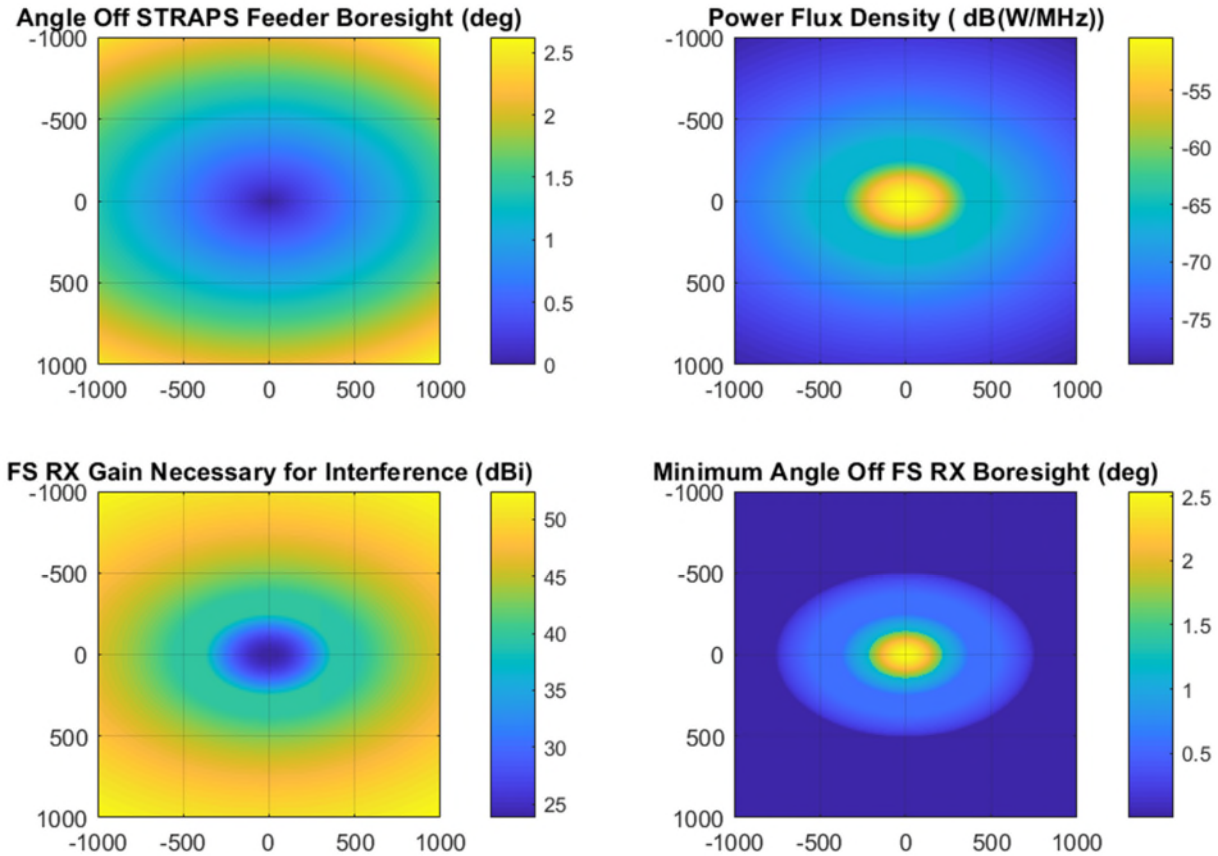

Figure 5: Metrics for FS RX interference applied to 2000 x 2000 meter area centered on SBCS GW location, including angle off STRAPS feeder boresight, PFD on the ground, FS RX gain toward STRAPS to receive harmful interference, and required minimum angle to point FS RX boresight away from STRAPS to prevent harmful interference. FS RX's with lower than a 39.5 degree elevation angle cannot receive harmful interference, and no harmful interference affects FS RX's at *any* elevation angle outside the 1.5 x 1 km ellipse.

In this case, if the SBCS GW and FS RX are exactly collocated, the FS RX must not aim within 2.5 degrees of the STRAPS. For this particular geometry this represents an exclusion cone of 2.5 degrees around a vector pointed east at 42 degrees elevation. As the STRAPS can move around the control volume, the direction the STRAPS interference could come from defines a solid angle as shown in

Figure 4 on the right. For an FS RX at a particular location relative to the GW, the corresponding minimum angle can effectively be added as margin around the GW field of regard.

Importantly, when the minimum angle falls off to 0 degrees, the FS RX can no longer receive harmful interference from the STRAPS no matter where it is pointed. In this example, the extent of the area where the GW placement can affect the terrestrial receivers is a 1.5 by 1 km ellipse centered on the GW.

If this GW had been at the center of the service area (rather than 10 km from the center) the projections would have been symmetric, and the field of regard would be the solid angle shown in

Figure 4 on the left (restricted to 62 degrees elevation or higher).

As illustrated in Figure 1 and Figure 3, the ITU-R F.699-8 pattern does not align exactly with the maximum transmit gain envelope described in §101.115. In the case of the 43 dBi FS RX, the mainlobe falls within the envelope and the sidelobe roll-off exceeds it out to 43 degrees off boresight. In the case of the Elefante Group SBCS feeder, the mainlobe falls within the envelope, but sidelobe roll-off exceeds it between 1.2 and 2.5 degrees off boresight before falling below the envelope again. Figure 6 presents the results using these bounding envelopes.

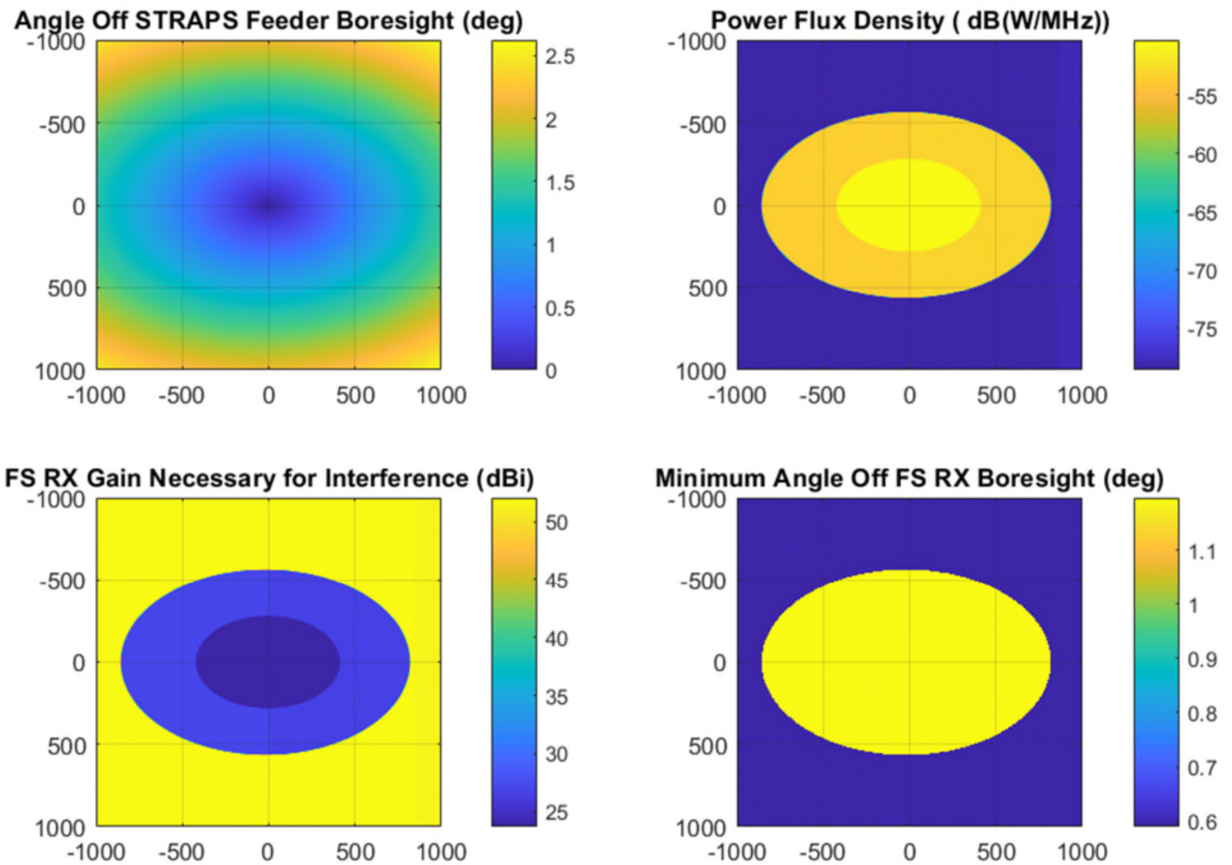

Figure 6: Metrics for FS RX interference applied to 2000 x 2000 meter area centered on SBCS GW location, including angle off SBCS feeder boresight, PFD on the ground, FS RX gain toward a STRAPS to receive harmful interference, and required minimum angle to point FS RX boresight away from a STRAPS to prevent harmful interference. FCC rules in Part 101.115 for maximum gain envelopes area applied. FS RXs with lower than a 40.8 degree elevation angle cannot receiver harmful interference, and no harmful interference can affect FS RX's at *any* elevation angle outside the 1.6 x 1.1 km ellipse.

In this case, if the SBCS GW and FS RX are exactly collocated, the FS RX must not aim within 1.2 degrees of the STRAPS. For this particular geometry, the result is an exclusion cone of 1.2 degrees around a vector pointed east at 42 degrees elevation. As the STRAPS can move around the control volume, the direction the SBCS feeder interference could come from defines a solid angle as shown in

Figure 4 on the right. For an FS RX at a particular location relative to the GW, the corresponding minimum angle can effectively be added as margin around the GW field of regard.

Importantly, when the minimum angle falls off to 0 degrees, the FS RX can no longer receive harmful interference from the SBCS feeder no matter where it is pointed. In this example, the extent of the area where the GW placement can affect the terrestrial receivers is a 1.6 by 1.1 km ellipse centered on the GW.

DISCUSSION: STUDY RESULTS

The primary result of this analysis is that downlinks from SBCS feeders to SBCS GWs as proposed for the Elefante Group reference design are no harder to coordinate than other FS transmitters, and in fact contribute significantly less to terrestrial congestion in the band. By virtue of their high elevation angle they present interference only to FS RXs that are both extremely high elevation AND located very near the GW.

Figure 7 illustrates the range of elevation angles for 4,900 E-Band links (both 71-76 and 81-86 GHz) registered in the San Francisco Bay Area. From this representative population, there are clearly very few extremely high elevation links. Indeed, only 11 receivers are higher than 30 degrees elevation and the highest, at 38.7 degrees, is still not high enough to reach the worst case 39.5 degree limit required for harmful interference described in Figure 5.

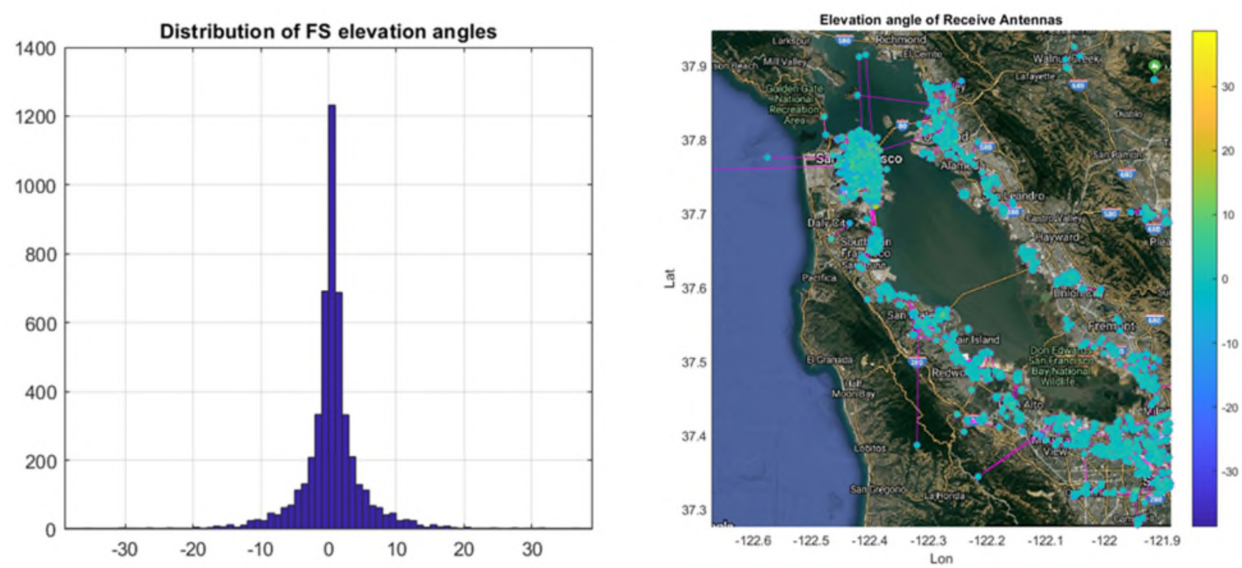

Figure 7: Distribution of elevation angles (left) and location (right) of E-band links in SF Bay Area

High elevation angle links appear to occur mostly within urban centers where lower elevation antennas are directed at the roofs of nearby, tall buildings. The chances that an FS link would be installed at sufficient elevation angle and in the correct azimuth direction to be harmfully interfered with are negligible, and such situations can easily be identified in the existing coordination procedure. SBCS GWs, with their high elevation angles, present only backlobes in all azimuth directions toward conventional FS transmitters, and thus present less of a coordination challenge to new FS TXs than conventional FS RXs, which will be more sensitive in the azimuth direction their beam is aimed. Therefore, SBCS Feeder links to GWs can operate compatibly with existing and future conventional FS receivers, and neither inordinately inhibit the growth and future deployment of the other.

Two factors are important in generalizing the proposed rulemaking to ensure this result, and bear on the concerns of other organizations interested in innovative new applications within the band.

The first is a difference between the GW and conventional FS transmitters. The GW has a field of regard over which it tracks the STRAPS (which relays GW transmissions to a fixed user terminal at the other end of the link), whereas the FS transmitters need no articulation and have a pointing vector definable as a single azimuth and elevation. Compatibility has been demonstrated using the worst case GW elevation angle to show that, in the Elefante Group reference design, the changes in GW pointing do not present a problem to conventional FS link receivers.

The second is the difference between the Elefante Group reference design GW gain pattern and the pattern mask described in §101.115 as it applies to the higher gain of GW antennas. The mask is described as a series of minimum attenuations from the maximum gain as a function of off-boresight angle, so scales directly with the antenna peak gain. The mask illustrated in Figure 3 does not represent a physically realizable antenna pattern, but rather a limit on sidelobes and peaks that can occur in limited directions in real designs. However, because the mask is defined only as attenuations relative to the peak gain, higher gain antennas are effectively permitted larger and unrealistic excursions above what a realistic pattern should present.

Without specific rules, there could be varying levels of compatibility for other SBCS designs or other services with overhead geometries. Some will be even more compatible, but some, given the two factors combined and unregulated, could result in less compatibility. For example, an overhead antenna both using the minimum 43 dBi gain (maximum beamwidth) and downlinking at lower elevations would project a much larger, more elongated ellipse within which harmful interference could occur, as well as a lower elevation that might include more of the population of FS RXs. If its field of regard included large azimuth shifts, it presents a very different coordination situation than the Elefante Group design. And if it was a higher gain antenna but included gain spikes up to the current regulatory limit, it could present intermittent interference across a large area.

This underlines the need for a regulatory framework for SBCS that maximizes the variety of possible implementations to not constrain innovation, but adequately protects the existing conventional FS infrastructure and its growth. To this end Elefante Group has proposed the general steps of:

1) Defining a minimum elevation that SBCS to GW downlinks (and perhaps other services with similar overhead geometry) could operate at, or a similar requirement on off-boresight PFD vs elevation that prevents large solid angles over large areas around GWs from being unavailable to conventional FS. The objective is to create parity between operators where downward directed transmitters from overhead geometries do not present more of a coordination challenge to new conventional FS links than FS links themselves, and potentially even less of a challenge.

2) Considering an alternative definition for gain pattern masks for higher gain antennas that more realistically reflects possible antenna designs, and will not require unnecessary conservatism in compatibility analyses in the band.

In comments on the Elefante Group Petition[3] several parties expressed concern that regulation related to SBCS along the lines described could hinder innovation, and particularly their own envisioned operations in the band.[4], Elefante Group welcomes constructive ideas, either through discussion or entry into the record, that can be considered as alternatives that also achieve the above objectives and support sharing in the band between new-comers and incumbent users.

DISCUSSION: PROPOSED COORDINATION APPROACH

As shown previously, SBCS feeder downlinks to SBCS gateway receivers are compatible with conventional FS links and present less of a coordination challenge to new FS links than other conventional FS links that utilize the full band. They can be coordinated through the existing FS coordination procedures as described in Part 101 Subpart Q.

The only challenge to using the existing process is the description of STRAPS location data which, in addition to the nominal station, should include the height and radius bounds of the STRAPS control volume to enable new links to conduct the coordination analysis that must be submitted when they register. In its Petition, Elefante Group has described a coordination and registration framework for SBCS that includes a registry of STRAPS that would necessarily include this information, as well as unique STRAPS identifiers. Thus, Elefante Group suggests that E-Band links between SBCS GW and STRAPS use exactly the same form as other FS E-Band links, but include the unique identifier of the STRAPS as its location name, and the designation “SBCS” in the location description. If the field length permits, the location description could even include the control volume dimensions.

For coordination studies, the analyst can follow a procedure similar to the methodology above but specific to the off-boresight angles with respect to the FS receivers analyzed (versus the generalized parametric analysis of angles). The analyst can readily determine the minimum elevation angle of the GW transmitter from its distance from the latitude, longitude of the STRAPS nominal station and the control volume dimensions.

CONCLUSIONS

SBCS feeder downlinks in the 71-76 GHz band are fully compatible with other FS links in the same band and can be coordinated and authorized using the existing process.

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3 *Petition to Modify Parts 2 and 101 of the Commission’s Rules to Enable Timely Deployment of Fixed Stratospheric-Based Communications Services in the 21.5-23.6, 25.25-27.5, 71-76, and 81-86 GHz Bands*, Petition for Rulemaking, RM-11809 (May 31, 2018) (“Petition”).

4 *See* Comments of Loon LLC, RM-11809, 4 (July 11, 2018); Comments of Aeronet Global Communications Inc., RM-11809, 4 (July 11, 2018); Comments of SES Americom, Inc. and O3b Limited, RM No. 11809, 2 (July 11, 2018).

Although a regulatory approach is suggested, consideration should be given to permit multiple implementations.

REFERENCES:

ITU-R F.1245-2: Mathematical model of average and related radiation patterns for line-of-sight point-to-point fixed wireless system antennas for use in certain coordination studies and interference assessment in the frequency range from 1 GHz to about 70 GHz

ITU-R F.699-7: Reference radiation patterns for fixed wireless system antennas for use in coordination studies and interference assessment in the frequency range from 100 MHz to about 70 GHz

ITU-R F.699-8: Reference radiation patterns for fixed wireless system antennas for use in coordination studies and interference assessment in the frequency range from 100 MHz to 86 GHz

Appendix A
Compatibility Analysis:
Potential for Interference between WorldVu MEO-Gateway Links and SBCS STRAPS-Gateway Links in the 71-76 and 81-86 GHz Bands
(Prepared by Lockheed Martin Corporation for Elefante Group, Inc.)

Introduction

WorldVu dba OneWeb (OW) proposes to operate a small number of gateway earth stations (GW) at geographically remote locations in the United States operating in the 71-76 GHz band in both directions – a waiver from the FCC would be needed for the uplinks – and Earth-to-space in the 81-86 GHz band.[1] Elefante Group (EG) proposes that Stratospheric-Based Communications Systems (SBCS) have access to the same bands for links between stratospheric platform stations (STRAPS) and SBCS-GW feeder terminals, in both the downlink and uplink direction in the 71-76 GHz Band and in the uplink direction in the 81-86 GHz band.[2]

The following compatibility analyses examine four interference paths possible between the OW-GW and SBCS GW feeder uplink and downlinks. For each, a parametric analysis was conducted using worst case assumptions to model Interference to Noise ratio (I/N) vs separation distance from OW-GWs to SBCS architectural elements (SBCS-GW or STRAPS), compared to threshold I/N protection criterion to determine a conservative separation distance beyond which no harmful interference is possible. For interference into OneWeb, an approximation of percentage time of exceedance is also calculated and compared to the allowable, and a possible coordination approach is also identified. The analyses and results are preliminary in nature because certain OW-GW characteristics are not available, and the dynamic aspects of OneWeb's Medium-earth orbit (MEO) constellation (which would demonstrate the expected infrequency of interference events and their relatively short duration) have not been fully accounted for at this time. Nonetheless, because conservative worst-case geometries and operating conditions were utilized, the results are useful as bounding analyses to investigate basic spectral compatibilities.

Result Summary

Table 1 summarizes the findings of this compatibility analysis in terms of separation distance between the OneWeb GW and SBCS architectural elements of the EG system for each of the four potential interference paths. Conservative assumptions are made to arrive at bounding distances for this preliminary analysis. These distances represent the separation needed to ensure no harmful interference is possible between the co-primary operations as dictated by static interference protection thresholds, not considering any probabilistic aspects of interference protection criteria. For closer separation distances, in each case, the percent of the OneWeb GW field of regard where interference could occur in either direction is very small and for interference into OneWeb, well below the allowable. Additionally, mitigation approaches exist to permit compatible operations at shorter separation distances when either 1) the interferer negotiates in

[1] WorldVu Satellites Limited Amendment to Petition for Declaratory Ruling Granting Access to the U.S. Market for the OneWeb V-Band System, File No. SAT-AMD-20180104-00004 (Jan. 4, 2018) (Amendment).
[2] Petition for Rulemaking of Elefante Group, Inc., RM-11809 (May 31, 2018) (Elefante Petition)

coordination with the victim to prevent harmful interference or 2) the victim chooses on its own to mitigate its received interference.

Table 1: Summary of results in terms of conservative minimum separation distance to fully meet I/N Protection Criterion

Interferer	Victim	Band	OneWeb GW Separation Distance for No Interference
OW-GW	STRAPS	81-86 GHz	64 km from STRAPS service area center
SBCS-GW	OneWeb NGSO	81-86 GHz	36 km from SBCS-GW
OneWeb NGSO	SBCS-GW	71-76 GHz	93 km from SBCS-GW
STRAPS	OW-GW	71-76 GHz	12.5 km from SBCS-GW

The effects of the OneWeb GW proposed uplink in 71-76 GHz band[3] are not considered, as the minimum elevation angles of the OneWeb GW transmitter and SBCS GW receiver (nominally 20 and 45 degrees respectively) present substantial spatial isolation and required separation will be negligible compared to the other interference paths. If SBCS also utilizes 71-76 GHz for uplink, the interference results will be essentially the same as the results for the 81-86 GHz uplinks. Where SBCS uses the 71-76 GHz Band for uplinks, and OneWeb uses its downlinks, the minimum elevation angles described above in the main text should ensure that the gateway receivers will be sufficiently isolated from SBCS-GW sidelobes to allow much smaller separation distances than in the same-direction scenarios.

SBCS Performance Characteristics

Reference SBCS feeder link performance characteristics are documented in Appendix A of the Elefante Petition [4] and summarized below:

[3] Amendment, Legal Narrative at 14.
[4] Elefante Petition, Appendix A.

Table 2: SBCS System Feeder Link Characteristics

Item	Units	System Design	
Category		Gateway	STRAPS
TX Band	GHz	81-86	71-76
RX Band	GHz	71-76	81-86
Bandwidth	MHz	5000	5000
Aperture Diameter	m	1	0.5
Boresight Gain	dBi	56.4	50.4
3dB Beamwidth	deg	0.22	0.44
Pattern		ITU-R F.1245	ITU-R F.1245
Polarization		RHCP/LHCP	RHCP/LHCP
Clear sky EIRP spectral density	dB(W/MHz)	5	-10.7
Hardware Max EIRP spectral density	dB(W/MHz)	24	14.3
Power control		Yes	Yes
Max Elevation Angle	deg	90	90
Min Elevation Angle	deg	45	45
Height above ground	m	10 typical	HAA
Receiver Noise Density	dB(W/MHz)	-136.4	-136.4
Protection Criteria (I/N)	dB	-6	-6

OneWeb Performance Characteristics

Table 3 presents performance characteristics of the OneWeb system used for these compatibility analyses. Most of the data were derived from the Schedule S Tech Report in the Amendment. Data from OneWeb are highlighted in blue in the table. Because some of the data necessary for analysis was not available, including some OW-GW characteristics, conservative assumptions were made, as highlighted in green in the table. The I/N protection criteria for all OneWeb links is assumed to be -12.2 dB with a 20% allowable exceedance time based on Recommendation ITU-R S.1432 and ITU WP4A liaison statement.[5]

[5] I/N of 6% of the satellite total system noise, equivalent to -12.2 dB (as calculated from G/T) is specified within Recommendation ITU-R S.1432 for FSS links below 30 GHz, and used here because criteria for the E-Band are not yet established. This value, however, is being considered by Working Party 4A and suggested and suggested -10.5 dB for $I/N_{thermal}$ in their July 23, 2018 liaison statement to Task Group 5/1 as protection criteria for FSS from IMT in the band considered under WRC-19 agenda item 1.13 (see https://www.itu.int/md/R15-TG5.1-C-0411/en). We note $I/N_{thermal}$ of -10.5 dB (for a given station which converts to $I/N_{Total\ System}$ of -12.2 dB, see https://www.itu.int/md/R15-WP4A-C-0659/en) from the liaison statement specifies this level of protection not be exceeded more than 20% of the time, and substantially higher interference for smaller percent times. For conservatism, these compatibility analyses only consider the lowest 20% threshold.

Table 3: Performance characteristics used for OneWeb compatibility analyses.
Blue = data from Schedule S Tech Appendix to Amendment. Green = data derived or assumed.

Parameter	**Units**	**Links**		
Function		GW UL	GW UL	GW DL
Beam Name		Gateway	Gateway	GTEA, GTEB
Node		UL TX	UL TX	DL
Freq Band	GHz	71-76	81-86	71-76
Bandwidth	MHz	5000.0	5000.0	5000.0
Peak Gain	dBi	61.9	61.9	53.1
Max EIRP Density	dB(W/MHz)	41.9	41.9	36.1
Max EIRP	dBW	78.9	78.9	73.1
Antenna Pattern		ITU-R S.465		
Beam Name		GREA, GREB	GREC, GRED	Gateway
Node		UL RX	UL RX	DL RX
Peak Gain	dBi	54.2	54.2	61.9
G/T	dB/K	26.4	26.4	37.33
System Noise Temp	K	602.6	602.6	288.40315
Noise density	dB(W/MHz)	-140.8	-140.8	-144
Antenna Ref Temp	K	290.0	290.0	0.0
Noise figure	dB	3.2	3.2	3
Antenna Pattern		ITU-R S.672		

The assumed OW-GW characteristics are conservatively derived as described below:

- Antenna Peak Gain: Based on the following description in the Amendment: "The gateway earth stations will typically utilize 2.4 m to 4.5 m antennas, depending on their location and the associated propagation characteristics and service requirements".[6] Antenna Peak Gain is calculated based on 2.4 m since this design will include the widest beam width and thus be most geometrically susceptible to the beam to beam alignments leading to interference. Since the documented MEO receive beams (GREA, GREB, GREC, GRED) are assumed to have the same gain in both the 71-76 and 81-86 GHz band, the gateway gain is treated the same for both frequency bands as well.
- Antenna Pattern: The ITU provides two references for modeling FSS Earth Station patterns for compatibility analyses, ITU-R S.465 and ITU-R S.1855, both of which are specified for 2-31 GHz. Lacking guidance for 71-76 GHz and since main lobe performance is the primary driver for these compatibility analyses, the ITU-R S.465 pattern was extrapolated to this band.
- Max EIRP: The gateway earth station transmitters are conservatively assumed to use 50W TWTAs without any output back off.
- G/T: The gateway G/T is calculated based on a conservatively assumed 3 dB noise figure.

OneWeb MEO satellites at 8,500 km nominal altitude and, as diagrammed for the specific interference cases, are examined with respect to the worst-case geometry for interference.

[6] Amendment, Attachment A, Technical Information to Supplement Schedule S, pg 4.

The OneWeb system uses dual polarization in a beam whereas EG proposes alternating polarization of channels within a beam (half the spectrum using one pole and half the other), however full spectrum overlap is conservatively assumed for the purposes of these analyses. Additionally, especially conservative at these frequencies, no atmospheric propagation loss is considered to avoid making assumptions regarding acceptable system availability.

Representative antenna patterns for each of the four RF nodes are pictured in Figure 1 and Figure 2. Note that ITU-R S.465 applied to OW-GW results in a peak gain cap out to 1 degree then roll-off and will produce conservative interference results.

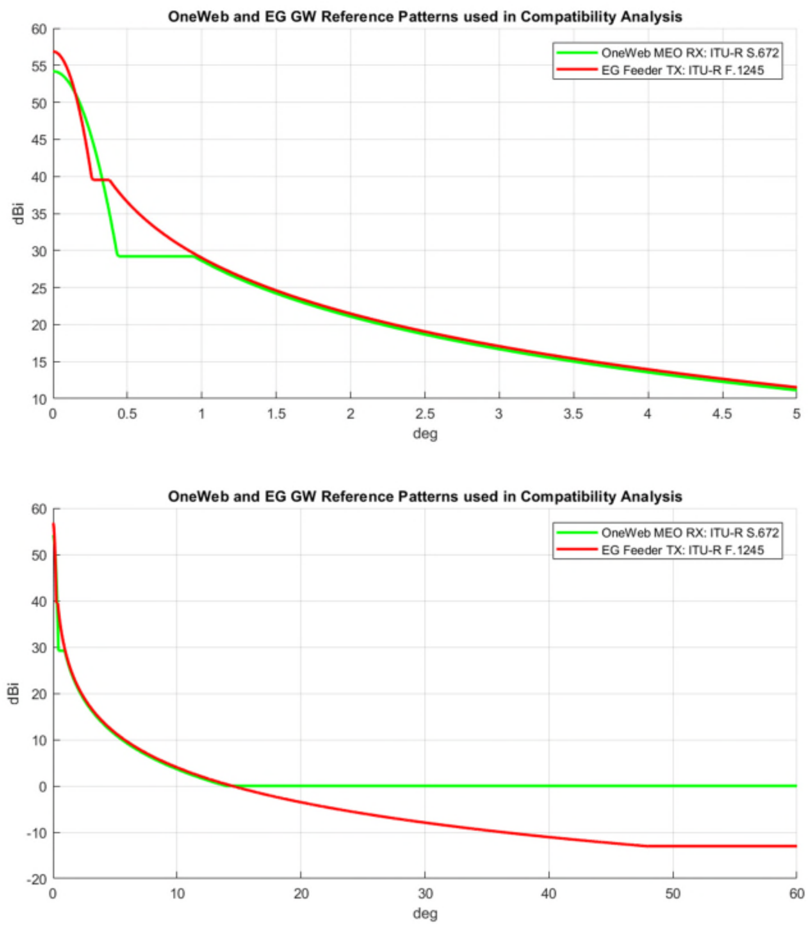
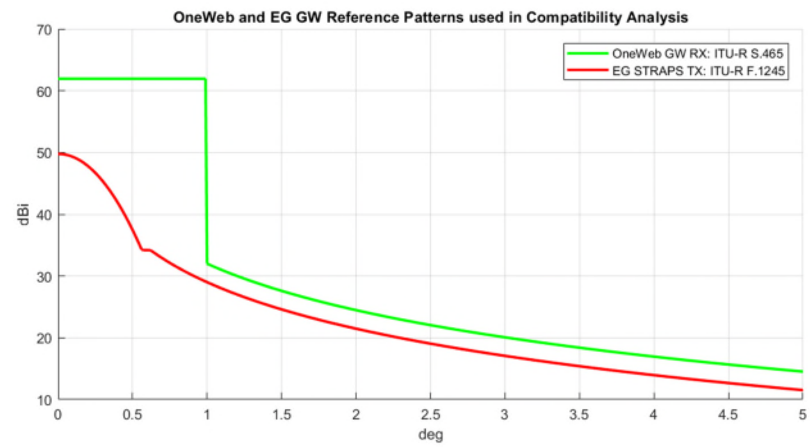


Figure 1: OneWeb MEO antenna patterns used in compatibility analyses.
Lower figure shows pattern roll-off out to 60 degrees, upper focus on 5 degrees off-boresight.



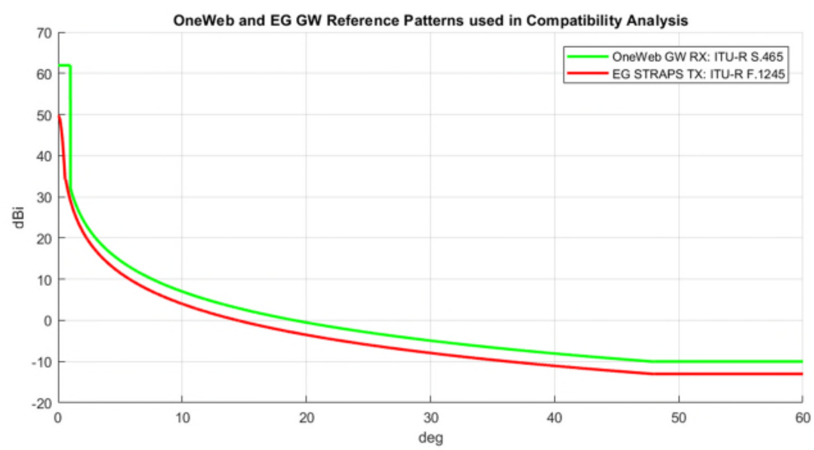


Figure 2: OneWeb Gateway antenna patterns used in compatibility analyses.
Lower figure shows pattern roll-off out to 60 degrees, upper focus on 5 degrees off-boresight.

Methodology

For each of the four interference paths, the worst-case geometric alignment is determined to arrive at the worst-case range and off-boresight angles the interfering transmitter and victim receiver present to each other. This geometry is then parameterized, so each term can be expressed as a function of separation distance. For each distance considered, the interference-to-noise margin (I/N) is determined as follows and compared to the I/N threshold for harmful interference for that victim.

I/N = Transmitter EIRP density – Transmitter Gain Roll-off from Peak – Free Space Loss + Receiver Peak Gain – Receiver Gain Roll-off from Peak – Receiver Noise Density

OneWeb Gateway Uplink Interference into SBCS STRAPS Gateway Uplink (81-86 GHz)

Figure 3 illustrates the geometry for this interference path. In the worst-case geometry, the OW-GW and SBCS-GWs are collocated, and the OW-GW attempts to transmit to an NGSO located directly behind the STRAPS. As separation distance, d, increases, the angle, theta, that the STRAPS receiver, aimed at the SBCS-GW, presents off-boresight to the OW-GW increases with consequent gain roll-off, reducing interference. When the SBCS-GW is at its nominal minimum elevation of 45 degrees, the distance required to achieve the same theta angle is at a maximum.

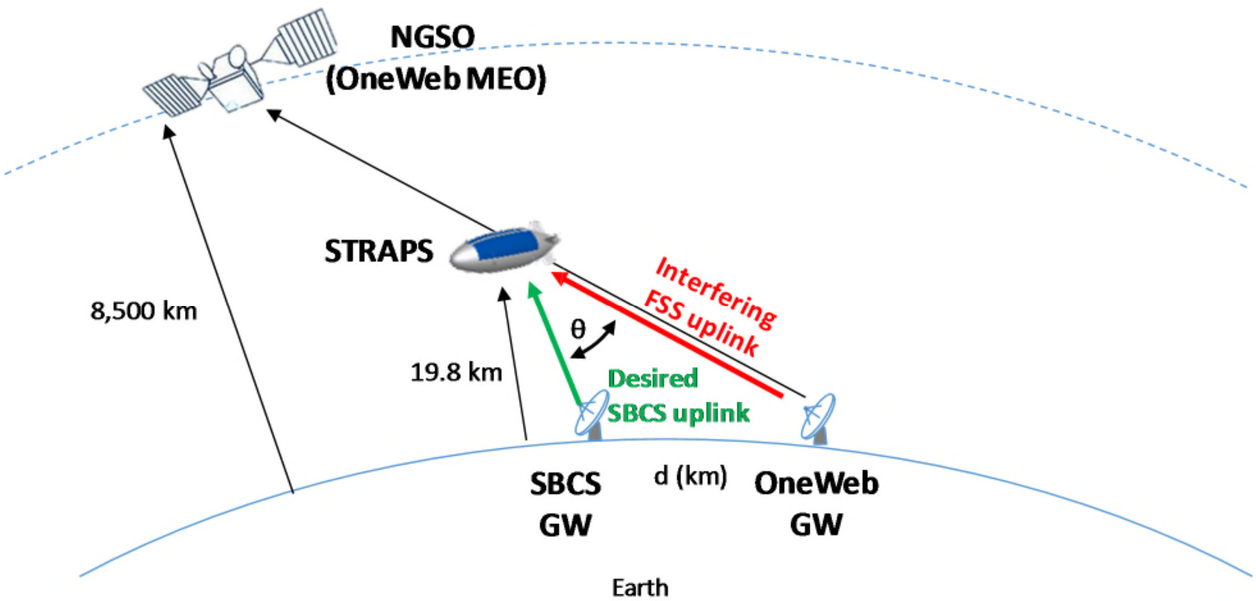


Figure 3: Geometry for OneWeb gateway uplink interference into STRAPS gateway uplink (not to scale).

Figure 4 illustrates the calculated I/N ratio for this geometry as a function of separation distance. For this analysis geometry, the -6 dB I/N threshold for SBCS links between STRAPS and feeder terminals is entirely satisfied outside a 37 km separation, which corresponds to the distance from the SBCS-GW at which the OW-GW sees the STRAPS at 20 degrees elevation. When the STRAPS is below the minimum elevation of the OneWeb GW, the EIRP presented falls off rapidly. When the OW-GW is above the minimum elevation angle and can therefore present its boresight to the STRAPS, the projected EIRP overwhelms even the assumed -12 dBi back lobes of the STRAPS receive antenna, exceeding the interference threshold regardless of incoming angle.

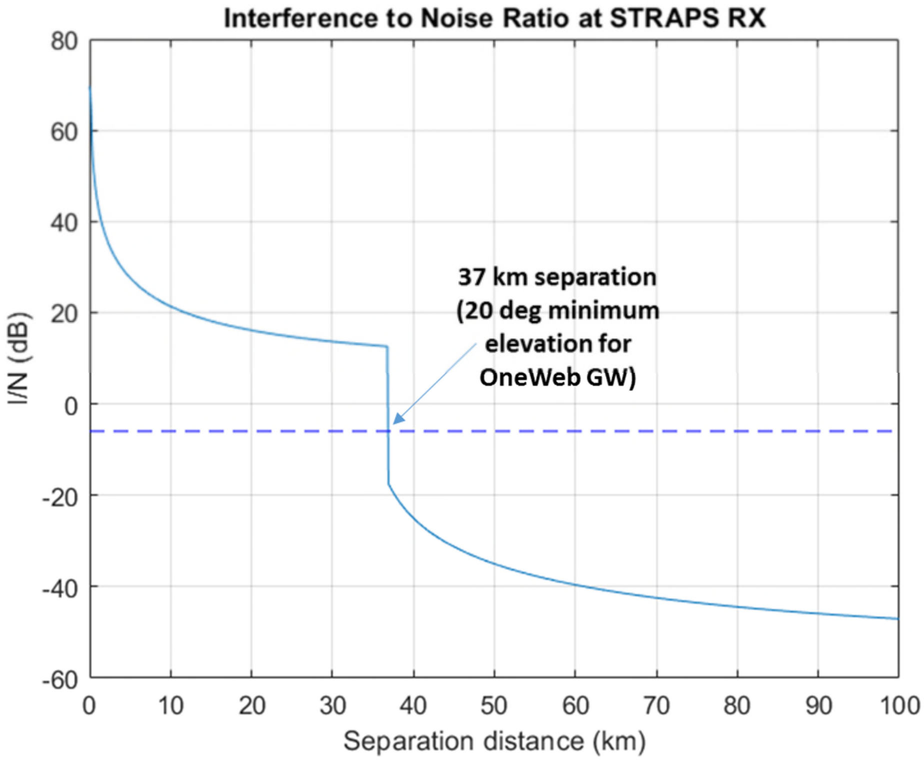


Figure 4: Comparison of I/N to -6 dB interference threshold 37 km separation, and ultimately 64 km separation from the center of the STRAPS service area necessary to fully mitigate interference

Noting, therefore, that the pointing direction of the STRAPS receiver is irrelevant when interference is experienced through the back lobe, this limit is tied to the position of the STRAPS independent of the position of the SBCS-GW. Although the STRAPS in the above analysis is 20 km further away from the OW-GW than the SBCS-GW is, and the STRAPS can operate up to 10 km away from the center of the STRAPS service area, the actual separation criteria for 100% protection of the STRAPS receiver should be with respect to distance from the STRAPS, not the SBCS-GW. The distance from the center of the service area that a 20 deg elevation transmitter boresight could aim directly at a STRAPS located 10 km from the center of the STRAPS service area in the direction of the OneWeb GW is 64 km, as illustrated in Figure 5.

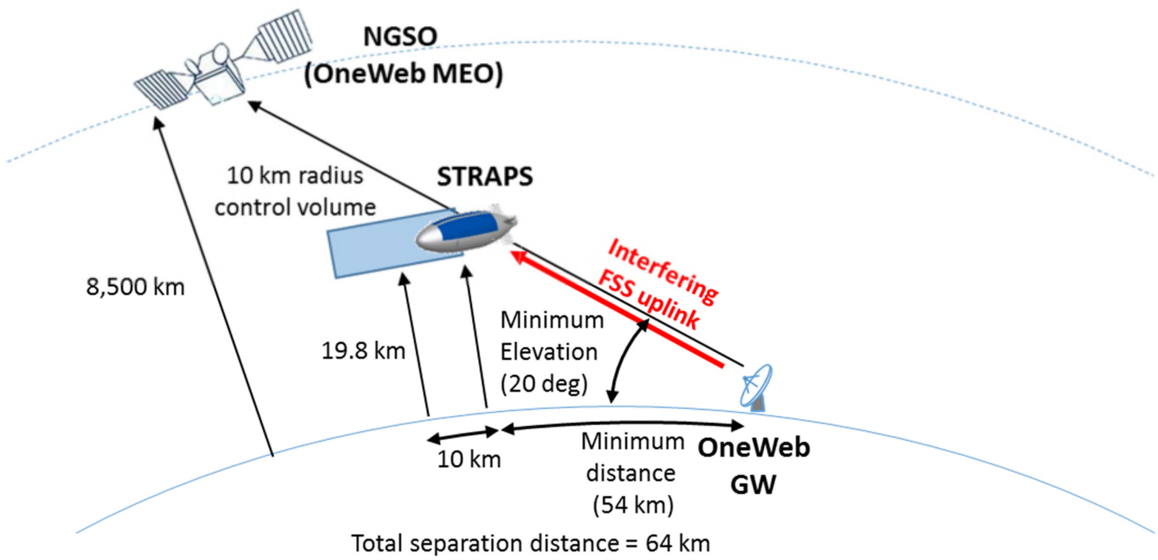


Figure 5: Interference from OneWeb GW into STRAPS receiver back lobe requires STRAPS to appear below the minimum 20 degrees elevation of the OneWeb GW to prevent direct illumination. This is accomplished with a 64 km separation.

Note that the exceedance of the threshold within this distance is dependent on the conservative estimation of the OW-GW transmit EIRP density with no back off assumed for the TWTA and it's likely that output power would be backed off for more linear operation in which case the separation distance would be reduced. Additionally, coordination of links, if operation is necessary at a shorter separation distance, could be accomplished through mitigations, such as applying an elevation mask to prevent aiming the OW-GW transmitter directly at the control volume of the STRAPS (the 10 km radius, +/- 1.5 km height cylinder centered on its nominal station within which the STRAPS will operate) or coordinating to not point within some small angle of towards the STRAPS based on the available STRAPS coordinates.

SBCS STRAPS Gateway Uplink Interference into OneWeb Gateway Uplink (81-86 GHz)

Figure 6 illustrates the geometry for this interference path. In the worst-case geometry, the OneWeb and SBCS-GWs are collocated, and the OW-GW attempts to transmit to an NGSO located directly behind the STRAPS. As separation distance, d, increases, the angle, theta, that the OneWeb MEO receiver presents off-boresight to the SBCS-GW increases with consequent gain roll-off, reducing interference. When the SBCS-GW is at its minimum elevation of 45 degrees, the distance required to achieve the same theta angle is at a maximum.

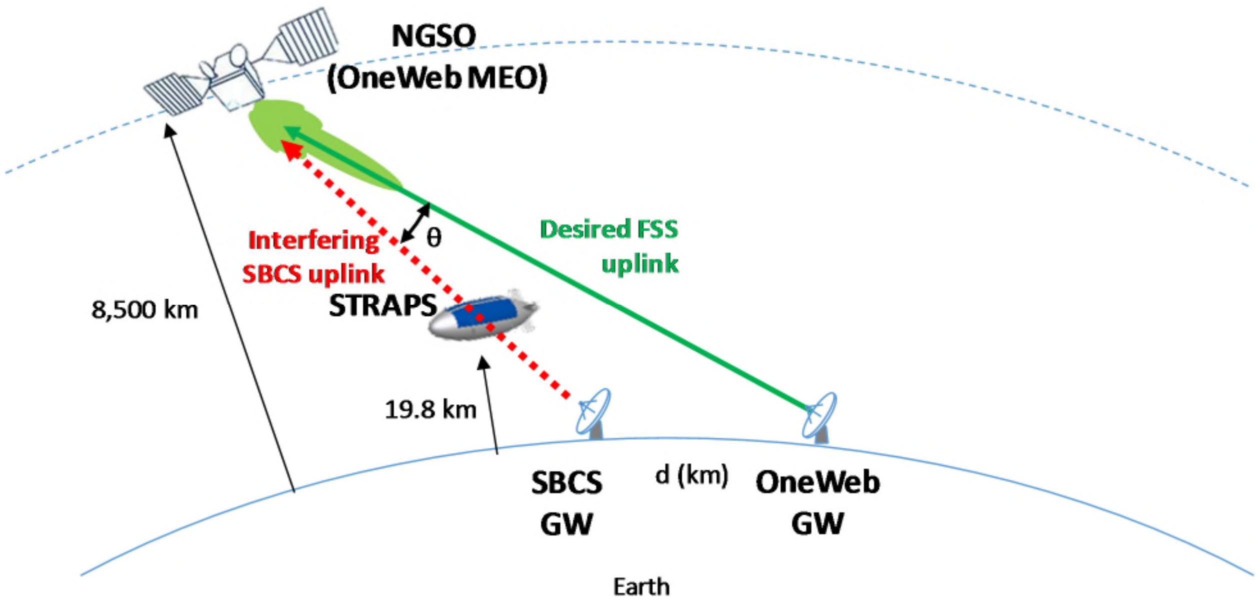


Figure 6: Geometry for STRAPS gateway uplink interference into OneWeb gateway uplink (not to scale).

Figure 7 illustrates the calculated I/N ratio for this geometry as a function of separation distance. The -12.2 dB I/N threshold is entirely satisfied outside a 36 km separation.

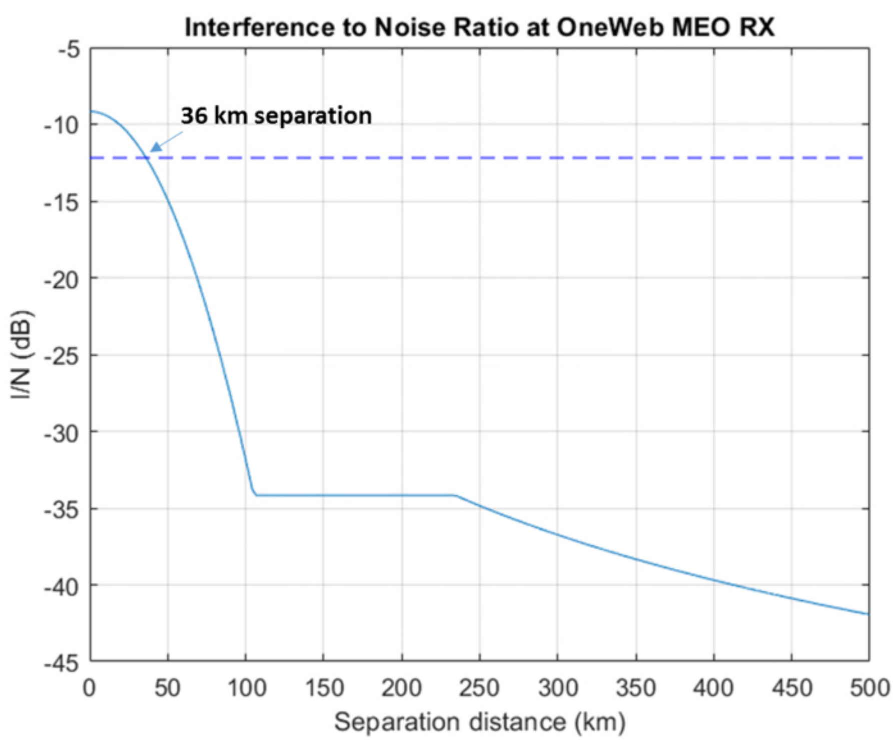


Figure 7: Comparison of I/N to -12.2 dB interference threshold indicates 36 km separation from SBCS-GW is necessary to fully mitigate interference

The maximum I/N exceedance is 3 dB with the OW-GW and SBCS-GW collocated. Thus, the threshold is recovered when the NGSO is seen at 0.11 deg off the boresight of the SBCS-GW beam, and represents only 0.0003 of 1% of the OW-GW field of regard (meaning, the full sky above 20 degrees elevation angle), well below the 20% minimum allowable.

OneWeb Gateway Downlink Interference into SBCS STRAPS Gateway Downlink (71-76 GHz)

Figure 8 illustrates the geometry for this interference path. In the worst-case geometry, the OneWeb and SBCS-GWs are collocated, and the NGSO attempts to transmit to an OW-GW located directly behind the STRAPS. As separation distance d increases, the angle θ_1 that the NGSO presents off-boresight to the SBCS-GW and the angle θ_2 that the SBCS-GW presents off-boresight to the NGSO increase, with consequent gain roll-offs, reducing interference. When the SBCS-GW is at its minimum elevation of 45 degrees, the distance required to achieve the same theta angles is at a maximum.

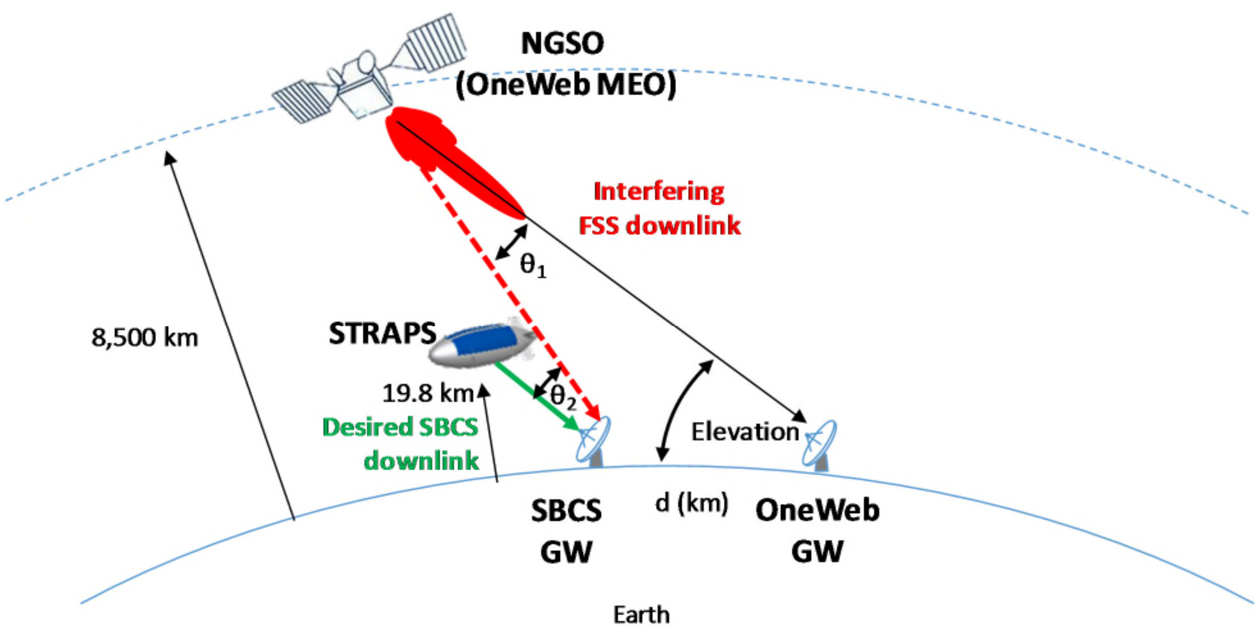


Figure 8: Geometry for OneWeb gateway downlink interference into STRAPS gateway downlink (not to scale).

In this case, one can anticipate that although the transmit beam rolls off rapidly with angle, spreading across the distance from MEO altitude will create a footprint on the ground centered on the OW-GW in which a victim receiver aiming close enough to the NGSO will receive interference. The degree of interference will depend on how closely aligned are the OW-GW and SBCS-GW apertures in elevation and azimuth angles.

Figure 9 illustrates the calculated I/N ratio for this geometry as a function of separation distance between the OW-GW and SBCS-GW. When the OW-GW and SBCS-GW are aligned in the same azimuth and elevation direction (assuming there is a corresponding OneWeb NGSO transmitting to its GW), interference can significantly exceed the -6 dB I/N threshold if the two are collocated, but a 0.5 degree difference in pointing directions between the two is sufficient to prevent harmful interference. The greater the separation distance, the lower the exceedance without a difference in angles, and the smaller the range of elevation angles over which interference can occur. This range tapers sufficiently to prevent all possible interference beyond 93 km separation.

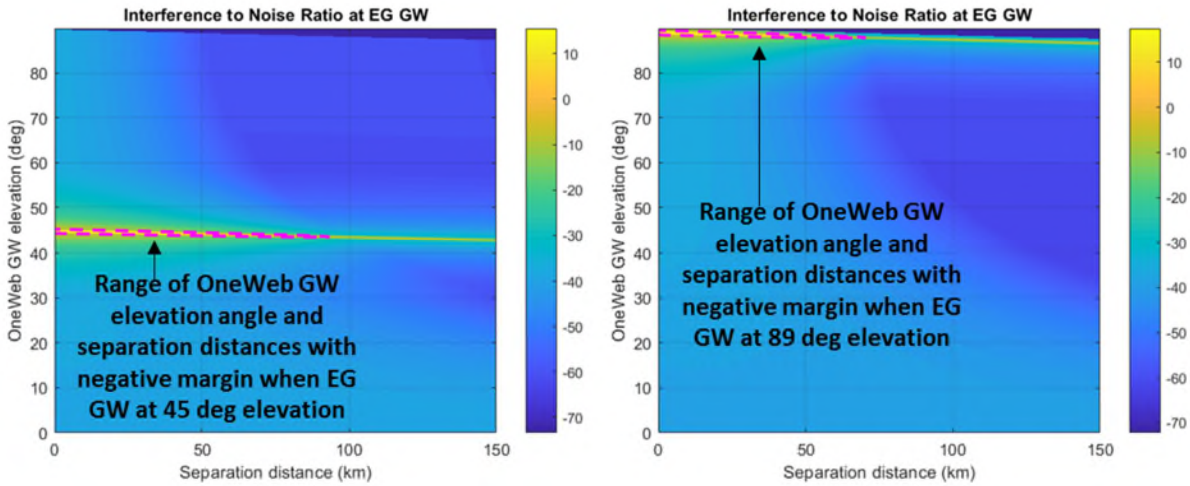


Figure 9: Comparison of I/N to -6 dB interference threshold (dotted magenta contour) indicates close alignment required. When SBCS-GW operates at minimum 45 deg elevation, OW-GW must be separated 93 km if pointed at same azimuth direction. At 89 deg elevation, minimum separation is 72 km.

Note that the likelihood of interference at shorter separations for a single MEO satellite is still small since there are there will be between 10-20 gateways per STRAPS in almost all cases, each of which could be interfered with over only 0.006% of the solid angle within the OW-GW field of regard. However, cumulative probability with thousands of satellites over days of passes is high therefore in case the OW-GW and SBCS-GW need to be located closely, further coordination may be required. One possible mitigation technique is for WorldVu to utilize the registered SBCS-GW location and STRAPS coordinates to predict the instances of time when such geometric alignments may occur to mitigate interference similar to OneWeb's plan to mitigate interference from its FSS NGSO links into FSS GSO links[7].

SBCS STRAPS Gateway Downlink Interference into OneWeb Gateway Downlink (71-76 GHz)

Figure 10 illustrates the geometry for this interference path. In the worst-case geometry, the OW and SBCS-GWs are collocated, and the NGSO attempts to transmit to an OW-GW located directly behind the STRAPS. As separation distance, d, increases, the angle, θ, that the STRAPS presents off-boresight to the OW-GW increases, with consequent gain roll-off reducing interference. When the SBCS-GW is at its minimum elevation of 45 degrees, the distance required to achieve the same theta angles is at a maximum.

[7] As noted in the OneWeb Amendment Technical Narrative pg 31, referencing the requirement in ITU Radio Regulation 22.2

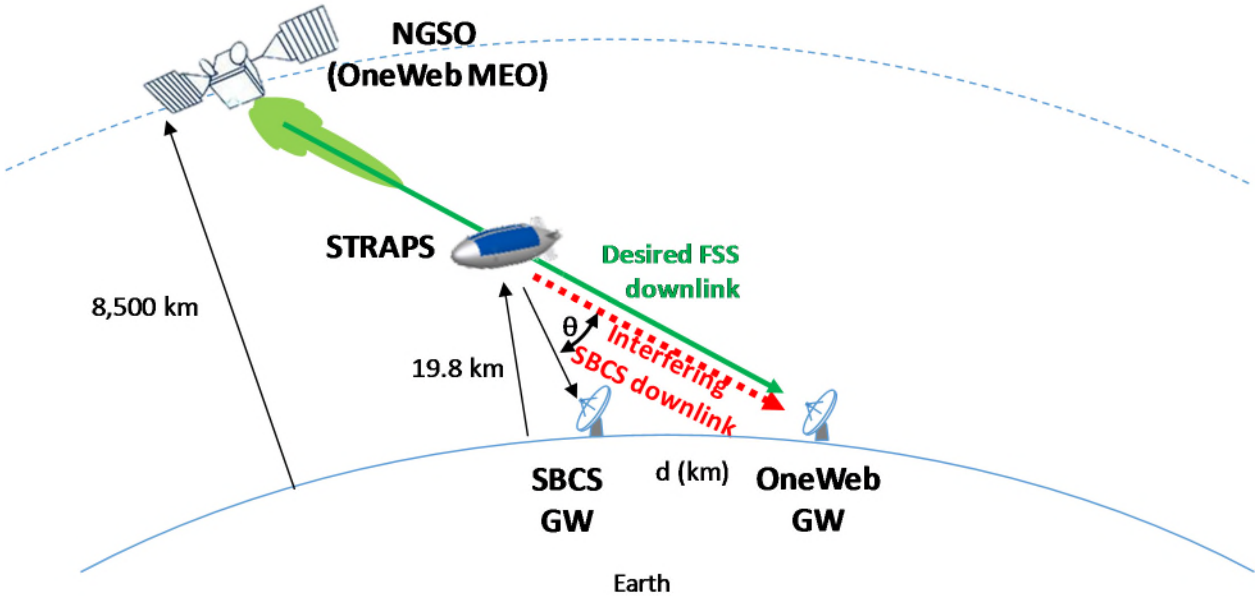


Figure 10: Geometry for STRAPS gateway downlink interference into OneWeb gateway downlink (not to scale).

In this case one can anticipate that the transmit beam rolls off rapidly with angle, creating only a small footprint of potential interference on the ground centered on the SBCS-GW in which an OW-GW receiver aiming close enough to the STRAPS will receive harmful interference.

Figure 11 illustrates the calculated I/N ratio for this geometry as a function of separation distance between the SBCS-GW and OW-GW. When the OW-GW and SBCS-GW are aligned in the same azimuth and elevation direction (assuming there is a corresponding OneWeb NGSO transmitting to its GW), significant exceedance of the -12.2 dB I/N threshold can occur if the two are collocated. However, at even a small separation distance of 12.5 km, no exceedance can occur. Likelihood of interference at shorter separations increases, as the angle the OneWeb GW must point off the STRAPS direction increases from 0 at 12.5 km separation to 6.25 degrees when the GWs are collocated. However, when the GWs are collocated, this represents 0.9 of 1% of the OW-GW field of regard (meaning, the full sky above 20 degrees elevation angle), well below the 20% minimum allowable.

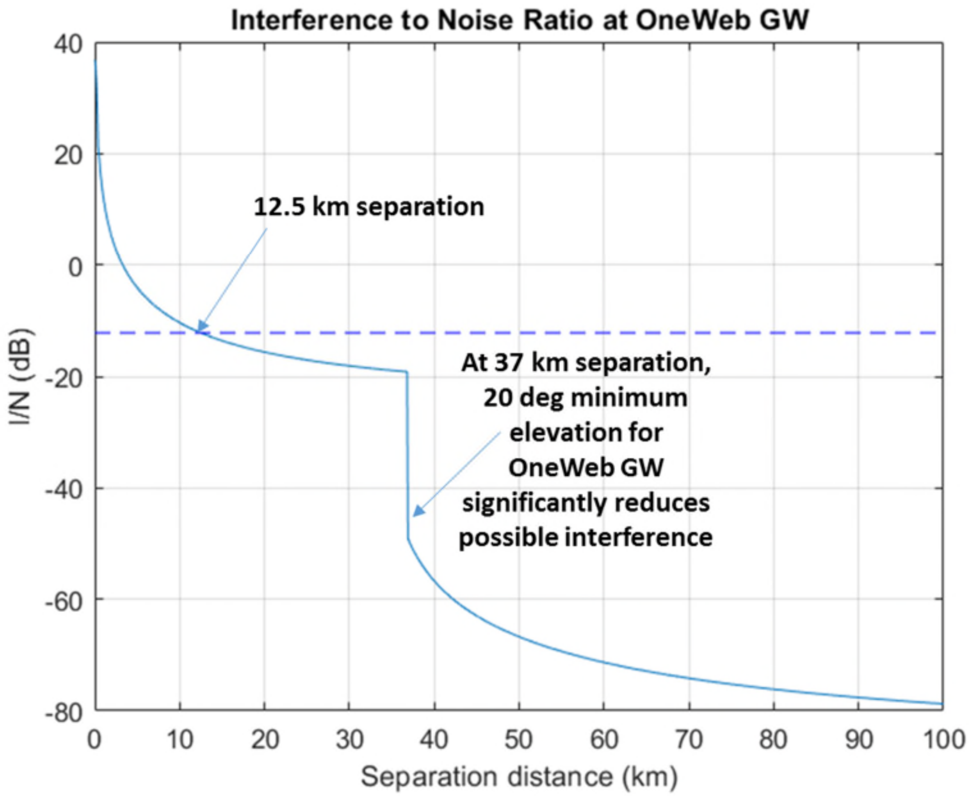


Figure 11: Comparison of I/N to -12.2 dB interference threshold for indicates 12.5km separation necessary to fully mitigate interference

Conclusion

These preliminary compatibility analyses demonstrate that, even with highly conservative assumptions, the bounding cases show likely compatibility between proposed SBCS E-Band feeder uplinks and downlinks and OneWeb gateway links. Even assuming worst-case separation distances, it is expected that interference from the SBCS system into the OneWeb system will meet the Protection Criteria since the percentage time of exceedance is much less than allowable.

For interference from the OneWeb system into the SBCS system, if the small number of OneWeb terminals planned for generally remote locations are located at least 93 km from the center of STRAPS service areas, they present no risk of harmful interference into the SBCS system. At smaller distances, further coordination and possible mitigation techniques as described above could be utilized.

To reiterate, compatibility analyses were conducted purposely using conservative assumptions for the OneWeb gateway performance characteristics not detailed in the MEO constellation license application. More realistic analysis can be conducted to reduce the conservatism when those characteristics are available, with an expected reduction in the separation distances described earlier.

Exhibit 9
Compatibility Analysis:
STRAPS Feeder Downlink Interference into
Radio Astronomy Service Ground Radio Receivers in the
71.0 – 76.0 GHz Band
(Prepared by Lockheed Martin Corporation for Elefante Group, Inc.)

SUMMARY

- Elefante Group is proposing to access the 71.0-76.0 GHz band for Feeder downlink communications from Stratospheric Platform Stations (STRAPS) to Gateway (GW) terminals on a co-Primary basis.

- This study assesses the compatibility of STRAPS Feeder downlinks with Federal Radio Astronomy Service Ground Radio Receivers which are authorized to operate in the 76-81 GHz band adjacent to the STRAPS GW 71-76 GHz downlink band.

- Worst-case operating conditions and interference geometry are utilized which include: 1) STRAPS transmitting at the maximum power level including power control margin, 2) worst-case location and largest quantity of GW terminals, 3) 100m Radio Astronomy Service (RAS) antenna with a minimum 5 deg elevation angle, 4) minimum RAS receiver interference threshold across various Radio Astronomy (RA) observation types, and 5) minimum STRAPS transmit rejection with RAS station observations made at 76 GHz (edge of band).

- Compatibility study results show that operation with a single STRAPS with the RAS station located 40 km from the center of the coverage area, results in less than 0.04% Sky Blockage relative to the 2% Single System Interference Allocation. Multiple STRAPS analysis under highly conservative and extreme theoretical conditions indicates a worst-case possible Sky Blockage of 0.67% relative to the 5% Total Interference Allocation.

- The worst-case evaluation assumes no front-end filtering in the radio telescope and operating conditions indicate significant margin relative to RAS station damage levels.

PURPOSE OF THE STUDY

Elefante Group is proposing to access the 71.0-76.0 GHz band for Stratospheric-Based Communications Services (SBCS) for Feeder downlinks to GWs, operating as a Fixed service. All or part of this band is allocated to Fixed, Fixed Satellite (space-to-earth), Mobile, Mobile Satellite (space-to-earth), Broadcasting, Broadcasting Satellite (space-to-earth), and Space Research (space-to-earth) service, with the adjacent 76-81 GHz band allocated to Radio Astronomy and Space Research (space-to-earth) services.

This study assesses the compatibility with RAS ground receivers in the 76-81 GHz adjacent band of STRAPS feeder downlink transmissions from a multi-beam stratospheric platform to ground-based GWs by determining the potential of such interference to exceed the Interference Threshold and associated percentage Sky Blockage allocation so that mitigation measures, if required, can be implemented to ensure that corresponding percent Sky Blockage protection level is met.

The study also examines the maximum interference power from the STRAPS feeder downlink that may be injected into the RAS Radio Telescope front end at 71-76 GHz compared to the RAS Damage Power Level assuming no rejection on the RAS receive side as described in ITU-RA.2188.

OPERATIONAL CHARACTERISTICS OF RAS GROUND RADIO RECEIVERS

General operational characteristics and Interference Allocation for RAS Ground Radio Receivers utilized in this study are shown in Table 1. Band-specific characteristics for including associated threshold interference levels based on ITU-R RA.314-0 and ITU-R RA 769-2 are shown in Table 2 for Continuum, Spectral Line, and VLBI operations at observation frequencies closest to 71-76 GHz.

Table 1: Case: General RAS Receiver Operational Characteristics and Interference Allocation

Parameter	Value	Notes
RAS Antenna Diameter	100m	Note (1)
RAS Antenna Peak Gain	99.0 dBi	Note (1)
RAS Antenna Pattern	ITU-R SA.509-3	
RAS Minimum elevation angle	5 deg	Assumed worst-case
Single System Interference Allocation	2%	ITU-R RA.1513
Total Interference Allocation	5%	ITU-R RA.1513
RAS Damage Power Level	5 mW assuming typical 25m RA antenna diameter	ITU-RA.2188

(1) Maximum antenna diameter, derived from 24 GHz antenna characteristics in ITU RA.1631, utilized to determine peak antenna gain at E-band.

Table 2: Band-Specific Characteristics and Threshold Interference Level

Observation Type	Frequency Range	Threshold Interference Level
Continuum	76.0-81.0 GHz	-228 dBW/MHz
Spectral Line Deuterated water (HDO) Rest Frequency 80.578 GHz	80.50-80.66 GHz	-209 dBW/MHz
VLBI	86.0 GHz	-173 dBW/MHz

OPERATIONAL CHARACTERISTICS OF SBCS

The SBCS will utilize STRAPS, User Terminals (UTs), and GW terminals to provide fixed services over a specific service area. Transmit characteristics of the Elefante Group STRAPS Feeder downlink utilized in this study are given in Exhibit 1.

For this study, worst-case operating conditions are utilized for a bounding analysis prior to considering, if appropriate, risk-based interference assessment using probability and statistical methods:

1) STRAPS transmitting at the maximum power level including power control margin resulting in the maximum power flux density, occupying the full channel bandwidth adjacent to the closest RAS observation frequency of 76.0 GHz.
2) Maximum quantity of 20 GW terminals located to have the minimum elevation angle towards the STRAPS which results in the highest level of interference into the RAS station.
3) Conservative 100m RAS antenna with a minimum 5 deg elevation angle.
4) Minimum RAS receiver threshold from the available Continuum, Line, and VLBI observation types shown in ITU RA.769-2 for observations made at the closest frequencies to 71-76 GHz. As shown in Table 2, this corresponds to Continuum observations at 76 GHz.
5) Minimum STRAPS transmit rejection of 60 dB assuming STRAPS feeder link operating at the edge of the 71-76 GHz band with nominal guard bands.

STUDY SCENARIO

Figure 1 illustrates the basic interference geometry applicable to this study assuming a single STRAPS and single GW located near a RAS station.

- STRAPS, nominally located at the center of its coverage area, transmits feeder downlink signals to the GW located out to a minimum elevation angle of 45 degrees.
- RAS station is assumed to be positioned in the same azimuth direction as the GW station and makes observations within its 2pi steradian Field of Regard (FOR) with a minimum elevation angle of 5 degrees
- For a given STRAPS and RAS station location, there will be a corresponding Solid Angle of Interference (SAI), “Sky Blockage,” towards the STRAPS over which the RAS Interference Threshold Limit is exceeded.

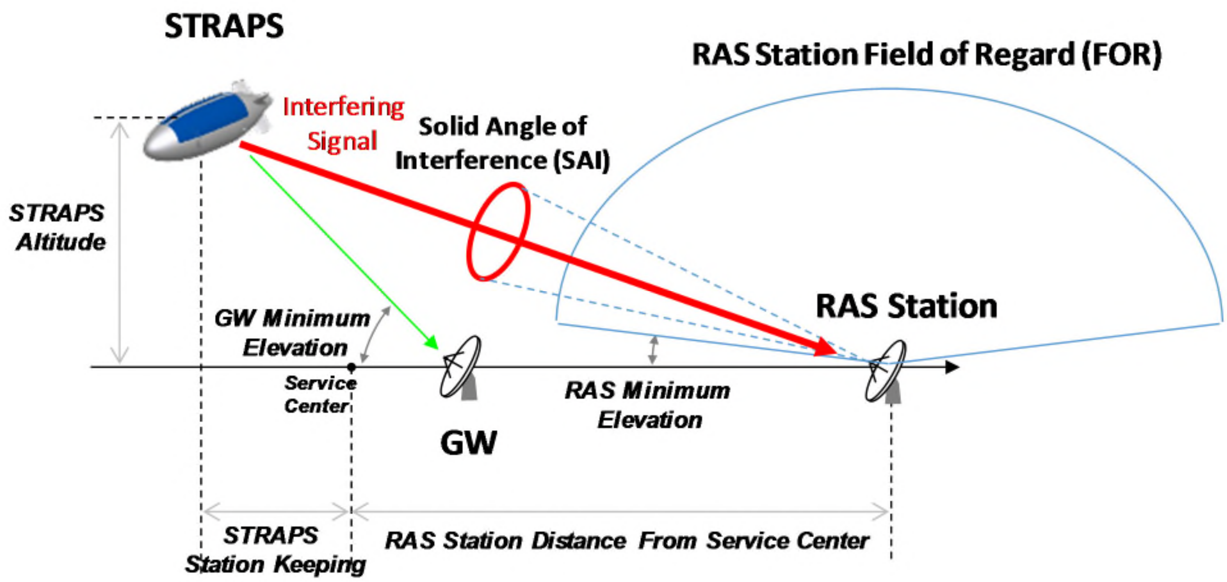


Figure 1: Interference Geometry

STUDY METHODOLOGY: SINGLE STRAPS

The study starts by assuming the STRAPS is transmitting at the maximum EIRP density with a feeder downlink beam pointed at a GW located in the same azimuth direction as the RAS station.

Additional GWs are located around the center of the coverage area, each at the minimum elevation angle of 45 degrees as illustrated in Figure 2 with corresponding maximum EIRP feeder link beams pointed to each of the GWs. (In practice, the STRAPS GWs would not be placed in a circular pattern, all with minimum elevation angles, but disbursed throughout an area 10 km in radius with elevation angles varying from the minimum up to 90 degrees which would decrease the interference level.)

For varying distance of the RAS station from the center of the service area and for each pointing direction of the RAS station, the aggregate interference power density from all GWs is calculated and compared to the Threshold Interference Level.

The resultant negative margin is compared to the peak STRAPS transmit antenna gain to determine the STRAPS off-boresight angle where the Threshold Interference Level would be met.

The calculated STRAPS transmit antenna off-boresight angle is converted to a solid angle assuming symmetric geometry, which represents the Solid Angle of Interference (SAI).

The SAI is compared to the RAS Station FOR to determine the percentage of the FOR over which the Threshold Interference Level is met, “Sky Blockage” which is then compared to Single System Interference Allocation of 2% to determine if the Protection Criteria are met.

The above calculation is repeated for varying levels of out of band rejection provided by the STRAPS at the edge of the RAS frequency band (76 GHz).

Results are compared to 60-70 dB nominal rejection achievable in the STRAPS feeder downlink assuming a nominal guard band of 140 MHz for the top most 450 MHz channel with a band edge at 75.860 GHz.

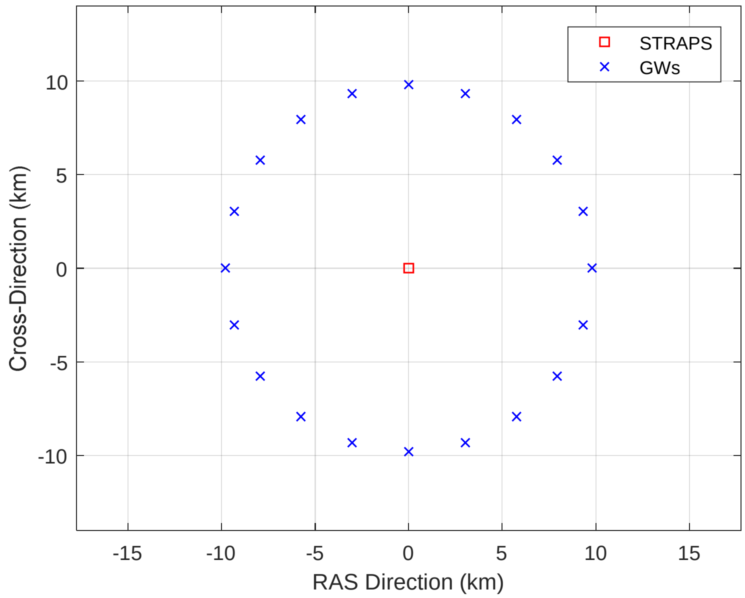


Figure 2: Gateways located around center of coverage area at minimum elevation angle

STUDY RESULTS: SINGLE-STRAPS

Single-STRAPS compatibility analysis was completed, and the percentage of Sky Blockage evaluated under the following worst-case assumptions:

1) STRAPS at minimum altitude of 18.3 km from a possible 18.3-21.3 km range
2) STRAPS transmit rejection of 60 dB from a possible 60-86 dB range
3) Maximum number of 20 GWs from a likely range of 10-20 GWs per service area
4) RAS station located at 40 km away from center of coverage area[1]

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[1] Evaluation of current Federal and Non-Federal RAS stations, not considering associated radio telescope operational frequencies, indicates that RAS stations are generally located away from major urban population centers. Typical distances from RAS stations to urban centers are 120-230 km with Haystack Observatory in Westford, MA located 45 km from Boston, MA and SRI International Antenna Facility in Palo Alto, CA which is within the San Francisco Bay Area. For the purposes of this compatibility study, although results are presented for varying RAS station distances, 40 km distance was considered as a bounding minimum case with the idea that any exceptions are unlikely, and any necessary interference mitigation would be considered on a case-by-case basis.

Results of the compatibility study for the STRAPS located at the nominal center of service area are shown in Figure 3 which indicates that the Sky Blockage would be less than 0.04%. This result is well below the 2% Single System Interference Allocation.

To understand the impact of STRAPS motion during normal station keeping, the compatibility study was repeated with the STRAPS located at the station keeping boundary at 10 km from the center of the coverage area and away from the RAS station, which further decreases the STRAPS off-boresight angle.

Corresponding results are shown in Figure 4. Accounting for normal station keeping motion results in a minor change to the interference performance. Again, the Sky Blockage is less than 0.04% under normal station keeping motion, well below the 2% Single System Interference Allocation.

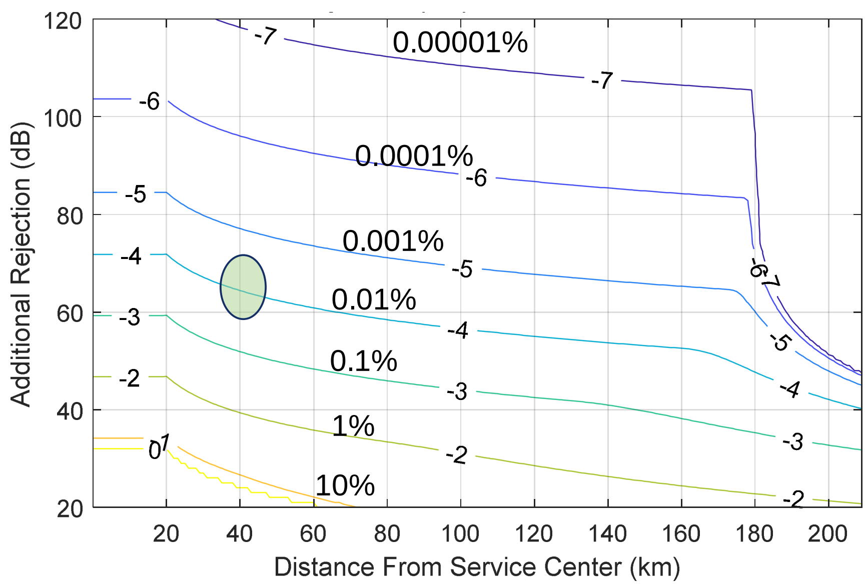

Figure 3: Percent Sky Blockage with Single STRAPS at center of coverage area (Maximum number of Gateways (20) at minimum elevation angle)

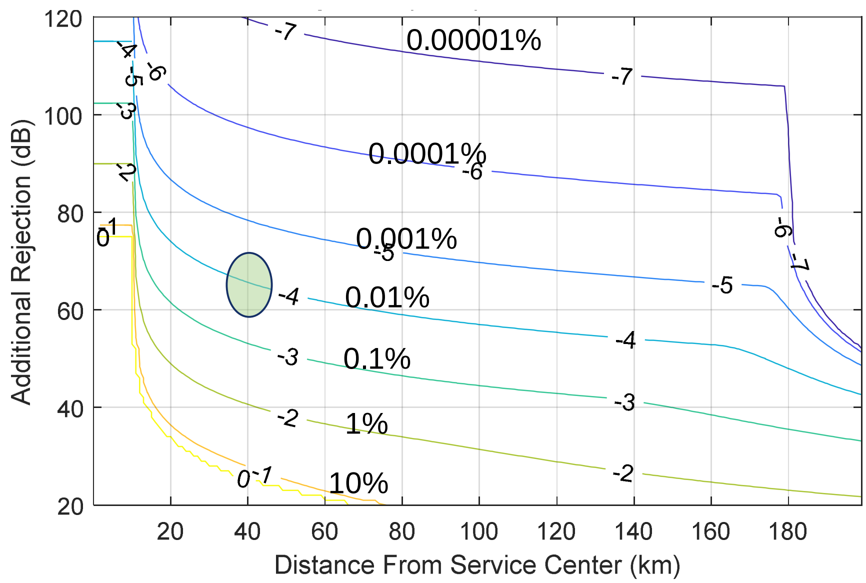

Figure 4: Percent Sky Interference with Single STRAPS at maximum horizontal motion (-10 km) (Maximum number of Gateways (20) at minimum elevation angle)

STUDY METHODOLOGY: MULTIPLE-STRAPS

Considering that a majority of RAS stations are intentionally located away from major urban centers, it is unlikely that more than one STRAPS will be close enough to cause interference into the RAS station. However, in certain instances, it is feasible that a few STRAPS may be positioned to serve large metropolitan areas such as Greater Los Angeles and RAS stations may be deployed in such a large metropolitan area with radio telescopes operating at 76 GHz. In this situation, one STRAPS may be close to the RAS and the others would be further away.

One approach to understand the impact of total interference from multiple STRAPS into the RAS station is to extrapolate the single STRAPS compatibility study results by additive sum of the percent Sky Blockage appropriately adjusted by the STRAPS distance from the service center. Even conservatively using the results from Figure 4, 137 STRAPS would have to be located 40 km away (a physically unrealistic STRAPS deployment scenario) to exceed the 5% Total Interference Allocation which is greater than the maximum number of STRAPS within the RAS FOR as further discussed in the multiple STRAPS study below.

STUDY RESULTS: MULTIPLE-STRAPS

To fully address any concerns regarding cumulative effects of many STRAPS located within the RAS station FOR, worst-case bounding compatibility studies were conducted assuming a grid of STRAPS separated by 40 km as shown in Figure 5. Note that 40 km separation is the closest practical separation between STRAPS as discussed in the Elefante Group Petition for Rulemaking, RM-118089, filed May 31, 2018 (Appendices T and U).

Utilizing the worst-case conditions cited in the Single-STRAPS compatibility study and the maximum 10 km horizontal station keeping motion assumed for the STRAPS closest to the RAS station, the associated bounding case multiple STRAPS compatibility results are shown in Figure 6, indicating a maximum possible Sky Blockage of 0.67%. This result is well below the 5% Total Interference Allocation.

As Figure 6 indicates, although 582 STRAPS are visible (above the horizon), only 72 STRAPS contribute to the cumulative Sky Blockage. The number of STRAPS contributing to Sky Blockage is limited by the RAS station 5-degree minimum elevation angle. It should also be noted that more than 50% of the contribution comes from STRAPS located within 100 km of the RAS station.

Considering that the number of STRAPS visible to the RAS station would increase with higher STRAPS and RAS station altitudes, the corresponding impact on percent Sky Blockage was examined.

As Figure 7 indicates, increasing the STRAPS altitude has a negligible impact on cumulative Sky Blockage even though the number of visible STRAPS increases to 672. Furthermore, as Figure 8 indicates, although an increase in RAS station altitude to 4 km (~13,000 feet representing LBO VLBA telescopes in Mauna Kea) increases the total number of visible STRAPS from 672 in the prior case to 1260 above the horizon, the corresponding number of STRAPS above the 5-degree RAS station minimum elevation angle decreases from 90 to 60. Therefore, the cumulative Sky Blockage drops from 0.66% to 0.59%.

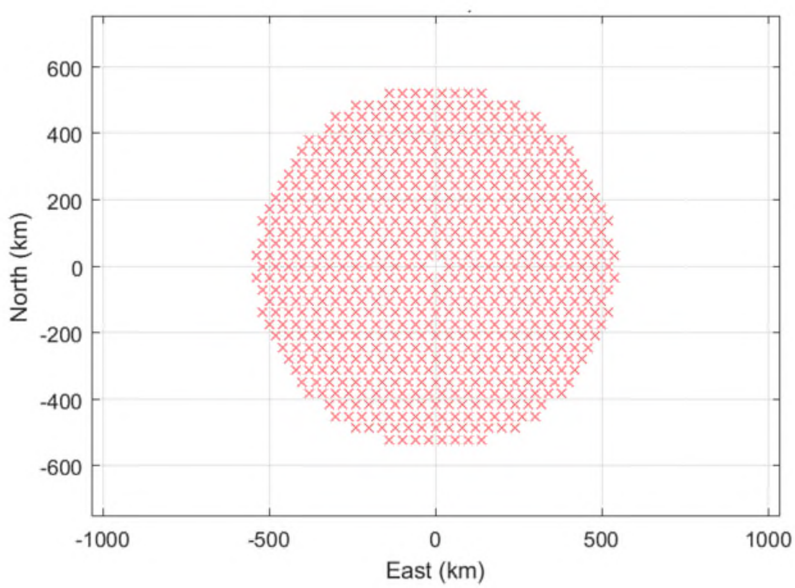

Figure 5: STRAPS constellation using 21.3 km altitude and worst-case 40 km separation 50m RAS altitude

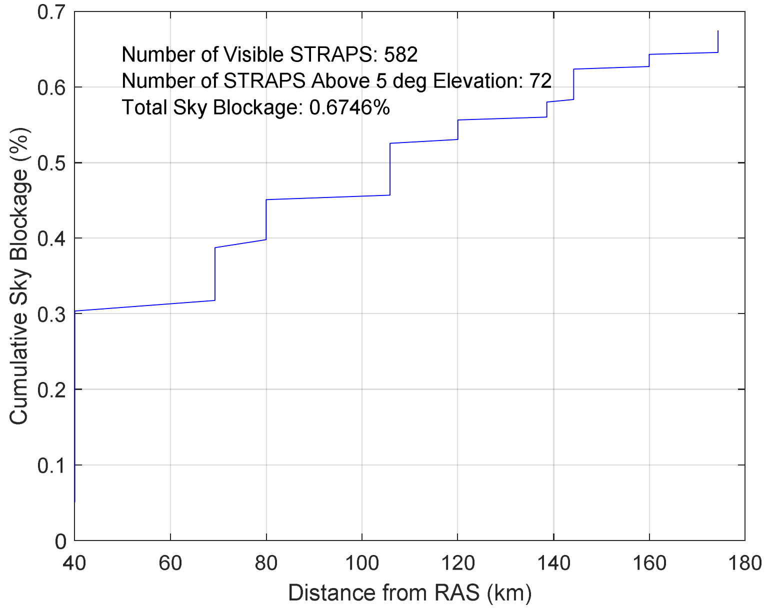

Figure 6: Cumulative Sky Blockage with Multiple STRAPS (STRAPS altitude 18.3 km, RAS altitude ~0km)

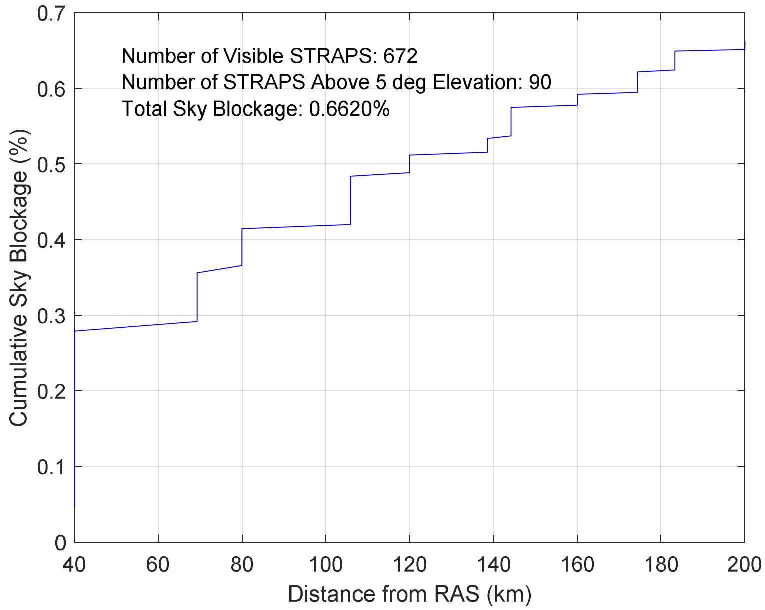

Figure 7: Cumulative Sky Blockage with Multiple STRAPS (STRAPS altitude 21.3 km, RAS altitude ~0km)

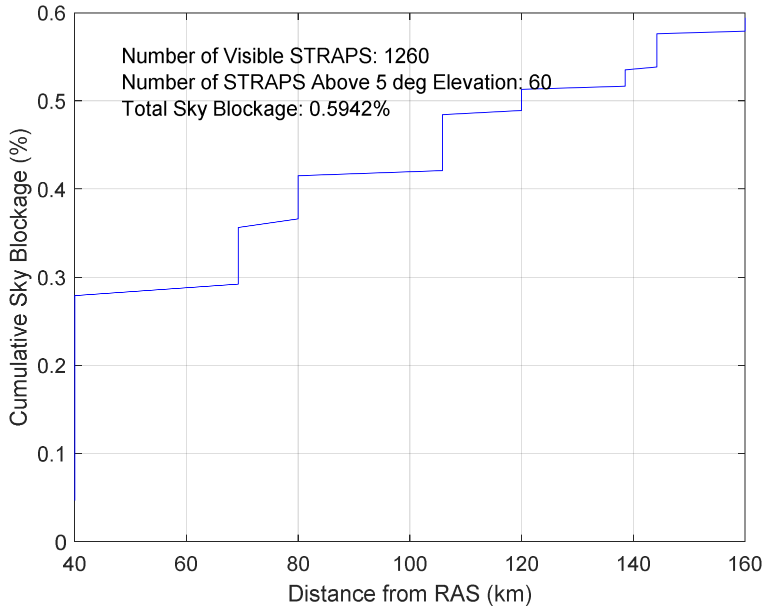

Figure 8: Cumulative Sky Blockage with Multiple STRAPS (STRAPS altitude 21.3 km, RAS altitude 4km)

DAMAGE LEVEL COMPATABILITY STUDY RESULTS

In addition to compatibility analyses related to meeting the RAS Protection Criteria, the worst-case multi-STRAPS scenario as illustrated in Figure 6 with the STRAPS at 18.3 km altitude was used to determine the maximum in-band power received at the RAS station and comparing to the RAS Damage Power Level shown in ITU-R.2188.

The maximum aggregate received power density at the RAS station in the 71-76 GHz was determined to be -95 dBW/MHz. The corresponding received power was calculated by integrating this power density over the 450 MHz feeder link channel bandwidth since any given STRAPS will be transmitting one channel worth of power in a given beam.

The worst-case total in-band interference power is 0.14 microwatts, significantly less than the 5 mW worst-case RAS Damage Level. This seems reasonable since the RAS station is assumed to be located 40 km from the center of the coverage area and the closest feeder beam is pointed towards a GW located 9.8 km from the of the coverage area. In this scenario, there is significant isolation provided by the STRAPS antenna pattern to ensure protection of the RAS station from in-band emissions from the STRAPS.

STRAPS STATION KEEPING MOTION

If Radio Telescope observations require knowledge of the solid angle over which interference may exceed the protection criteria, the variability in the STRAPS location due to horizontal motion and altitude change during normal station keeping needs to be accounted for. Each STRAPS location may be published in near real-time to comply with FAA requirements and could also be made available to the RAS station to account for STRAPS location variation so that any observations can account for shifts in Sky Blockage.

To better assess the effect of STRAPS location variability on the RAS station viewpoint, an analysis was performed assuming STRAPS altitude change of +/- 1.5 km and horizontal motion of +/- 10 km during normal station keeping. The results, as shown in Figure 9, indicate that STRAPS location variability has a minor impact on Sky Blockage even if STRAPS location information is not utilized by the RAS station.

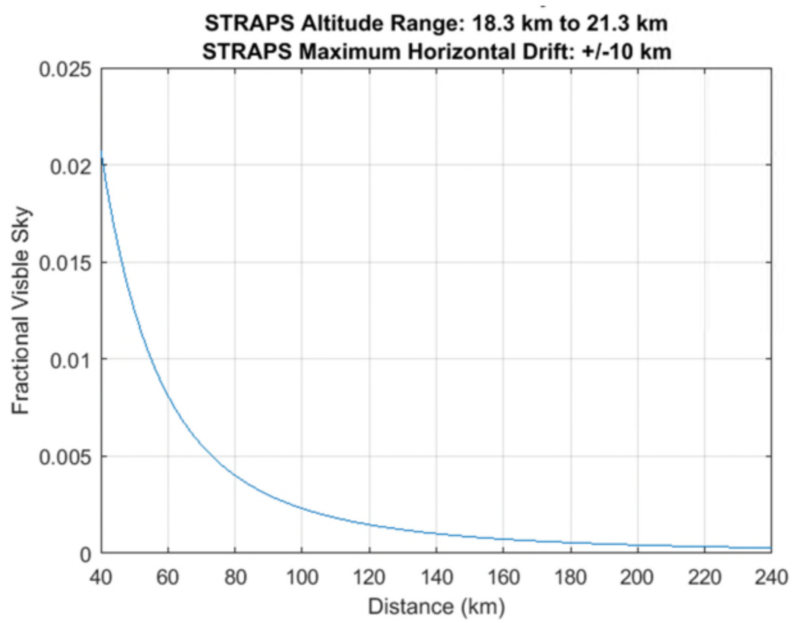

Figure 9: RAS Fractional Sky variability due to STRAPS location variability

CONCLUSIONS

Results from Single STRAPS and Multiple STRAPS analysis scenarios indicate that even under extreme worst-case operational and geometric assumptions, interference from STRAPS 71-76 GHz feeder downlink is below the most stringent RAS protection criteria. Additionally, the in-band power level received at the RAS station is well below damage levels. No additional mitigation is necessary.

It should be noted that these stated results assume nominal transmit filtering and studies have been performed to demonstrate that additional rejection may be achievable which further illustrates the conservatism in the analysis.

REFERENCES:

ITU-R RA.314-0: Preferred frequency bands for radio astronomical measurements

ITU-R SA.509-3: Space research earth station and radio astronomy reference antenna radiation pattern for use in interference calculations, including coordination procedures, for frequencies less than 30 GHz

ITU-R RA 769-2: Protection criteria used for radio astronomical measurements

ITU-R RA.1513: Levels of data loss to radio astronomy observations and percentage-of-time criteria resulting from degradation by interference for frequency bands allocated to the radio astronomy service on a primary basis

ITU RA.1631: Reference radio astronomy antenna pattern to be used for compatibility analyses between non-GSO systems and radio astronomy service stations based on the epfd concept

ITU-R RA.2188: Power flux-density and e.i.r.p. levels potentially damaging to radio astronomy receivers