Before the
FEDERAL COMMUNICATIONS COMMISSION
Washington, DC 20554

In the Matter of	)	
	)	
Use of Spectrum Bands Above 24 GHz For Mobile Radio Services	)	GN Docket No. 14-177
	)	
Establishing a More Flexible Framework to Facilitate Satellite Operations in the 27.5-28.35 GHz and 37.5-40 GHz Bands	)	IB Docket No. 15-256
	)	
Petition for Rulemaking of the Fixed Wireless Communications Coalition to Create Service Rules for the 42-43.5 GHz Band	)	RM-11664
	)	
Amendment of Parts 1, 22, 24, 27, 74, 80, 90, 95, and 101 To Establish Uniform License Renewal, Discontinuance of Operation, and Geographic Partitioning and Spectrum Disaggregation Rules and Policies for Certain Wireless Radio Services	)	WT Docket No. 10-112
	)	
Allocation and Designation of Spectrum for Fixed-Satellite Services in the 37.5-38.5 GHz, 40.5-41.5 GHz and 48.2-50.2 GHz Frequency Bands; Allocation of Spectrum to Upgrade Fixed and Mobile Allocations in the 40.5-42.5 GHz Frequency Band; Allocation of Spectrum in the 46.9-47.0 GHz Frequency Band for Wireless Services; and Allocation of Spectrum in the 37.0-38.0 GHz and 40.0-40.5 GHz for Government Operation	)	IB Docket No. 97-95

REPLY COMMENTS OF STRAIGHT PATH COMMUNICATIONS INC.

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TABLE OF CONTENTS

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In the Matter of Use of Spectrum Bands Above 24 GHz For Mobile Radio Services	)))))	GN Docket No. 14-177
Establishing a More Flexible Framework to Facilitate Satellite Operations in the 27.5-28.35 GHz and 37.5-40 GHz Bands	))))	IB Docket No. 15-256
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REPLY COMMENTS OF STRAIGHT PATH COMMUNICATIONS INC.

Straight Path Communications Inc. ("Straight Path") submits these reply comments in response to the comments of other parties on the Further Notice of Proposed Rulemaking ("*FNPRM*")[1/] in the above-referenced proceedings, in which the Commission seeks comment on

[1/] *Use of Spectrum Bands Above 24 GHz For Mobile Radio Services; Establishing a More Flexible Framework to Facilitate Satellite Operations in the 27.5-28.35 GHz and 37.5-40 GHz Bands; Petition for Rulemaking of the Fixed Wireless Communications Coalition to Create Service Rules for the 42-43.5 GHz* making additional spectrum available for the deployment of fifth generation ("5G") mobile wireless technologies, and refining the rules adopted in the *Report and Order*.[2/]

I. SUMMARY AND INTRODUCTION

Straight Path congratulates the Commission for continuing to ensure that the United States maintains its leadership position in the deployment of terrestrial wireless services. The *Report and Order* provided additional flexibility for bands previously dedicated for fixed wireless services and dedicated additional spectrum for 5G operations. The *FNPRM* would potentially make even more spectrum available and would further address certain rules already adopted that would govern the millimeter wave bands.

Some of the comments submitted in response to the *FNPRM* continue to exhibit a troubling trend. That is, instead of considering how to best promote mobile terrestrial broadband services, they propose alternatives that will only impede the introduction of those services. Most problematic is the attempt by satellite industry participants to potentially derail the Commission's good work by proposing rules that would unnecessarily require shared use of mobile wireless terrestrial spectrum. While the Commission must ensure that there is sufficient spectrum for satellite providers to offer the services for which satellite service is appropriate, it must critically evaluate the most efficient way that mobile broadband services can be provided and reject requests to use precious spectrum resources to meet those needs in an inefficient

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Band; Petition for Rulemaking of the Fixed Wireless Communications Coalition to Create Service Rules for the 42-43.5 GHz Band; Allocation and Designation of Spectrum for Fixed-Satellite Services in the 37.5-38.5 GHz, 40.5-41.5 GHz and 48.2-50.2 GHz Frequency Bands; Allocation of Spectrum to Upgrade Fixed and Mobile Allocations in the 40.5-42.5 GHz Frequency Band; Allocation of Spectrum in the 46.9-47.0 GHz Frequency Band for Wireless Services; and Allocation of Spectrum in the 37.0- 38.0 GHz and 40.0-40.5 GHz for Government Operations, Report and Order and Further Notice of Proposed Rulemaking, FCC 16-89 (rel. July 14, 2016) (subparts referred to respectively as the "*Report and Order*" and the "*FNPRM*").

[2/] *Id*.

manner. Accordingly, as Straight Path demonstrates below, no additional spectrum capacity should be dedicated for satellite broadband service. Similarly, the Commission should reject attempts to allow further use, by satellite services, of bands that will be shared with terrestrial operations. The attempts to create more intense use of the spectrum by satellite providers will threaten the provision of mobile terrestrial services, which is contrary to the public interest.

Just as sharing with satellite services will potentially decrease the utility of spectrum for terrestrial operations, so too will use-it-or-share-it rules that will create uncertainty regarding, and thereby depress investment in, licensed terrestrial services. Straight Path also agrees with other commenting parties who suggest the Commission make more of the Local Multipoint Distribution Service ("LMDS") spectrum available for mobile wireless terrestrial use. Finally, Straight Path encourages the Commission to adopt in-band spectrum aggregation limits.

II. NO ADDITIONAL SPECTRUM CAPACITY SHOULD BE DEDICATED FOR SATELLITE BROADBAND

Several commenters assert that additional spectrum should be allocated to satellite broadband service to meet the needs of those people in rural areas that lack broadband access.[3/] However, providing additional spectrum for satellite service will not address this perceived need. *First*, most of the existing rural broadband access connections are not provided by satellite. Despite the fact that satellite communication has existed for more than five decades,[4/] it has failed to play a major role in providing broadband connection to the American public in general and to consumers in rural areas. Over the past three decades, while both the terrestrial wireless

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[3/] *See*, *e.g.*, Comments of the Boeing Company, GN Docket No. 14-177, *et al.*, at 7-17 (filed Sept. 30, 2016) ("Boeing Comments"); Comments of the Satellite Industry Association, GN Docket No. 14-177, *et al.*, at 5-7 (filed Sept. 30, 2016).

[4/] *See* David J. Whalen, "Communication Satellites: Making the Global Village Possible," Nat'l Aeronautics and Space Administration History Division, *available at* http://history.nasa.gov/satcomhistory.html.

industry and satellite industry have been providing broadband access to the public, wireless terrestrial broadband has achieved market success, providing more than 375 million mobile broadband connections in the United States, while satellite serves approximately two million people.[5/]

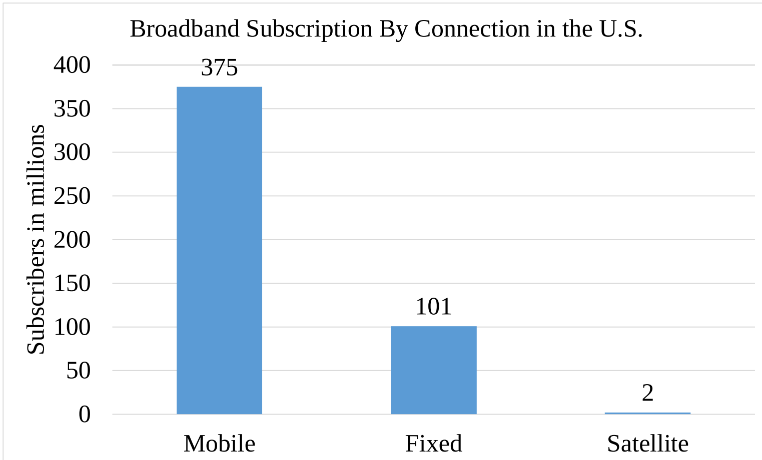

Figure 1. Satellite plays a minor role in providing broadband connections to American public[6/]

Second, the incremental societal cost of potentially providing satellite broadband to some unserved areas of the country is great. The amount of spectrum required by fixed satellite service ("FSS") to provide broadband access to the two million subscribers that might benefit from the service far exceeds the amount of spectrum allocated to support the mobile broadband services to the general public. For example, the O3b system requires 3.6 gigahertz of spectrum to operate,[7/] while the ViaSat-1 system needs 3 gigahertz.[8/] In comparison, the entire amount of

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5/ *See* Comments of the Satellite Industry Association, GN Docket No. 14-177, *et al.*, at 2 (filed Jan. 28, 2016) ("SIA Comments on *NPRM*").

6/ *See* OECD Broadband Portal at 1.1.1-1.1.2 (Dec. 2015), *available at* http://www.oecd.org/sti/broadband/1.1-TotalBBSubs-bars-2015-12.xls (reporting total fixed and wireless broadband subscriptions by country); SIA Comments on *NPRM* at 2 (reporting data on satellite broadband connections).

7/ *See* O3b Networks, Presentation to ITU Regional Seminar in Almaty, Kazakhstan, "O3b – A different approach to Ka-band satellite system design and spectrum sharing," at 7 (Sept. 5-7, 2012), *available at* https://www.itu.int/md/dologin_md.asp?lang=en&id=R12-ITURKA.BAND-C-0010!!PDF-E.

spectrum allocated in the *Report and Order* for the Upper Microwave Flexible Use Service ("UMFUS") is 3.85 gigahertz.

Figure 2. Satellite industry generates around 4% of the global telecommunications industry revenues[9/]

Despite the fact that the satellite industry only generates around 4% of the revenue of the telecommunications industry, it already has tens of gigahertz of spectrum allocated for its use. Boeing now asks the Commission to make available another 10 gigahertz of spectrum for its contemplated non-geostationary satellite orbit ("NGSO") system.[10/] Part of the reason for this aggressive demand is the extreme inefficiency in spectrum utilization for satellite broadband in comparison with terrestrial services. As Straight Path highlighted in its initial comments in this proceeding, geostationary satellite orbit ("GSO") systems are about 100,000 times less efficient in providing broadband access than terrestrial system.[11/] This results in very limited capacity despite of the vast amount of spectrum used. As ViaSat admits, with 3 gigahertz of spectrum, ViaSat-1 can only "serve around 700k subscribers – and can't add any more because the satellite

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8/ *See* ViaSat Inc., "FCC Int'l Bureau Presentation," at 12 (Apr. 13, 2011), *available at* http://licensing.fcc.gov/myibfs/download.do?attachment_key=910374.

9/ *See* Satellite Industry Association, "Satellite 101: Satellite Technology and Services," at 5 (May 2012), *available at* http://www.sia.org/wp-content/uploads/2014/11/Website-Refresh14-Satellite-101.pdf.

10/ *See* Boeing Comments at 27-30.

11/ *See* Comments of Straight Path Communications Inc., GN Docket No. 14-177, *et al.*, at 27-30 (filed Jan. 26, 2016) ("Straight Path Comments on *NPRM*").

is full."[12/] NGSO systems, with the increased number of satellites, may be able to improve on that disparity, but will still fall far short of what terrestrial services can achieve. While Boeing is asking for 10 gigahertz of spectrum to provide broadband access to users, terrestrial services are already providing fixed broadband access to 270 million Americans,[13/] and are providing mobile broadband services to 97% of the population.[14/] This means that even if satellite broadband were to become a viable option to deliver broadband access after another 10 gigahertz of spectrum, 3,000 satellites, and 10 years behind multiple nationwide 4G LTE deployment, it will still be fighting an uphill battle in most markets on cost and capacity against fiber, cable, fixed wireless, and mobile broadband providers. With increasingly better wired infrastructure for terrestrial based services, terrestrial broadband will continue to extend its reach into areas where it was not economically viable in the past. Conversely, with its low spectrum utilization, limited capacity, and high cost in comparison with terrestrial services (*e.g.*, the cost of ViaSat-1 is around $500 million while the cost of ViaSat-2 is expected to be $625 million),[15/] satellite broadband will not be able to address a meaningful share of broadband access market, or meaningful amount of traffic in broadband access beyond its current niche market. Allocating additional spectrum to

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12/ *See* Nilesh Christopher, "Companies racing to launch satellites to provide super fast internet," The Economic Times (Oct. 24, 2016), *available at* http://economictimes.indiatimes.com/tech/internet/companies-racing-to-launch-satellites-to-provide-super-fast-internet/articleshow/55020588.cms?from=mdr.

13/ *See Inquiry Concerning the Deployment of Advanced Telecommunications Capability to All Americans in a Reasonable and Timely Fashion, and Possible Steps to Accelerate Such Deployment Pursuant to Section 706 of the Telecommunications Act of 1996, as Amended by the Broadband Data Improvement* Act, 2015 Broadband Progress Report and Notice of Inquiry on Immediate Action to Accelerate Deployment, 30 FCC Rcd. 1375, Appendix D (Feb. 4, 2015) ("*2015 Broadband Progress Report*").

14/ *See id.* at Table 15.

15/ *See* Peter B. de Selding, "ViaSat-2's 'First of its Kind' Design Will Enable Broad Geographic Reach," SpaceNews (May 17, 2013), *available at* http://spacenews.com/35369viasat-2s-first-of-its-kind-design-will-enable-broad-geographic-reach/.

satellite broadband while depriving 5G terrestrial networks of the much needed spectrum that would provide broadband access to the general population will not serve the public interest.

The Commission must reject the repeated requests from the satellite industry to expand its use of the 37/39 GHz bands. Sizeable exclusion zones must be established for each satellite station to protect it from terrestrial interference. It is unrealistic to assume that satellite end user equipment can function without protection from 5G base stations and user equipment. Boeing has argued against an appropriate EIRP limit necessary for 5G to be functional and economically viable, citing the severe interference that those EIRP limits will cause to satellite stations.[16/] Now that those EIRP limits have been adopted, Boeing's argument that satellite end-user equipment can somehow be deployed along with densely-deployed 5G equipment contradicts its previous position.

In the *Report and Order*, the Commission meaningfully accommodated the satellite industry's requests in the 37/39 GHz bands. The satellite industry's further request to expand its use in the 37/39 GHz bands is in stark contrast with the lack of development and investment in these bands, and the abundant spectrum already available for the satellite industry's use that has been lying fallow (*e.g.*, the 40–42 GHz band). Accordingly, Straight Path recommends that the Commission allow use of the adjacent 40–42 GHz band by terrestrial services. The record in this proceeding has shown that 5G services with reduced EIRP level can share the spectrum with FSS.[17/] Access to the 40–42 GHz band can significantly increase the capacity of 5G systems in the 37/39 GHz bands with minimum added cost. The 5G ecosystem will also benefit from the increased economy of scale with 5.5 gigahertz of contiguous spectrum from 37–42.5 GHz.

16/ *See* Letter from Bruce Olcott, Counsel to The Boeing Company to Marlene H. Dortch, Secretary, Federal Communications Commission, in GN Docket No. 14-177, *et al*., at 4-5 (filed July 5, 2016).

17/ *See id.*

III. THE COMMISSION SHOULD NOT INCREASE THE POWER FLUX DENSITY LIMITS FOR SATELLITE OPERATIONS IN THE 39 GHZ BAND

A. Analysis of Satellite Interference to 5G Services.

In its previous comments in this proceeding, Straight Path provided an analysis of various interference scenarios between FSS and 5G services in the 39 GHz band.[18/] Here, Straight Path provides an update on that analysis by incorporating the progress in 3GPP regarding modeling of 5G base stations ("BS") and mobile stations ("MS"). The analysis focuses on the 39 GHz band, but the conclusion should be applicable to the 37 GHz band as well.

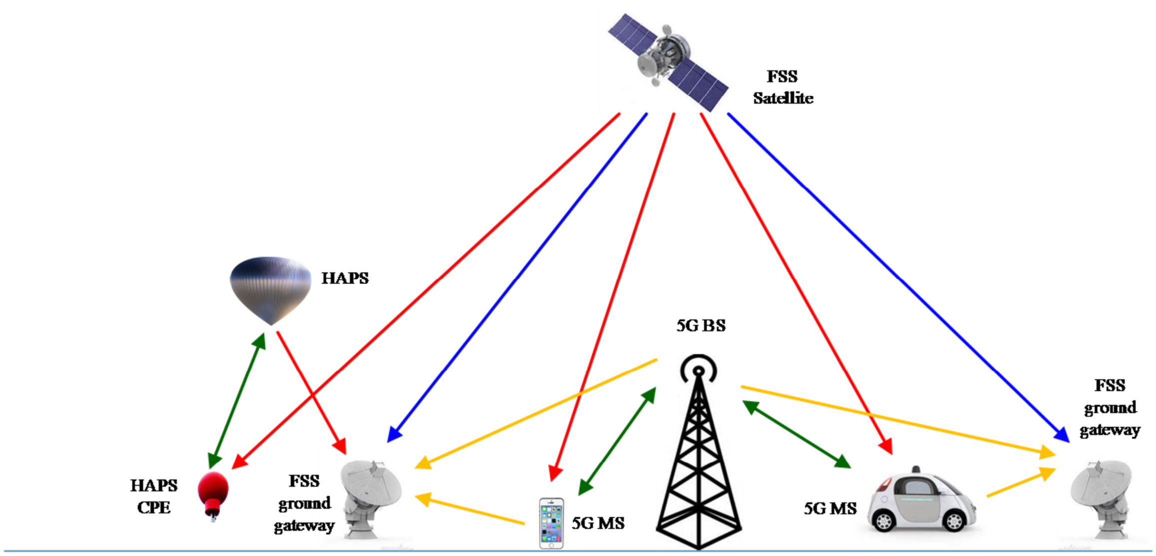

Figure 3. Interference between 5G and satellite broadband services at 37 and 39 GHz bands[19/]

The interference scenarios between FSS and 5G services are illustrated in *Figure 3*, above. In the *FNPRM*, the Commission seeks comments on whether the FSS PFD limit should be increased from -117 dBW/m^2/MHz to -105 dBW/m^2/MHz. To address this issue, Straight Path focuses on the following two interference scenarios:

18/ *See* Straight Path Comments on *NPRM* at 30-37.

19/ *See id.*

(1) FSS interference to 5G MS receivers (5G downlink); and

(2) FSS interference to 5G BS receivers (5G uplink).

We use the antenna models from 3GPP for 5G New Radio ("NR") system evaluation.[20/] The antenna arrays are modeled as a uniform rectangular panel array, as illustrated in *Figure 4*. The rectangular panel array antenna can be described by the following tuple (M_g, N_g, M, N, P). M_g is the number of panels in a column; N_g is the number of panels in a row. On each antenna panel, antenna elements are placed in the vertical and horizontal direction, where N is the number of columns, M is the number of antenna elements with the same polarization in each column. The antenna panel is either single polarized (P=1) or dual polarized (P=2). For mobile stations, each panel is additionally parameterized by a pair of orientation parameters (Ω, Θ). The current agreement in 3GPP is to support up to 256 antenna elements for base stations and up to 32 antenna elements for mobile stations in bands around 30 GHz (which includes the 28 GHz, 37 GHz, and 39 GHz bands).[21/]

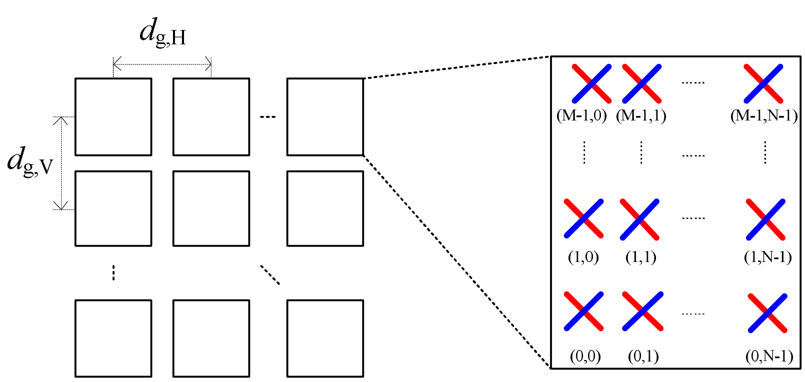

Figure 4. Base station and mobile station antenna array model

20/ *See* 3GPP TR 38.900 v14.1.0, *Study on channel model for frequency spectrum above 6 GHz*, at 22–23 (Sept. 2016), *available at* http://www.3gpp.org/ftp/Specs/archive/38_series/38.900/38900-e10.zip.

21/ *See* 3GPP TR 38.802 v0.1.0, *Study on New Radio (NR) Access Technology; Physical Layer Aspects*, at Table A.2.1-4 (Aug. 2016), *available at* http://www.3gpp.org/ftp/Specs/archive/38_series/38.802/38802-010.zip ("3GPP August 2016 Technical Report").

B. Interference From FSS Satellites to UMFUS Mobile Stations.

For 5G mobile stations, we assume a 32-element uniform planar array arranged in 4×8 fashion. The radiation pattern of each antenna element is generated according to Table 1, below.

Table 1. Mobile station antenna radiation pattern[22/]

Parameter	Values
Antenna element radiation pattern in θ'' dim (dB)	$A_{E,V}(\theta'') = -\min\left[12\left(\frac{\theta'' - 90^0}{\theta_{3dB}}\right)^2, SLA_V\right], \theta_{3dB} = 90^0, SLA_V = 25$
Antenna element radiation pattern in φ'' dim (dB)	$A_{E,H}(\varphi'') = -\min\left[12\left(\frac{\varphi''}{\varphi_{3dB}}\right)^2, A_m\right], \varphi_{3dB} = 90^0, A_m = 25$
Combining method for 3D antenna element pattern (dB)	$A''(\theta'', \varphi'') = -\min\left\{-\left\lfloor A_{E,V}(\theta'') + A_{E,H}(\varphi'')\right\rfloor, A_m\right\}$
Maximum directional gain of an antenna element $G_{E,max}$	5dBi

Note: (θ'', φ'') are in local coordinate system.

In a real deployment, the orientation of the mobile station is arbitrary. The impinging angle of satellite interference can also be arbitrary due to reflection, diffraction, and scattering of clutters around a user. For simplicity, we assume the mobile station antenna panel broad side is pointed at 45^o above the horizon. As shown in *Figure 5*, the angle between the uplink receiver beam boresight with the horizon is denoted as ϕ, and the angle between the satellite interference impinging direction with the horizon is denoted as θ. The impinging direction of the satellite interference does not necessarily equal the angle of arrival of the satellite spot beams. Terrain, buildings, and trees can all create reflections, diffractions, and scatterings that can change the direction that electronic magnetic waves travel.

[22/] *See id.* at Table A.2.1-8.

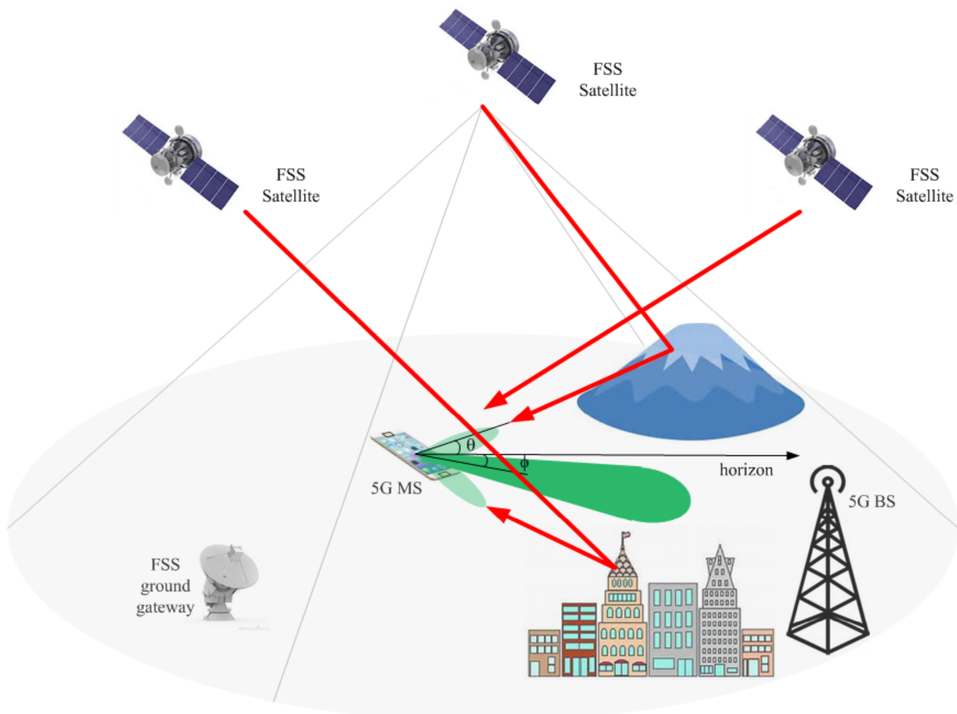

Figure 5. Interference from FSS satellites to 5G mobile stations

As the mobile station communicates with different base stations and via different paths with the same base station, the mobile station forms receiver beams towards different spatial directions. The boresight of the receiver beams should closely follow the angle of arrival of the downlink transmission from the serving 5G base station via the strongest path, while the overall beam pattern follows the following formula:

$$A(\theta) = 10\log_{10}\left(\left|\frac{sin\left(\frac{N\pi}{2}(\cos\theta - cos\phi)\right)}{sin\left(\frac{\pi}{2}(\cos\theta - cos\phi)\right)}\right|\right) + G_{E,max} + A_{E,V}(\theta)$$

Note that for simplicity, we assume $\varphi = 0$ to reduce the 2-dimensional Uniform Planar Array ("UPA") antenna pattern $A(\theta, \varphi)$ to 1-dimensional Uniform Linear Array ("ULA") antenna pattern $A(\theta)$. The amount of satellite interference received by the mobile station receiver antenna array depends on the boresight of the receiver beam ϕ, and the satellite interference impinging angle θ, and the power flux density of the FSS downlink.

We choose a rise of the noise floor as the measure, because it directly impacts the link budget of 5G systems. In fact, 5G systems will be noise limited, largely due to the ability to form narrow beams to concentrate energy to the users being served. As a result, the reduction of link budget due to rise of the noise floor will directly translate into reduction of the cell coverage, and increased deployment cost as a result. We quantify this impact below.

We take 0.5 dB as the threshold for a manageable rise in the noise floor due to interference from satellite. In addition to the impact of reduced wireless footprint and increased deployment cost, a 0.5 dB satellite interference will also reduce the signal-to-noise ratio of 5G services by 0.5 dB, thereby impacting the user experience. We also quantify the impact of this below.

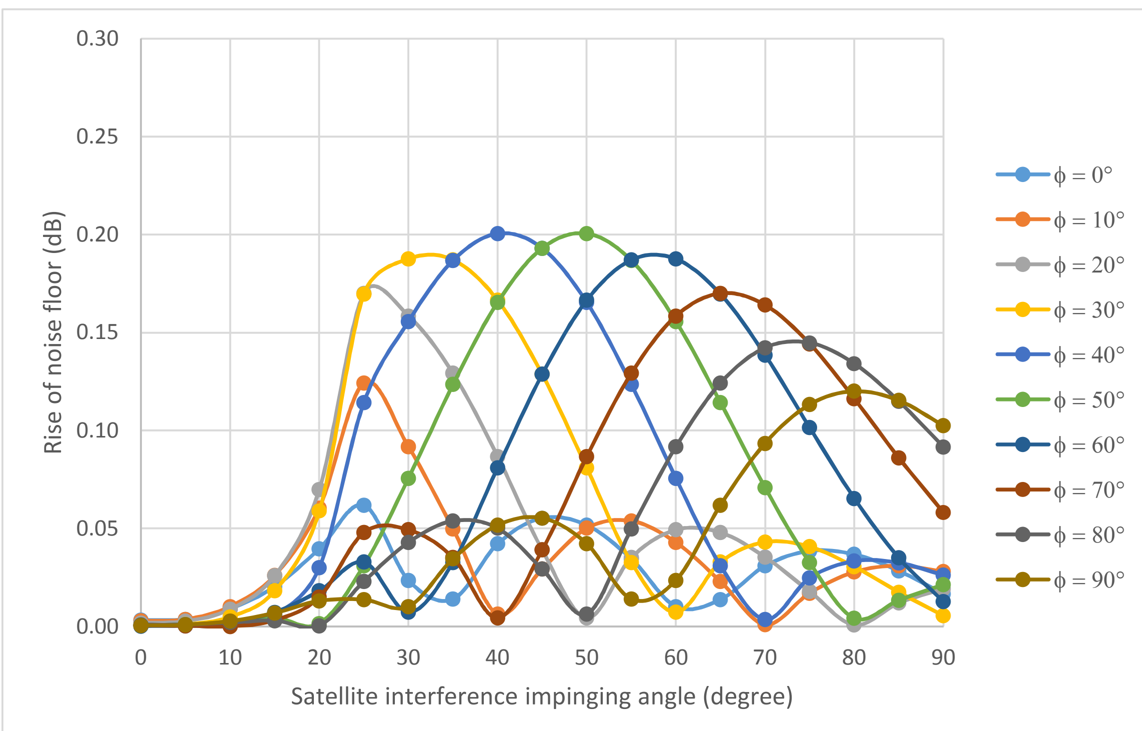

Figure 6. Rise of noise floor caused by satellite interference (4×8 UE antenna array, -117 dBW/m²/MHz PFD limit)

Figure 6 shows the rise of the noise floor at the MS receiver due to satellite interference with a PFD limit of -117 dBW/m^2/MHz. The rise of the noise floor at MS receivers is less than 0.2 dB for most of the cases with satellite PFD level of -117 $dBW/m^2/MHz$. In this case we assume the antenna array broadside is pointing at 45^o above the horizon and the PFD. Should a user tilt the mobile station antenna panels at a different angle, the results may be different. However, we believe the impact from satellite interference to MS receivers with -117 $dBW/m^2/MHz$ PFD limit is generally manageable.

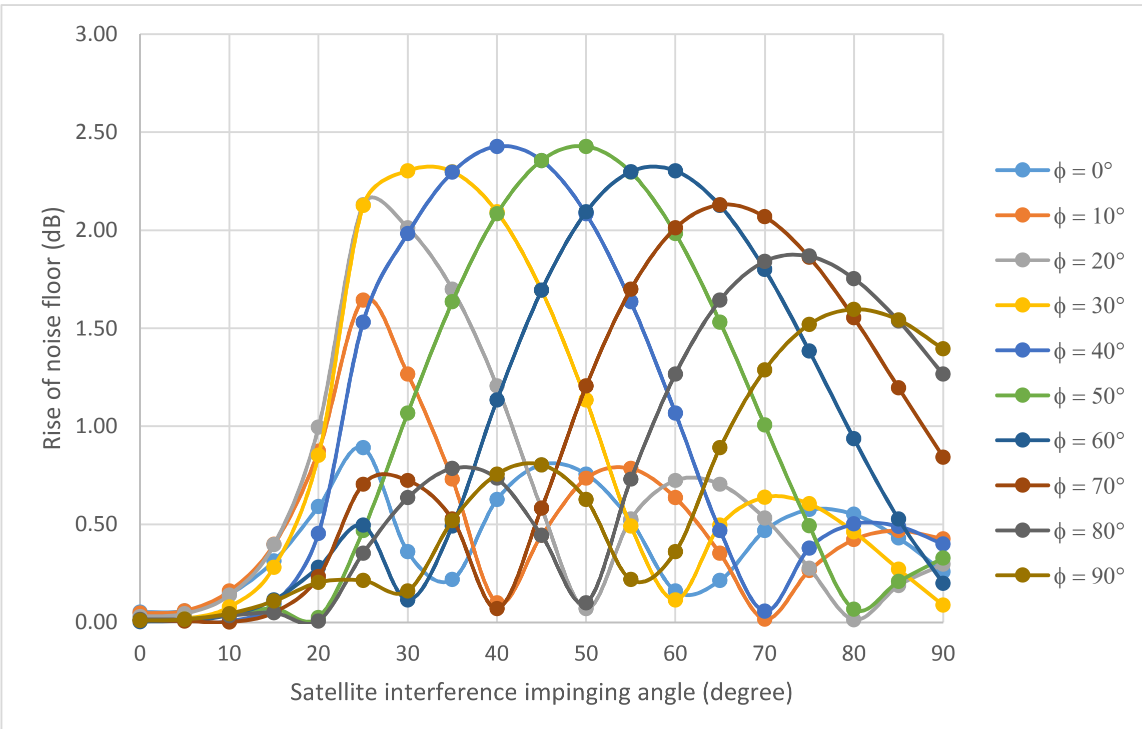

Figure 7. Rise of noise floor caused by satellite interference (4×8 UE antenna array, -105 $dBW/m^2/MHz$ PFD limit)

Figure 7 shows the rise of the noise floor at the MS receiver due to satellite interference for a PFD limit of -105 $dBW/m^2/MHz$. In this case, the satellite interference exceeds 0.5 dB for most of the receiver beam angles and satellite interference impinging angles. The worst case scenarios occur when the satellite interference impinging angle coincides with the receiver beam boresight, where the rise of noise floor is often more than 2 dB. This level of satellite interference is not acceptable.

C. Interference From FSS Satellites to UMFUS Base Stations.

For 5G BS, we assume a 256-element uniform planar array arranged in 16×16 fashion. The radiation pattern of each antenna element is generated according to Table 2.

Table 2. Base Station Antenna Radiation Pattern[23/]

Parameter	Values
Antenna element vertical radiation pattern (dB)	$A_{E,V}(\theta'') = -\min\left\{12\left(\frac{\theta''-90^\circ}{\theta_{3dB}}\right)^2, SLA_V\right\}, \theta_{3dB} = 65^\circ, SLA_V = 30\,\text{dB}$
Antenna element horizontal radiation pattern (dB)	$A_{E,H}(\varphi'') = -\min\left\{12\left(\frac{\varphi''}{\varphi_{3dB}}\right)^2, A_m\right\}, \varphi_{3dB} = 65^\circ, A_m = 30\,\text{dB}$
Combining method for 3D antenna element pattern (dB)	$A''(\theta'',\varphi'') = -\min\left\{-\left[A_{E,V}(\theta'') + A_{E,H}(\varphi'')\right], A_m\right\}$
Maximum directional gain of an antenna element $G_{E,max}$	8 dBi

We assume the BS antenna panel broad side is pointed at horizon. As shown in *Figure 8*, the angle between the uplink receiver beam with the horizon is denoted as ϕ, and the angle between the satellite interference impinging direction with the horizon is denoted as θ. Again, the impinging direction of the satellite interference does not necessarily equal the angle of arrival of the satellite spot beams due to reflections, diffractions, and scatterings of electronic magnetic waves.

[23/] *See id* at Table 7.3.-1.

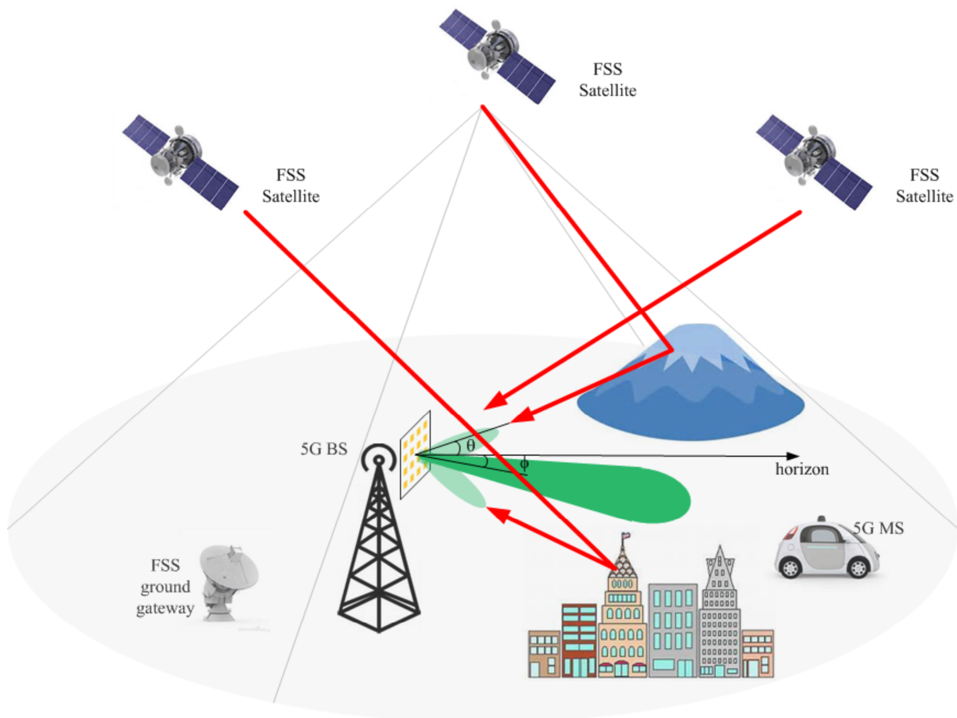

Figure 8. Interference from FSS satellites to 5G base stations

As the BS communicates with different MS, the BS forms receiver beams towards the mobile stations. The boresight of the receiver beam should closely follow the angle of arrival of the uplink transmission from the 5G mobile stations being served, while the overall beam pattern follows the following formula:

$$A(\theta) = 10\log_{10}\left(\left|\frac{sin\left(\frac{N\pi}{2}(\cos\theta - cos\phi)\right)}{sin\left(\frac{\pi}{2}(\cos\theta - cos\phi)\right)}\right|\right) + G_{E,max} + A_{E,V}(\theta)$$

For simplicity we assume $\varphi = 0$ to reduce the 2-dimensional UPA antenna pattern $A(\theta, \varphi)$ to 1-dimensional ULA antenna pattern $A(\theta)$. The amount of satellite interference received by the BS receiver antenna array depends on the boresight of the receiver beam ϕ, and the satellite interference impinging angle θ, and the ground power flux density of the satellite downlink.

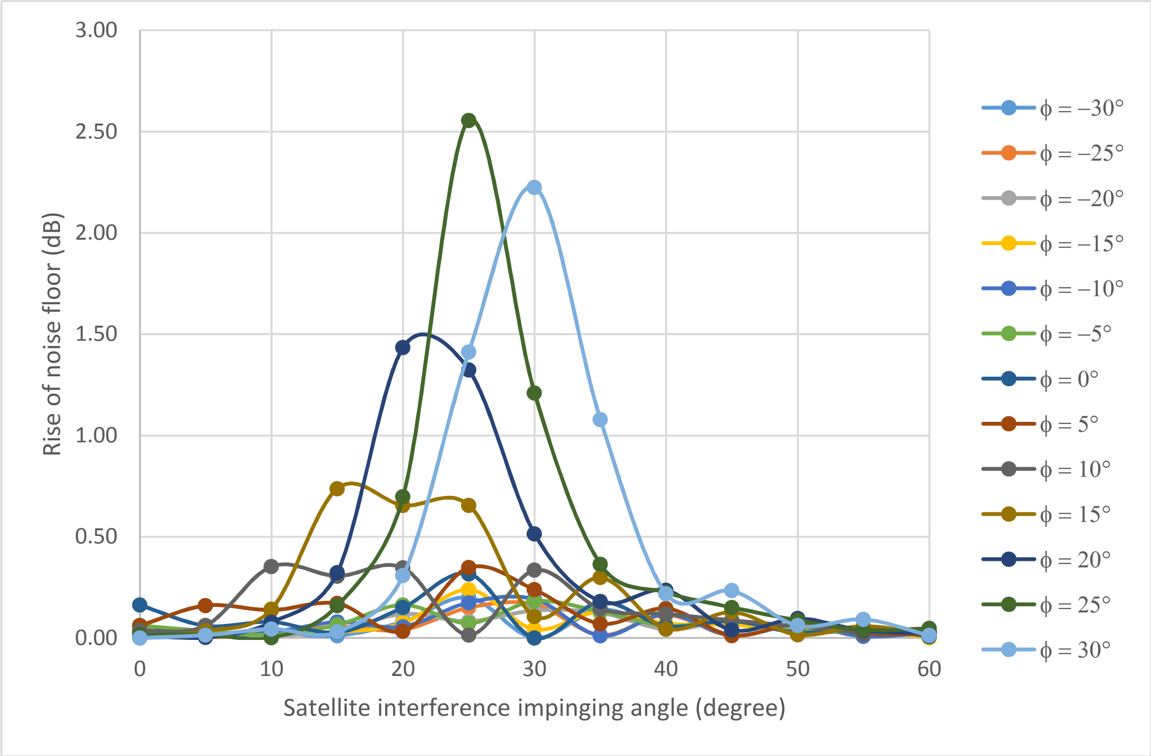

Figure 9. Rise over noise floor caused by satellite interferers (16×16 base station antenna array, -117 dBW/m^2/MHz PFD limit)

Figure 9 shows the rise of the noise floor at the BS receiver due to satellite interference for a PFD limit of -117 dBW/m^2/MHz. For BS receiver beams with boresight more than 15^o above horizon, the rise of the noise floor due to satellite interference often exceeds the 0.5 dB threshold. For example, for a receiver beam with a boresight pointing upwards at a 25^o angle and a satellite interference impinging angle at 25^o, the rise of noise floor can be as much as 2.5 dB. In this case we assume the panel broadside is pointing at horizon. Should an operator decide to tilt the BS antenna panel upwards (*e.g.*, serving a tall building nearby), that BS will suffer greater interference from the satellite than what is shown in this analysis.

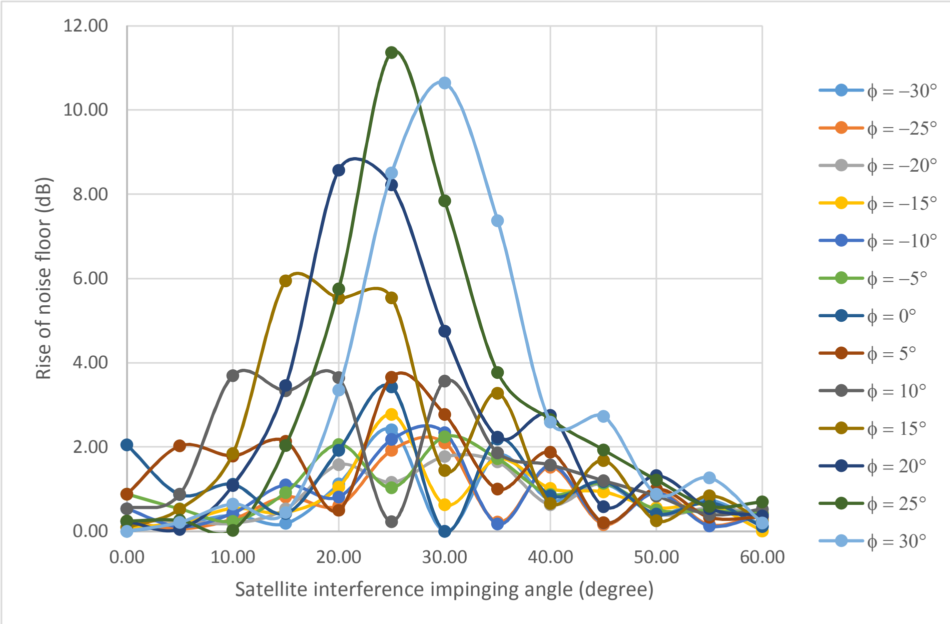

Figure 10. Rise over noise floor caused by satellite interferers (16×16 base station antenna array, -105 dBW/m^2/MHz PFD limit)

Figure 10 shows the rise of the noise floor at the BS receiver due to satellite interference for a PFD limit of -105 dBW/m^2/MHz. In this case, the satellite interference exceeds 0.5 dB for most of the receiver beam boresight angles and satellite interference impinging angles. In the worst-case scenario for a receiver beam with boresight pointing upwards at 25^o angle and a satellite interference impinging angle at 25^o, the rise of the noise floor is more than 11 dB. Clearly, this level of satellite interference is not acceptable. Again, we assume the panel broadside is pointing at horizon. A BS with an antenna panel tilted upwards (*e.g.*, to serve tall office or residential buildings in dense urban areas) will suffer greater interference from a satellite than what is shown in this analysis.

D. The Impact of a Rise of the Noise Floor to 5G Service in the 37–40 GHz Band.

As 5G systems in the millimeter wave bands will be noise-limited, a rise of the noise floor in the system will have a direct impact on the coverage and capacity of each 5G cell. *Figure 11* shows the impact of a rise of the noise floor caused by FSS downlink to 5G services in the 37–40 GHz band. *Figure 11(a)* shows the coverage area loss due to a rise of the noise floor.

The coverage area loss depends on the path loss exponent. For millimeter wave frequencies in mobile wireless environments (*e.g.*, dense urban, urban, suburban, rural areas, etc.), the path loss exponent is typically around 2.0 – 4.0. As a result, for 1 dB rise of the noise floor, the coverage area of each 5G cell is reduced by about 10% – 20%. *Figure 11(b)* shows the capacity loss due to a rise of the noise floor, which is estimated as

$$W \log_2 \left(\frac{N_0 + I_{FSS}}{N_0} \right)$$

where $W = 3\ GHz$ and the term $\frac{N_0 + I_{FSS}}{N_0}$ represents rise of noise floor. For a 1 dB rise of the noise floor, the capacity loss in each 5G cell is about 1 Gbps. Assume 300,000 5G cells are eventually deployed in this band. For an NGSO system with 3,000 satellites as proposed by Boeing, each satellite would need to provide 100 Gbps capacity to make up the capacity loss it inflicted on 5G services. In comparison, a similar NGSO system that is currently being deployed by OneWeb ("WorldVu") provides 6 Gbps capacity per satellite.[24/] In short, having FSS overlaying on terrestrial services results in net capacity loss for the nation and thus the impact of FSS must be limited.

[24/] *See* "OneWeb satellite constellation," Wikipedia.org, *available at* https://en.wikipedia.org/wiki/OneWeb_satellite_constellation (last visited Oct. 31, 2016).

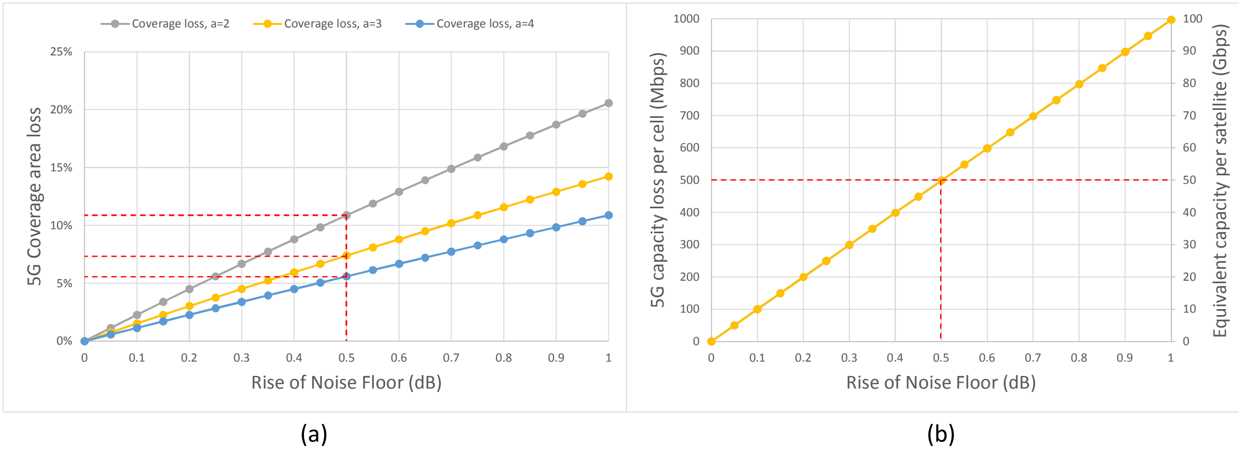

Figure 11. Impact of Rise of Noise Floor to 5G services

Straight Path proposed to use a 0.5 dB rise of the noise floor as a threshold in evaluating the FSS impact on terrestrial services, which equates to around 500 Mbps capacity loss for an impacted 5G cell. Although a consistent loss of capacity at this magnitude cannot be tolerated, the damage is somewhat mitigated by the fact that these LEO satellites are moving at an orbit speed of 128 minutes per cycle,[25/] which makes the impact to terrestrial services only last around a few minutes each time it occurs. However, with a large constellation and hundreds of thousands of 5G cells, these service degradation/interruption periods can happen quite often to millions of users. It is also possible some 5G services that operators are contemplating may not be able to tolerate these service degradation/interruption periods. Moreover, the terrestrial operators will have to take into account this impact while planning and deploying their networks in order to mitigate the quality degradation that customers may perceive. This will inevitably increase the complexity and cost of deploying terrestrial 5G services in this band.

E. FSS PFD Must Not Exceed -117 dBW/m^2/MHz in the 37.6–40 GHz Band.

The analysis above shows that, with the current -117 dBW/m^2/MHz PFD limit, the rise of the noise floor caused by FSS satellites already exceeds the 0.5 dB threshold in many cases.

25/ *See* "Orbital Speed," Wikipedia.org, *available at* https://en.wikipedia.org/wiki/Orbital_speed (last visited Oct. 31, 2016).

Moreover, the -105 dBW/m^2/MHz PFD limit will cause a rise of the noise floor as much as 11 dB for some 5G base stations and can shut down those base stations entirely.

In comparison, the co-channel interference limit for 5G services in the 37/39 GHz bands is at -77.6 dBm/m^2/MHz (equivalent to -107.6 dBW/m^2/MHz) at the market border. In other words, the Commission's rules require that a terrestrial operator can only create interference at PFD level of -107.6 dBW/m^2/MHz at the market border. The increased PFD limit of -105 dBW/m^2/MHz would create interference 2.6 dB higher than the co-channel interferer over the *entire* 5G deployment across the nation in the 37/39 GHz bands. This will unacceptably degrade terrestrial services and undermine the purpose of this proceeding.

F. Effective Power Flux Density With Limiting Assumptions on UMFUS Receivers and Antenna Pointing Directions Should *Not* Be Used to Calculate the Aggregate Satellite Interference.

Boeing proposes to calculate the aggregated interference from multiple satellites using the Equivalent Power Flux Density ("ePFD") approach.[26/] This proposal is problematic, and likely inadequate, in evaluating satellite interference to 5G receivers. As Boeing admits, "[a]n aggregated ePFD approach relies primarily on a model of the intended receiver."[27/] Boeing notes that "[t]o successfully use the ePFD methodology, a model of UMFUS receive terminals must be established, along with assumptions regarding the operational pointing of the UMFUS antennas."[28/] As the Commission promotes flexible use in these bands, it is likely that many different receivers and antennas will be deployed. Interference studies that pick a limited number of receivers and assume a few pointing directions of these receivers are not adequate. When mobile broadband usage becomes ubiquitous, it will be hard, if not impossible, to limit the

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26/ *See* Boeing Comments at 31.

27/ *See id.* at 29.

28/ *See id.* at 32.

usage scenarios without leaving out millions of users. For smartphones, it is uncertain how the users are going to hold the mobile devices. For connected and autonomous vehicles, it is entirely possible the receivers will be mounted on top of vehicles that are directly exposed to satellite interference. Even for base stations, there are many deployment scenarios. In order to limit the system evaluation workload, 3GPP only evaluates a few deployment scenarios (*e.g.*, indoor, urban micro, urban macro, rural), and a few configurations for each deployment scenarios for 5G.[29/] The chosen deployment scenarios and configurations are by no means exhaustive, or even representative. Often, corner cases, instead of representative cases, are chosen to stress test the system design to make sure the system can still function and perform in extreme situations. For example, the entire suburban deployment scenario is omitted in 5G system evaluation, while suburban deployments represent one of the most important scenarios for the United States. It would create a substantial amount of work and controversy if the Commission decided to define ePFD as Boeing proposed and undertake the task of selecting the representative receivers and antenna pointing directions for 5G services. Instead, Straight Path suggests the simple approach of aggregating interference from multiple satellites by adding the PFD levels from multiple satellites with overlapping coverage. This approach is equivalent to the ePFD approach as Boeing proposed with arbitrary receivers and random pointing direction. In other words, Straight Path recommends that the Commission *not* impose limitations on the receivers and antenna pointing directions for 5G services.

29/ *See* 3GPP August 2016 Technical Report at 17-31.

IV. THE COMMISSION SHOULD NOT ADOPT A USE-IT-OR-SHARE-IT SHARING FRAMEWORK IN ANY OF THE EXCLUSIVELY-LICENSED UMFUS BANDS

The record in this proceeding shows broad opposition to the Commission's proposed use-it-or-share it rules for the millimeter wave bands.[30/] Straight Path and other commenters believe that adoption of an untested and unproven sharing framework would subject licensees to substantial uncertainty and could discourage investment in and delay deployment of innovative mobile broadband services.[31/] The Commission has set aside ample spectrum for unlicensed use, and it is unclear whether there will be any demand or need for opportunistic access to licensed millimeter wave spectrum.[32/] It is therefore unnecessary and premature to experiment with an unproven sharing model that could compromise the primary purpose of this proceeding—to maintain U.S. leadership in 5G.[33/]

30/ *See, e.g.*, Comments of T-Mobile USA, Inc., GN Docket No. 14-177, *et al.*, at 24-26 (filed Sept. 30, 2016) ("T-Mobile Comments"); Verizon's Comments on Further Notice, GN Docket No. 14-177, *et al.*, at 2-4 (filed Sept. 30, 2016) ("Verizon Comments"); Comments of CTIA, GN Docket No. 14-177, *et al.*, at 19-22 (filed Sept. 30, 2016) ("CTIA Comments"); Comments of 5G Americas, GN Docket No. 14-177, *et al.*, at 14-23 (filed Sept. 30, 2016) ("5G Americas Comments"); Comments of Mobile Future, GN Docket No. 14-177, *et al.*, at 5-6 (filed Sept. 30, 2016) ("Mobile Future Comments"); Comments of Nextlink Wireless, LLC, GN Docket No. 14-177, *et al.*, at 22-28 (filed Sept. 30, 2016) ("Nextlink Comments"); Comments of Ericsson, GN Docket No. 14-177, *et al.*, at 19-20 (filed Sept. 30, 2016) ("Ericsson Comments"); Comments of Qualcomm Incorporated, GN Docket No. 14-177, *et al.*, at 15 (filed Sept. 30, 2016) ("Qualcomm Comments"); Comment of Intel Corporation, GN Docket No. 14-177, *et al.*, at 16-21 (filed Sept. 30, 2016) ("Intel Comments").

31/ *See, e.g.*, Verizon Comments at 2 ("Sharing frameworks are most likely to succeed if operators are confident about their ability to recoup large capital investments based on having access to the spectrum.").

32/ *See, e.g.*, Intel Comments at 15-19; 5G Americas Comments at 18-20; Mobile Future Comments at 5-6.

33/ *See, e.g.*, CTIA Comments at 19-22 ("Implementing a 'use it or share it' mandate would wreak havoc on the millimeter wave bands, thwarting the Commission's central goal of facilitating the transition to 5G."); Verizon Comments at 2 ("Verizon and others have described the risks of heavy reliance on untested sharing proposals, such as the 'use it or share it' approach").

Numerous parties voice concerns that a use-it-or-share-it requirement in the millimeter wave bands could discourage investment and delay 5G rollout.[34/] Qualcomm calls the proposed regime "bad policy" given the nascent state of mobile deployment in the bands.[35/] Ericsson cautions against premature consideration of sharing mechanisms like use-it-or-share-it that may discourage 5G development.[36/] CTIA likewise suggests that it would be premature to implement a use-it-or-share-it framework in the millimeter wave bands "[i]n light of the nascent nature of 5G technology."[37/] It explains that licensees will need "unfettered access to their licensed spectrum" in order to test new technologies and experiment with novel deployments.[38/]
Mobile Future similarly cautions that a use-or-share requirement would "needlessly limit licensees' flexibility to examine different uses and technologies, and could imperil development of innovative 5G technologies in the bands."[39/]

Straight Path also agrees with parties who question the usefulness of opportunistic access to exclusively licensed millimeter wave spectrum. For example, Intel explains that "since the use-it-or-share-it spectrum is encumbered compared to the available dedicated unlicensed [millimeter wave] substitutes, it is unlikely to be used in a meaningful way."[40/] 5G Americas also believes that a use-it-or-share-it approach is unnecessary.[41/] It acknowledges that such an approach might be justified if there were "demonstrated shortages or disproportionately low

[34/] *See, e.g.*, CTIA Comments at 19-22; Mobile Future Comments at 5-6; Ericsson Comments at 19-20; Qualcomm Comments at 14-15.

[35/] Qualcomm Comments at 14-15.

[36/] Ericsson Comments at 19-20 (Ericsson instead urges the Commission to rely on frequency coordination).

[37/] CTIA Comments at 19.

[38/] *Id.* at 20.

[39/] Mobile Future Comments at 6.

[40/] Intel Comments at 17.

[41/] *See* 5G Americas Comments at 19-20.

allocations of unlicensed spectrum access opportunities" in the millimeter wave bands. But the Commission just added seven gigahertz of spectrum for unlicensed use, "resulting in an unprecedented contiguous 14 GHz allocation for unlicensed use in the 57-71 GHz band, with the possibility of even more unlicensed allocations in the second wave of nearly 18 GHz of [millimeter wave] spectrum proposed in the Further Notice."[42/]

Arguments in favor of the proposed use-it-or-share-it framework are unpersuasive. For example, the Open Technology Institute at New America and Public Knowledge state that the proposed scheme presents "absolutely no downside or risk for licensees" because a licensee would retain the right to displace opportunistic use once that licensee is ready to commence operations.[43/] Federated Wireless similarly argues that UMFUS licensees "face no possibility of loss of rights, as their commencement of operations necessarily precludes opportunistic users."[44/] But it is not clear how the sharing model would actually work in practice, and the introduction of regulatory uncertainty could result in a chilling effect on innovation and investment. Bearing in mind the primary purpose of this proceeding, the Commission should not impose limitations on licensees' flexibility to develop, test, and deploy 5G technologies and services.

V. THE COMMISSION SHOULD EXPAND THE UMFUS FRAMEWORK TO ADDITIONAL LMDS SPECTRUM

Straight Path's comments on the *FNPRM* request that the Commission authorize flexible mobile and fixed services in additional LMDS band spectrum.[45/] Specifically, Straight Path recommended that the Commission expand the UMFUS framework to include the LMDS A3

42/ *Id*.

43/ Comments of Open Technology Institute at New America and Public Knowledge, GN Docket No. 14-177, *et al.*, at 16-19 (filed Sept. 30, 2016).

44/ Comments of Federated Wireless, Inc., GN Docket No. 14-177, *et al.*, at 11 (filed Sept. 30, 2016).

45/ Comments of Straight Path Communications Inc., GN Docket No. 14-177, *et al.*, at 3-4 (filed Sept. 30, 2016) ("Straight Path Comments on *FNPRM*").

band (31.075-31.225 GHz), B1 band (31-31.075 GHz), and B2 band (31.225-31.3 GHz). This would create an additional contiguous 300 megahertz of spectrum from 31 GHz to 31.3 GHz that could support innovative 5G wireless service.

Nextlink and Verizon also encourage the Commission to adopt mobile service rules in the remaining LMDS frequencies.[46/] Nextlink observes that the remaining LMDS bands are in fact "much stronger candidate bands for mobile use than most of the new higher frequency bands suggested by the Further Notice, and can more quickly unleash the powers of 5G technologies."[47/] Like Straight Path, Nextlink explains that spectrum channels smaller than 500 megahertz in bandwidth can support next-generation services.[48/] Nextlink also notes that while the Commission did not adopt service rules for the remaining LMDS bands because they did not offer at least 500 megahertz of contiguous spectrum, the Commission has since "disavowed this gating criterion" by proposing to apply the UMFUS rules to significantly smaller bands in the *FNPRM*.[49/]

Verizon similarly suggests that repurposing the remaining LMDS spectrum would "promote synergies" with 5G operations using the already-repurposed 28 GHz spectrum.[50/] It notes that "equipment that is developed and manufactured for 5G use in the A1 frequencies could readily be designed to also take advantage of the additional capacity by using the A2, A3,

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46/ *See* Nextlink Comments at 3-17; Verizon Comments at 3-5.

47/ Nextlink Comments at i, 4-5.

48/ *Id.* at 6-9 ("[T]he record evidence establishes that operators will be able to deploy next-generation services over channels significantly smaller than 500 megahertz, and the Commission should not give up on the remainder of the LMDS band simply because it does not contain the Commission's desired amount of contiguous spectrum.").

49/ *Id.* at i, 6.

50/ Verizon Comments at 4-5.

B1, and B2 frequencies."[51/] Straight Path agrees that many of these efficiencies could be accomplished by extending the UMFUS rules to at least include the LMDS and A3 and B bands, and it strongly encourages the Commission to do so.

VI. THE COMMISSION SHOULD ADOPT IN-BAND SPECTRUM AGGREGATION LIMITS

It is more important that the Commission impose a band-specific spectrum screen rather than an overall one-third limit for all millimeter wave bands. As Straight Path has explained, millimeter wave spectrum is not fungible.[52/] In addition to their different propagation characteristics, the bands may be subject to different regulatory obligations. T-Mobile and Competitive Carriers Association ("CCA") note that an in-band aggregation limit would account for these differences and would ensure that competing providers are not foreclosed from acquiring spectrum in any given band.[53/] T-Mobile observes that it is "not reasonable to assume that access to a particular millimeter wave band will be a substitute for access to all millimeter wave bands."[54/] CCA similarly advises that band-specific aggregation limits "will allow the Commission to tailor the applied limit depending on the best use case for each band, and prevent anti-competitive aggregation of a single band."[55/]

Verizon opposes spectrum aggregation limits for future millimeter wave spectrum.[56/] Verizon claims that such limits are unnecessary because a large amount of new millimeter wave spectrum "is in the 5G pipeline," and thus it "would be impossible for any firm to exclude a

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51/ *Id.* at 5.

52/ Straight Path Comments on *FNPRM* at 12.

53/ *See*, *e.g.*, T-Mobile Comments at 28; Comments of Competitive Carriers Association, GN Docket No. 14-177, *et al.*, at 2-4 (filed Sept. 30, 2016) ("CCA Comments").

54/ T-Mobile Comments at 28.

55/ CCA Comments at 3.

56/ *See* Verizon Comments at 7-8.

competitor by purchasing 'too much' of the spectrum released early on because that competitor will continuously have new opportunities to correct its lack of spectrum by bidding on the additional spectrum coming through the pipeline."[57/] But Verizon's argument also fails to recognize that millimeter wave spectrum is not fungible. Spectrum that is "in the 5G pipeline" is not necessarily interchangeable with all other millimeter wave spectrum released by the Commission. An in-band screen is therefore necessary to promote competition within each particular millimeter wave band.

TIA and Mobile Future argue that spectrum aggregation limits are premature and could hinder technological development.[58/] The opposite is true. Technological development is fostered by competition, and competition will be stymied if spectrum is concentrated in the hands of a limited number of licensees. Aggregation limits must be imposed now. If the Commission waits until a handful of entities have acquired all of the millimeter wave spectrum competition will have already been compromised and consumers harmed.

57/ Verizon Comments at 7-8.

58/ *See* Comments of the Telecommunications Industry Association, GN Docket No. 14-177, *et al.*, at 20-21 (filed Sept. 30, 2016); Mobile Future Comments at 6.

VII. CONCLUSION

The Commission should continue the work it has already done in this proceeding by ensuring that spectrum in the millimeter wave bands are available to support mobile terrestrial services. That means that the Commission must not allow valuable spectrum resources for less-efficient satellite service or adopt rules with shared services that will infringe on the most productive use of these spectrum assets. It should also consider making additional spectrum in the LMDS bands available for terrestrial operations. Additionally, the Commission should impose in-band spectrum aggregation limits to promote competition in the millimeter wave bands.

Respectfully submitted,

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