July 7, 2016

BY ELECTRONIC FILING

Marlene H. Dortch
Secretary
Federal Communications Commission
445 12th Street, S.W.
Washington, DC 20554

Re: *Use of Spectrum Bands Above 24 GHz For Mobile Radio Services, et al.*, GN Docket No. 14-177, IB Docket Nos. 15-256 and 97-95; RM-11664; and WT Docket No. 10-112

Dear Ms. Dortch:

WorldVu Satellites Ltd., doing business as OneWeb ("OneWeb") is in the process of constructing advanced satellites and earth stations to communicate using the 27.50-28.35 GHz band ("28 GHz band") to provide broadband service to customers throughout the United States and worldwide. OneWeb will be spending billions of dollars to deploy this constellation of non-geostationary satellite orbit ("NGSO") satellites and has similar concerns to other satellite operators.[1] In this proceeding, the Broadband Satellite Companies have focused on strategies for sharing in the 28 GHz band between the Fixed-Satellite Service ("FSS") and the proposed Upper Microwave Flexible Use ("UMFU") service. During this process, much has been written and discussed about the status of mobile and FSS services in this band. Unfortunately, through all the rhetoric, no consensus has emerged to guide the Commission towards an appropriate solution. OneWeb proposes that the Commission adopt reasonable EIRP density limits skywards for UMFU stations as part of its upcoming Report and Order, or alternatively through a Future NPRM.

The CTIA and the Wireless Joint Filers continue to argue that FSS as a service is secondary to (fixed) LMDS in the United States, and that consequently, the FSS shall not cause interference or claim protection from future UMFU systems. The opposite argument is made by the SIA and the Broadband Satellite Companies, who argue that UMFU is a new service and therefore FSS must retain its relative primary status. Notwithstanding what the FCC decides with respect to these domestic matters, one aspect remains clear – the United States has a treaty

[1] The Broadband Satellite Company operators and others have invested many billions of dollars in advanced geostationary and non-geostationary 28 GHz satellite systems serving U.S. and global customers and network operations that rely on the existing regulatory and operating environment.

obligation under the International Telecommunication Union ("ITU") Radio Regulations to protect international FSS satellites from interference caused by terrestrial deployments.

OneWeb believes that when it comes to sharing between UMFU transmit stations (base stations or access points as well as subscriber stations) and FSS satellite receivers, there is a relatively simple solution that would be win-win-win. The solution presented in this letter and its accompanying study, clearly show that technical rules can be applied to UMFU stations on an individual transmitter basis that are not so onerous as to constrain their development and deployment, while providing a certain level of assurance to the FSS operators that their satellites will not be subject to harmful interference. Such a rules-based solution would be beneficial to the terrestrial operators as it would provide a clear set of technical criteria by which they can design their systems. It would also be beneficial to the FSS operators who would be able to predict the maximum levels of interference from any given UMFU station into their satellites and take appropriate measures to reduce the probability of aggregate interference from future UMFU deployments. Lastly, it would benefit the Commission in that it would solve a thorny issue and prevent the deployment of mobile stations that contravene the United States' treaty obligations under the ITU Radio Regulations.

EIRP density limits on UMFU stations. The earlier proposal by the Broadband Satellite Companies for an aggregate skywards emission limit on UMFU stations was rejected by the terrestrial proponents as not being necessary or practicable. Consequently, OneWeb proposes that each individual UMFU station be limited to a maximum EIRP density above 5° elevation angle in all azimuth directions around such stations so that FSS satellites will not receive harmful interference from a *reasonable* deployment of UMFU stations. The suggested EIRP density mask for UMFU base stations (or access points) is:

- 32 dBm/100 MHz for elevation angles 25 degrees above the horizon
- 37 dBm/100 MHz for elevation angles between 15 and 25 degrees above the horizon
- 50 dBm/100 MHz for elevation angles between 5 and 15 degrees above the horizon

As demonstrated in the accompanying technical study, such an EIRP mask would allow deployment of UMFU stations without the need individually to coordinate with the satellites, while giving some level of assurance to the satellite operators that their FSS receivers would not experience harmful interference from UMFU deployments. The proposed EIRP masks are not sufficiently low to ensure protection of the FSS satellites in all circumstances, however, through careful system planning and design parameters, new FSS networks can mitigate interference.

The concern from FSS operators is that even a relatively few UMFU base stations deployed within the footprint of the satellite receive beam[2] could potentially cause harmful interference into the satellite networks, depending on their link design. Even for less sensitive links that are dominated by downlink noise such as the OneWeb forward links, a few dozen UMFU base stations are enough to significantly reduce the overall link margin and reduce the

[2] The study considers the satellite -1dB and -3dB contours, but UMFU stations can also be located throughout the beam footprint, thereby increasing the risk of service disruption due to aggregate interference.

signal availability. Unless certain limits are imposed on the UMFU EIRP density, the interference can be severe with even a very moderate terrestrial deployment.

The above EIRP density mask is similar in intent and application to the mask adopted by WRC-03 applicable to Radio LANs in the band 5250-5350 MHz for the protection of EESS and SRS[3], so the concept is not new, but has been previously implemented.

Looking at the proposed technical characteristics of UMFU base stations, the above EIRP density mask would easily be met through careful system design and with minimal, if any, impact to the manufacturing and deployment of UMFU base stations. This is clearly demonstrated in the companion technical study.

EIRP limits on UMFU subscriber terminals. The subscriber terminals, also referred to as User Equipment (or UE), are seen as less problematic in that their expected emission levels are much lower than the base stations.[4] Nevertheless, their interference levels will ultimately depend on the UE antenna pattern and their deployment configuration. It is anticipated that UMFU base stations will be deployed in a 3 or 4-sector configuration, with each sector providing a steerable beam to serve a single UE per channel, at any given time. Consequently, using a reference bandwidth of 100 MHz as was done in all studies to date, the impact to the FSS satellites from the UE deployment should be negligible as long as each UE's EIRP mask above the horizon, is 10 dB or more below the EIRP density of the base stations.[5]

The notional design according to the previously cited sources is for a 43 dBm/100 MHz UE with 26 dBm/100 MHz transmit power and 17 dBi gain. If all UE's were to respect this condition, and assuming that the vast majority would operate near the horizon, their interference contribution to the FSS satellites would be minimal as compared to the base stations. However, unless the FCC imposes some modest restrictions on the UE antenna pattern, the interference could be in fact worse than for the base station. As an example, if an UMFU operator deploys a 3 dBi quasi-omnidirectional vehicular antenna with 10W (40 dBm) transmit power, the EIRP over the entire sky in a 100 MHz band could be 43 dBm/100 MHz. This would still meet the proposed maximum EIRP that the terrestrial proponents have presented, but could be 11 dB higher than the levels we proposed earlier for base stations above 25 degrees elevation.

We believe that a simple and elegant solution would be to specify either an EIRP density mask as a function of elevation angle, as proposed for the base stations, or alternatively, a transmit antenna gain pattern combined with an operational elevation angle restriction. An example of the first approach would be:

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[3] ITU-RR, Resolution **229** (Rev. WRC-12), which states *inter alia*, "…when operating above a mean e.i.r.p. of 200 mW, these stations shall comply with the following e.i.r.p. elevation angle mask where θ is the angle above the local horizontal plane (of the Earth) …".

[4] As per "Wireless Joint Filers" June 1st letter, where the maximum EIRP of the UE's are 43 dBm/100 MHz.

[5] Even though there may be 4 UE's associated with each base station, the latter's sectoral configuration means that typically the interference from multiple UE's associated with one base station will be predominantly caused by the one unit with its main beam that is pointing closest to the victim FSS satellite.

- 22 dBm/100 MHz for elevation angles 25 degrees above the horizon
- 27 dBm/100 MHz for elevation angles between 15 and 25 degrees above the horizon
- 40 dBm/100 MHz for elevation angles between 5 and 15 degrees above the horizon

The above values are 10 dB lower than the proposed levels for the base station. The mask can bet met with the proposed UE design described earlier, as long as the UE main beams operate at low elevation angles.[6]

Transmit power limits on UMFU stations. To further prevent interference, OneWeb proposes that UMFU stations be limited to a maximum transmit power level of 10 dBW (40 dBm) per station in accordance with No. **21.5** of the ITU Radio Regulations.[7] Whilst this maximum transmit power level is lower than some of the configurations proposed by the terrestrial operators[8], the proposed UMFU system designs are still quite preliminary and can easily be adapted. Imposing such a power limit is not a huge constraint on the terrestrial systems, as the desired EIRP levels can be achieved with additional antenna gain, which further improves sharing with satellites when the terrestrial station main beam is pointed at or below the local horizon. As the Wireless Joint Filers have demonstrated in their many presentations[9], the UMFU base stations will typically operate with 6° to 12° downtilt, so with a reasonable antenna pattern, this power limit will not be exceeded.

Transmit power control. The Wireless Joint Filers have repeatedly indicated that interference will be mitigated through the use of transmit power control. We concur that this technique is effective in controlling interference and would urge the Commission to mandate the use of power control to maintain the UMFU transmit signals to the minimum required to meet the link performance and only allow the maximum EIRP in cases of impaired propagation conditions.

Additional safeguards for currently operating FSS networks. The FCC may also wish to assess the probability of interference into existing FSS satellites[10], by further exploring potential limitations on UMFU stations in areas where receive beams of existing FSS satellites may suffer harmful interference, in cases where the above EIRP density mask may not be sufficient to meet the FSS interference objectives. For example, many GSO FSS networks are currently operating

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[6] According to letters from the "Wireless Joint Filers, the 43 dBm/100 MHz UE typically has 12 dB reduced EIRP at 5°, 14 dB at 15° and 22 dB reduction at 30° elevation angles. *See* letter from "Wireless Joint Filers" to Marlene H. Dortch, GN Docket No. 14-177 filed June 1, 2016 at Exhibit B-13.

[7] ITU Radio Regulation No. **21.5** "The power delivered by a transmitter to the antenna of a station in the fixed or mobile services shall not exceed … +10 dBW in frequency bands above 10 GHz, except as cited in No. **21.5A**."

[8] *See* letter from the "Wireless Joint Filers" to Marlene H. Dortch, GN Docket No. 14-177 filed June 1, 2016. Stations with a 75 dBm/100 MHz EIRP, achieved using a 29 dBi gain 16 by 16 elements antenna array require a transmit power of 46 dBm per 100 MHz bandwidth. A 100 MHz carrier would exceed the ITU Regulations by 6 dB and a carrier occupying the entire 850 MHz range would have 15 dB excess power.

[9] *See* letters from "Wireless Joint Filers" to Marlene H. Dortch, GN Docket No. 14-177 filed May 6, May 12 and June 1, 2016. In the May 6th letter, the EIRP was 62 dBm/100 MHz with 12° downtilt; the May 12th letter reaffirmed these assumptions, whereas the June 1st letter increased the EIRP to 75 dBm/100 MHz but decreased the downtilt angle to "6° or more of mechanical downtilt".

[10] Currently there are several GSO FSS satellites and one non-GSO system (O3b) all operating on the equatorial plane. Thus, the area of the sky that may need additional protection is very well defined.

with receive beams located over densely populated areas of the United States, and thus the assumptions used in the technical analysis may not cover all these deployments. In these cases, there may be a need to further limit the UMFU base station EIRP towards the geostationary and O3b equatorial orbits to ensure protection of existing satellites.

Conclusion

The study provided with this letter refutes some of the assertions made by the Wireless Joint Filers in their ex-parte letters and provides the rationale for assessing realistic interference potential from UMFU stations into the FSS satellite receivers, not based on average or mean interference from very large number of stations, but rather the impact of a few stations when there is no limit on their skywards emission.

Accordingly, OneWeb urges the Commission to review the record to recognize that interference potential is very real, but that there is a compromise solution that consists of the application of reasonable per station EIRP limits that will not preclude or even constrain the deployment of UMFU services, while giving a level of assurance for the FSS operations. We believe these could be discussed in detail through a Future NPRM, should the Commission not be able to adopt such limits in its upcoming Report and Order.

Respectfully submitted,

/s/ Kalpak Gude

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Kalpak Gude
Vice President, Legal Regulatory
WorldVu Satellites Ltd./OneWeb
1400 Key Boulevard
10th Floor
Arlington, VA 22209

cc:	Diane Cornell	Edward Smith
	Daudeline Meme	Johanna Thomas
	Brendan Carr	Erin McGrath
	Jon Wilkins	Mindel de la Torre
	Julius Knapp	Michael Ha
	Jose Albuquerque	Brian Regan

The FCC Must Adopt an Emission Envelope for UMFU to Protect FSS Systems in the 28 GHz Band

July 7, 2016

OneWeb

GN Docket No. 14-177

Overview

- UMFU skyward aggregate interference in 27.5-28.35 GHz ("28 GHz band") can result in severe degradation of broadband satellite service to US customers
- Results show that <u>even with low</u> UMFU base station deployment density, the permissible interference levels at the satellite can be exceeded unless the skywards emissions from UMFU transmitters are reduced
- An "aggregate" emission limit would be <u>ideal</u>, however, to maintain UMFU deployment flexibility a per transmitter EIRP density limit is proposed
- The UMFU limit on emissions radiated skyward that should be adopted is provided as an EIRP density per base station of:
    - 32 dBm/100 MHz for elevation angles 25 degrees above the horizon
    - 37 dBm/100 MHz for elevation angles 15-25 degrees above the horizon
    - 50 dBm/100 MHz for elevation angles 5-15 degrees above the horizon
- The UMFU user equipment EIRP density limits should be 10dB more stringent
- The FCC should also limit the transmit power to a maximum of 40 dBm (10dBW) in accordance with the ITU Radio Regulations for all transmitters

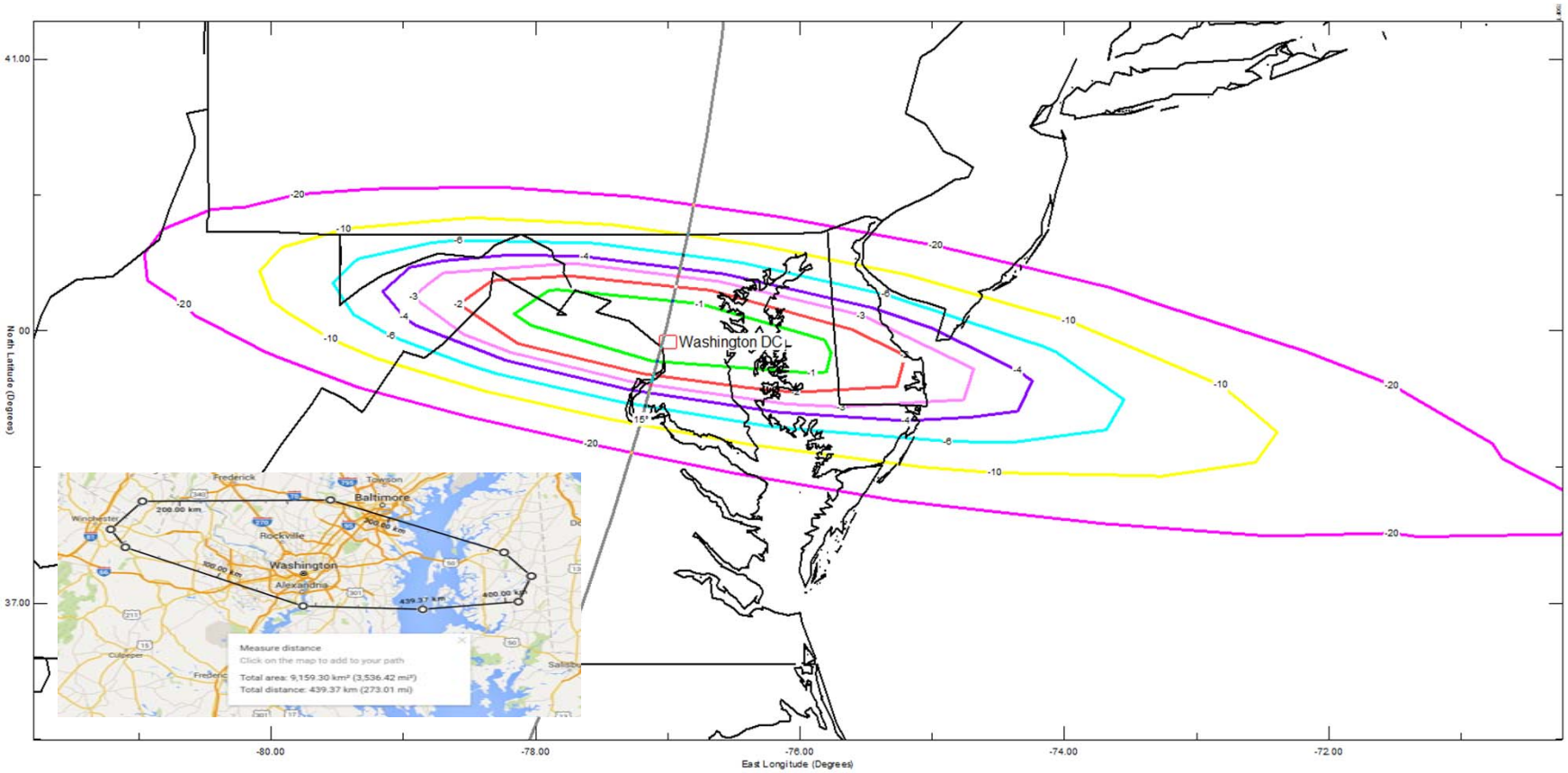
Case study: the OneWeb LEO system

- OneWeb uses Ka-band for feederlinks, so the impact of an increase in uplink thermal noise may not be as serious as for some GSO and other NGSO systems
- The impact of an increase in uplink thermal noise can be considered over the entire forward link (gateway to satellite to user terminal)
  - Typical link budget figures:
    - Uplink thermal C/N = 23 dB (under clear sky conditions)
    - Uplink and downlink intra- and inter-system interference allowances C/I = 17 dB
    - Downlink thermal C/N= 13.4 dB
    - Total C/(N+I) = 11.5 dB (under clear sky conditions)
  - Uplink UMFU interference impact:

Uplink I/N (thermal)	C/Iup by UMFU	Link degradation	Equivalent link ΔT/T
-12 dB	35 dB	-0.02	0.4%
-3 dB	26 dB	-0.15	4%
0 dB	23 dB	-0.30	7%
3 dB	20 dB	-0.57	14%

Example OneWeb satellite beam

OneWeb satellite receive beam over DC area
Peak gain is 37 dBi
Area of the -1dB contour (green) is approximately 9000 km^2



Worst-case interference from UMFU to OneWeb

		OneWeb Beam at EOC (15 deg elev.)			OneWeb Beam at EOC (15 deg elev.)		
		Beam 1dB	Beam 3dB	Beam 10dB	Beam 1dB	Beam 3dB	Beam 10dB
elev angle	degrees	15	15	15	15	15	15
Sat Noise temp	K	440	440	440	440	440	440
distance [1]	km	2762	2762	2762	2762	2762	2762
FSS Noise density	dBm/Hz	-172.2	-172.2	-172.2	-172.2	-172.2	-172.2
FSS sat Rx gain	dBi	36	34	27	36	34	27
5G AP gain	dBi	23	23	23	29	29	29
Tx power	dBm	39	39	39	46	46	46
FSL	dB	-190.1	-190.1	-190.1	-190.1	-190.1	-190.1
other losses	dB	-4	-4	-4	-4	-4	-4
gain red to sat	dB	-15.0	-15.0	-15.0	-30.0	-30.0	-30.0
I (LoS single entry)	dBm	-111.1	-113.1	-120.1	-113.1	-115.1	-122.1
ratio (LOS/nLoS)		100%	100%	100%	100%	100%	100%
Interf. Reduction	dB	0.0	0.0	0.0	0.0	0.0	0.0
Io (interference density)	dBm/Hz	-191.1	-193.1	-200.1	-193.1	-195.1	-202.1
I/N = Io/No	dB	-18.95	-20.95	-27.95	-20.95	-22.95	-29.95
Number of UMFU sites	I/N=-12.2dB	5	7	38	7	12	60
Number of UMFU sites	I/N=0 dB	78	124	623	124	197	988

[1] *The OneWeb case considers a single instant in time at a particular elevation angle to illustrate the impact at that point in time*

Results are similar to GEO and MEO cases presented in the Annex

UMFU interference into OneWeb LEO system

- The number of UMFU sites transmitting towards a OneWeb LEO satellite in line-of-sight conditions, that would cause a 0.5 dB overall link degradation, under clear sky depends on where they are situated:
  - 80 to 120 sites within the -1 dB contour, or
  - 120 to 200 sites within the -3 dB contour, or
  - 600 to 1000 sites within the -10 dB contour
- Combining these figures into a possible UMFU deployment scenario:
  - 26 sites within the -1dB contour, 41 sites within the -3dB contour and 200 sites within the -10 dB contour (for 62 dBm with 15 dB antenna discrimination)
  - 41 sites within the -1dB contour, 66 sites within the -3dB contour and 330 sites within the -10 dB contour (for 75 dBm with 30 dB antenna discrimination)
- These values correspond to about 0.003 UMFU base stations per km^2
- Even if 90% of the UMFU sites add negligible interference levels (located indoors, signals blocked, high diffraction loss towards satellite, etc.); the interference from a deployment density of <u>0.03 UMFU</u> base stations per km^2 would result in a significant degradation to OneWeb

The Solution – Reasonable EIRP Density Limits

- Even a modest deployment of UMFU base stations (e.g., 0.03 sites per km^2) with 10% of these having clear line-of-sight to the FSS satellites can cause significant increase in noise floor and reduce link margins (see Annex for interference calculations into GSO)
- The area covered by the -1 dB contour of various satellites is 9000 km^2 (case for OneWeb or Viasat) and reaching 30000 km^2 (-3 dB), so as depicted in Slide 4, the likelihood of a few hundred sites with visibility to the satellite is quite high
- To avoid uplink interference into OneWeb satellites, an off-axis EIRP density mask should be applied to the UMFU base stations and subscriber units
- As demonstrated in the next slide (and the figure on slide 22 in the annex), a reasonable antenna mask results in a maximum EIRP density which would help protect the OneWeb satellites and may also be effective in reducing interference into GSO satellites

Calculations of required UMFU antenna gain

		Calculations with EIRP = 62 dBm			Calculations with EIRP = 75 dBm			OneWeb Beam at EOC (15 deg elev.)			OneWeb Beam at EOC (15 deg elev.)		
		Class 1	Class 2	Class 3 [2]	Class 1	Class 2	Class 3 [2]	Beam 1dB	Beam 3dB	Beam 10dB	Beam 1dB	Beam 3dB	Beam 10dB
elev angle	degrees	15	15	5	15	15	5	15	15	15	15	15	15
Sat Noise temp	K	1000	650	570	1000	650	570	440	440	440	440	440	440
distance [1]	km	36000	36000	8000	36000	36000	8000	2762	2762	2762	2762	2762	2762
FSS Noise density	dBm/Hz	-168.6	-170.5	-171.0	-168.6	-170.5	-171.0	-172.2	-172.2	-172.2	-172.2	-172.2	-172.2
FSS sat Rx gain	dBi	60	60	28	60	60	28	36	34	27	36	34	27
5G AP gain	dBi	23	23	23	29	29	29	23	23	23	29	29	29
Tx power	dBm	39	39	39	46	46	46	39	39	39	46	46	46
FSL	dB	-212.4	-212.4	-199.3	-212.4	-212.4	-199.3	-190.1	-190.1	-190.1	-190.1	-190.1	-190.1
other losses	dB	-4	-4	-4	-4	-4	-4	-4	-4	-4	-4	-4	-4
gain red to sat	dB	-25.0	-25.0	-15.0	-38.0	-38.0	-25.0	-25.0	-25.0	-25.0	-38.0	-38.0	-38.0
I (LoS single entry)	dBm	-119.4	-119.4	-128.3	-119.4	-119.4	-125.3	-121.1	-123.1	-130.1	-121.1	-123.1	-130.1
ratio (LOS/total)		100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
Interf. Reduction	dB	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Io (interference density)	dBm/Hz	-199.4	-199.4	-208.3	-199.4	-199.4	-205.3	-201.1	-203.1	-210.1	-201.1	-203.1	-210.1
I/N = Io/No	dB	-30.8	-28.9	-37.3	-30.8	-28.9	-34.3	-28.95	-30.95	-37.95	-28.95	-30.95	-37.95
Number of UMFU sites	I/N=-12.2dB	73	47	324	73	47	162	47	75	375	47	75	375
Number of UMFU sites	I/N=0 dB	1206	784	5379	1206	784	2696	784	1243	6231	784	1243	6231

261+414+2077 = 2753 total

[1] *The O3b and OneWeb cases consider a single instant in time at a particular elevation angle to illustrate the impact at that point in time*

- Improved results compared to slide 5 and Annex
- Does not guarantee interference-proof FSS operations, but reduces levels
- May require UMFU to reduce power, increase bandwidth or increase downtilt

Provides a more equitable solution – burden sharing

Summary of results

- Specifying a reasonable antenna mask (or EIRP density as a function of elevation angle) in FCC rules would allow co-existence with FSS while not constraining deployment of UMFU stations
- With improved UMFU base station antennas that can easily be implemented as demonstrated by the terrestrial proponents, such an EIRP mask can be effortlessly achieved
- Combining these figures into a possible UMFU deployment scenario:
  - 261 sites within the -1dB contour, 414 sites within the -3dB contour and 2077 sites within the -10 dB contour all contributing to the aggregate interference levels into OneWeb satellites
- If 90% of the UMFU sites do not contribute significantly to the FSS interference (as discussed before), the total number of sites could be increased ten-fold, resulting in an average deployment density of 0.3 UMFU base stations per km^2 before the aggregate interference reaches the unacceptable level
- OneWeb can minimize interference by placing gateways outside major populated areas (outside cities)

Conclusions

- FCC should adopt a maximum EIRP mask per UMFU base station which is a function of elevation angle above local horizon; we propose:

EIRP (5-15° elevation)	EIRP (15-25° elevation)	EIRP (>25° elevation)
50 dBm/100 MHz	37 dBm/100 MHz	32 dBm/100 MHz

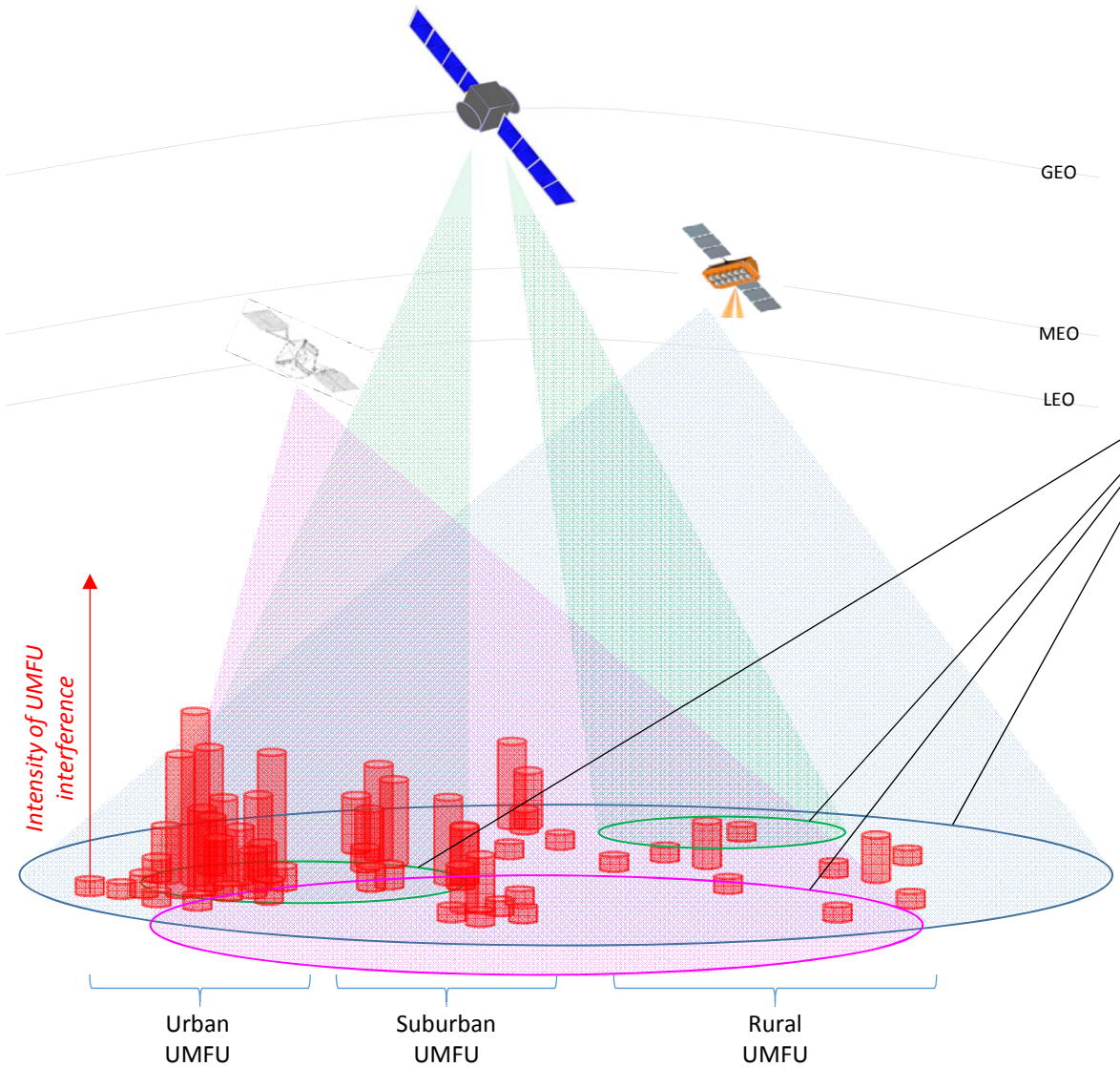
* FCC should limit the transmit power to 10 dBW (40 dBm) per station in accordance with No. 21.5 of the ITU Radio Regulations

- Such a mask will not ensure protection of FSS satellite receivers, but dramatically reduces the probability of harmful interference
- An EIRP density mask does not add a significant burden on terrestrial UMFU operations, as it can be met through a combination of:
  - Better antenna sidelobes
  - Reduced transmit power (noting that 46 dBm/100 MHz proposed for the larger UMFU antenna array violates the ITU Radio Regulations)
  - Increased bandwidth at a given power level
  - Antenna downtilt

Annex

Detailed Analysis

UMFU Aggregate Interference Scenario



FSS satellites operate at various altitudes

- GEO: 35,786 km
- MEO: e.g. 8,000 km
- LEO: e.g. 1,200 km

Satellite receive beams in 28 GHz have an area of 31,000 km^2 up to 1,756,000 km^2

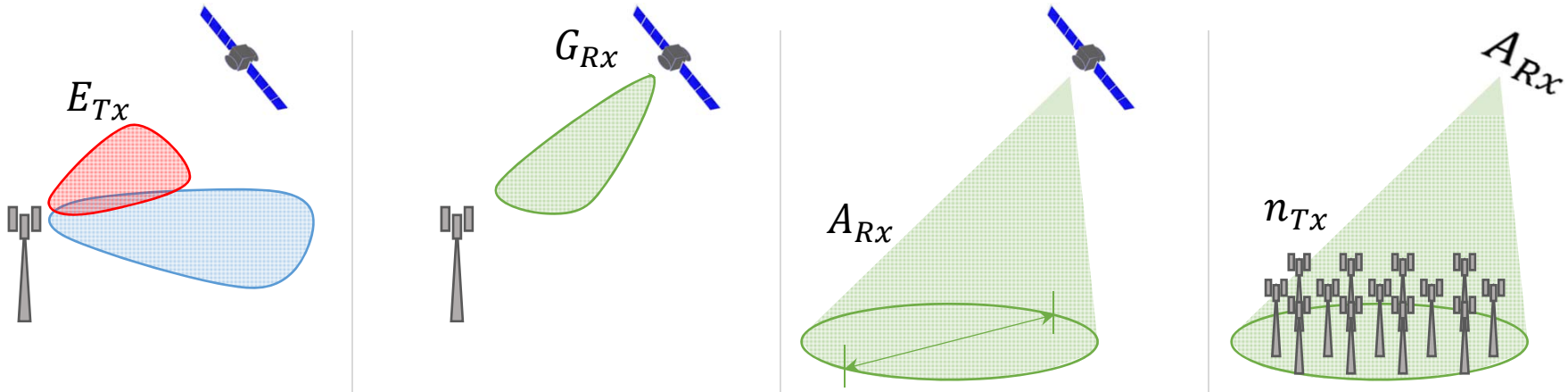
UMFU deployment assumptions:

- Deployment density from 1 BS to 10 BS per km^2

The Challenge
FSS satellites, at any orbit, will receive aggregated UMFU interference potentially from urban, suburban and rural deployments

UMFU and FSS parameters that drive the compatibility between the two services

Four fundamental parameters that drive the interference (Isat) from UMFU into FSS:



EIRP of the UMFU in direction of FSS satellite

Gain of the satellite antenna in the direction of the UMFU

Area of the satellite antenna receive beam on the Earth

Number of transmitting UMFUs within area, A_{Rx}

I_{sat} is proportional to each of the variables meaning an increase any value on the right side of equation results in an increased I_{sat}.

$$I_{sat} \text{ α } E_{Tx} \times n_{Tx}(A_{Rx}) \times G_{Rx}$$

FSS is deployed and in operation, so A_{Rx} and G_{Rx} values are fixed for in-orbit systems.

The E_{Tx} and n_{Tx} of UMFUs in a given area are the future systems that can be carefully designed to be compatible with FSS satellite receivers without unduly constraining either service

FSS satellite parameters and calculation methodology

- Satellite parameters vary amongst FSS operators
  - Satellite noise temperature: 440 K – 1300 K
  - Peak receive antenna gain: 36 dBi – 61 dBi
  - Orbit altitude: 1200 km – 36000 km
  - Area of satellite receive beam (-3 dB contour): 31000 km^2 – 1756000 km^2
- FSS Protection criteria
  - 6% increase in noise floor → $I_{UMFU}/N_{thermal} < -12.2$ dB is valid for uplink thermal noise-limited FSS systems
  - Certain systems that are not limited by their uplink thermal noise can tolerate higher levels of UMFU interference
- The maximum permissible aggregate interference from UMFU emissions into FSS satellite receivers is determined using the parameters above
  - The area of the satellite receive beams varies and various UMFU deployment scenarios are used to determine the allowable per station EIRP mask
  - The resulting EIRP density is expressed as an UMFU EIRP mask in dBm/MHz for several elevation angles above the horizon

Annex – Detailed calculations worksheet

1	elev angle	degrees	15	minimum angle of FSS operation
2	Sat Noise temp	K	440	specific to FSS satellite
3	distance [1]	km	2762	for OneWeb - calculated per row 1 angle
4	FSS Noise density	dBm/Hz	-172.2	-228.6 + 30 + 10 log (row 2)
5	FSS sat Rx gain	dBi	36	specific to FSS satellite
6	5G AP gain	dBi	23	provided in Nokia study
7	Tx power	dBm	39	provided in Nokia study
8	FSL	dB	-190.1	92.5 + 20 log (27.5) + 20 log (row 3)
9	other losses	dB	-4	3dB for polarization discrimination; 1 dB other
10	gain red to sat	dB	-25.0	Key parameter: depends on UMFU antenna
11	I (LoS single entry)	dBm	-121.1	SUM of rows 5 to 10
12	ratio (LOS/total)		100%	100% LOS to find minimum UMFU deployment
13	Interf. Reduction	dB	0.0	10 log (row 12)
14	Io (interference density)	dBm/Hz	-201.1	row 11 - 10 log (100 MHz) + row 13
15	I/N = Io/No	dB	-28.95	row 12 - row 4
16	Number of UMFU sites	I/N=-12.2dB	47	10 ^ ((-12.2 - row 15)/10)
17	Number of UMFU sites	I/N=0 dB	784	10 ^ ((0 - row 15)/10)
	Number of sites in contour		261	row 17/3 (to combine -1dB, -3dB and -10dB figures)
	contour area	km2	9000	9000 for -1dB, 17000 for -3dB, 50000 for -10dB
	density		0.0291	row 18/row 19 - density of LOS, unobstructed UMFU

Replicating the Nokia Study – Interference into FSS Receivers

Exhibits			Nokia calcs with EIRP = 62 dBm			Nokia calcs with EIRP = 75 dBm		
			Class 1	Class 2	Class 3 [2]	Class 1	Class 2	Class 3 [2]
Exhibit B-2	elev angle	degrees	15	15	5	15	15	5
	Sat Noise temp	K	1000	650	570	1000	650	570
	distance [1]	km	36000	36000	8000	36000	36000	8000
	FSS Noise density	dBm/Hz	-168.6	-170.5	-171.0	-168.6	-170.5	-171.0
	FSS sat Rx gain	dBi	58	58	27	58	58	27
Exhibit B-3	5G AP gain	dBi	23	23	23	29	29	29
	Tx power	dBm	39	39	39	46	46	46
	FSL	dB	-212.4	-212.4	-199.3	-212.4	-212.4	-199.3
	other losses	dB	-4	-4	-4	-4	-4	-4
Exh. B-8 & B-13	gain red to sat	dB	-34.0	-34.0	-22.0	-48.0	-48.0	-29.0
Exhibit B-9	I (LoS single entry)	dBm	-130.4	-130.4	-136.3	-131.4	-131.4	-130.3
Exhibits B-10 (for 62 dBm) and B-11 (for 75 dBm)	ratio (LOS/total)		50%	50%	50%	50%	50%	50%
	Interf. Reduction	dB	-3.0	-3.0	-3.0	-3.0	-3.0	-3.0
	Io (interference density)	dBm/Hz	-213.4	-213.4	-219.3	-214.4	-214.4	-213.3
	I/N = Io/No	dB	-44.8	-42.9	-48.3	-45.8	-43.9	-42.3
	Number of UMFU sectors	I/N=-12.2dB	1811	1177	4050	2280	1482	1017
	Number of UMFU sectors	I/N=0 dB	30059	19539	67209	37842	24598	16882

[1] *The O3b case considers a single instant in time at a particular elevation angle to illustrate the impact at that point in time*
[3] *These are the satellite orbital height (above Earth) and actual distance will be slightly larger*

Results are similar to June 1 ex-parte (Exhibits B-10 and B-11)

Average and Mean = Smoke and Mirrors

- Nokia interference analysis based on “average” or ”mean” interference
  - Mean UMFU antenna gain, and resulting mean EIRP, do not indicate potential for interference from fewer UMFU stations located directly in satellite main beam and radiating higher levels of interference towards the satellite
  - Average levels of interference are computed using the mean gain[1] of many hundreds of UMFU base stations, and the mean gain of 3 or 4 sectors[2] per base station

    [1] per June 1st, Joint Filers ex-parte, exhibits B-8 and B-9

    [2] per exhibits B-10 and B-11, however not clear how many sectors are assumed
  - 50% LOS/50% NLOS may only be justified when interference comes from several hundred or thousand of UMFU base stations located in populated urban areas
  - Satellite receive gain using the -3dB contour may be justified for the aggregate impact of several hundred or thousand of UMFU stations, but not for smaller numbers
- The worst interference situations occur when a few UMFU stations located in FSS main beam have line-of-sight to the satellite
  - Maximum UMFU EIRP must be used and free-space loss assumed
  - Satellite near peak gain (-1 dB) is justified due to small number of interfering UMFU stations

Realistic interference results

- Nokia “average” or ”mean” calculations underestimate interference
- This analysis uses the same methodology but assesses impact of the worst few UMFU base stations (much less than 100)
  - Main difference is the UMFU antenna gain towards the satellites at the stated elevation angles:
    - Exhibits B-8, B-10 and B-13 indicate a <u>mean</u> gain discrimination of -34 dB (at 15°) and -22 dB (at 5°) for the 64-element array (EIRP = 62 dBm)
    - Exhibit B-7 indicate <u>worst-case</u> gain reduction of -15 dB (red and black curves in the 15-20 degree range) and -5 dB (in the 5-10 degree range)
    - Exhibits B-8, B-10 and B-13 indicate a <u>mean</u> gain discrimination of -48 dB (at 15°) and -29 dB (at 5°) for the 256-element array (EIRP = 75 dBm)
    - Exhibit B-7 indicate a <u>worst-case</u> reduction of -30 dB (green curve in the 15-20 degree range) and -10 dB (in the 5-10 degree range)
  - 100% LOS scenario is justified when interference comes from only a few (less than a hundred) UMFU base stations
  - The use of the near peak satellite gain (-1 dB contour) is justified since number of interfering UMFU sources is small

Nokia Study – Revised for worst-case interference

Exhibits			Calculations with EIRP = 62 dBm			Calculations with EIRP = 75 dBm		
			Class 1	Class 2	Class 3 [2]	Class 1	Class 2	Class 3 [2]
Exhibit B-2	elev angle	degrees	15	15	5	15	15	5
	Sat Noise temp	K	1000	650	570	1000	650	570
	distance [1]	km	36000	36000	8000	36000	36000	8000
	FSS Noise density	dBm/Hz	-168.6	-170.5	-171.0	-168.6	-170.5	-171.0
	FSS sat Rx gain	dBi	60	60	28	60	60	28
Exhibit B-3	5G AP gain	dBi	23	23	23	29	29	29
	Tx power	dBm	39	39	39	46	46	46
	FSL	dB	-212.4	-212.4	-199.3	-212.4	-212.4	-199.3
	other losses	dB	-4	-4	-4	-4	-4	-4
estimated (Exh B-7)	gain red to sat	dB	-15.0	-15.0	-5.0	-30.0	-30.0	-10.0
	I (LoS single entry)	dBm	-109.4	-109.4	-118.3	-111.4	-111.4	-110.3
Similar to	ratio (LOS/total)		100%	100%	100%	100%	100%	100%
Exhibits B-10	Interf. Reduction	dB	0.0	0.0	0.0	0.0	0.0	0.0
(for 62 dBm)	Io (interference density)	dBm/Hz	-189.4	-189.4	-198.3	-191.4	-191.4	-190.3
and B-11	I/N = Io/No	dB	-20.8	-18.9	-27.3	-22.8	-20.9	-19.3
(for 75 dBm)	Number of UMFU sites	I/N=-12.2dB	7	5	32	12	7	5
	Number of UMFU sites	I/N=0 dB	121	78	538	191	124	85

[1] *These are the satellite orbital height (above Earth) and actual distance will be slightly larger*

[2] *The O3b case considers a single instant in time at a particular elevation angle to illustrate the impact at that point in time*

Results are much worse than ex-parte (Exhibits B-10 and B-11)

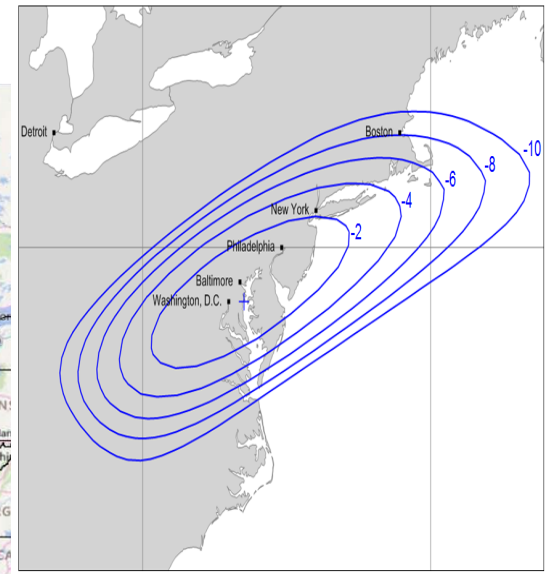
Impact of worst-case interference

- As few as 5 UMFU base stations transmitting at 62 dBm or 75 dBm per 100MHz would cause a 6% increase in uplink thermal noise of certain GSO satellites or the MEO satellite
  - Refer to slide 21, many more than 5 UMFU stations will be located in the -1dB contour of the GEO satellites, and many of these can have direct line-of-sight to the satellites that are at 15 degrees or more above the horizon.
- Even if a satellite network could accommodate a 100% increase in uplink thermal noise, 80 to 120 UMFU base station would cause a 0 dB I/N level, and this number of sites will most likely be exceeded within the satellite (-1 dB) footprint
- Specifying a maximum EIRP (or maximum EIRP density per 100 MHz) is not sufficient to protect the FSS satellite receivers
  - FCC needs to adopt an EIRP density which is a function of elevation angle
  - It cannot expect the UMFU industry to take protective measures on its own

GSO FSS Satellite Beams

Examples of GSO satellite beams clearly showing large coverage area of their -1dB contour (used in the previous calculations)

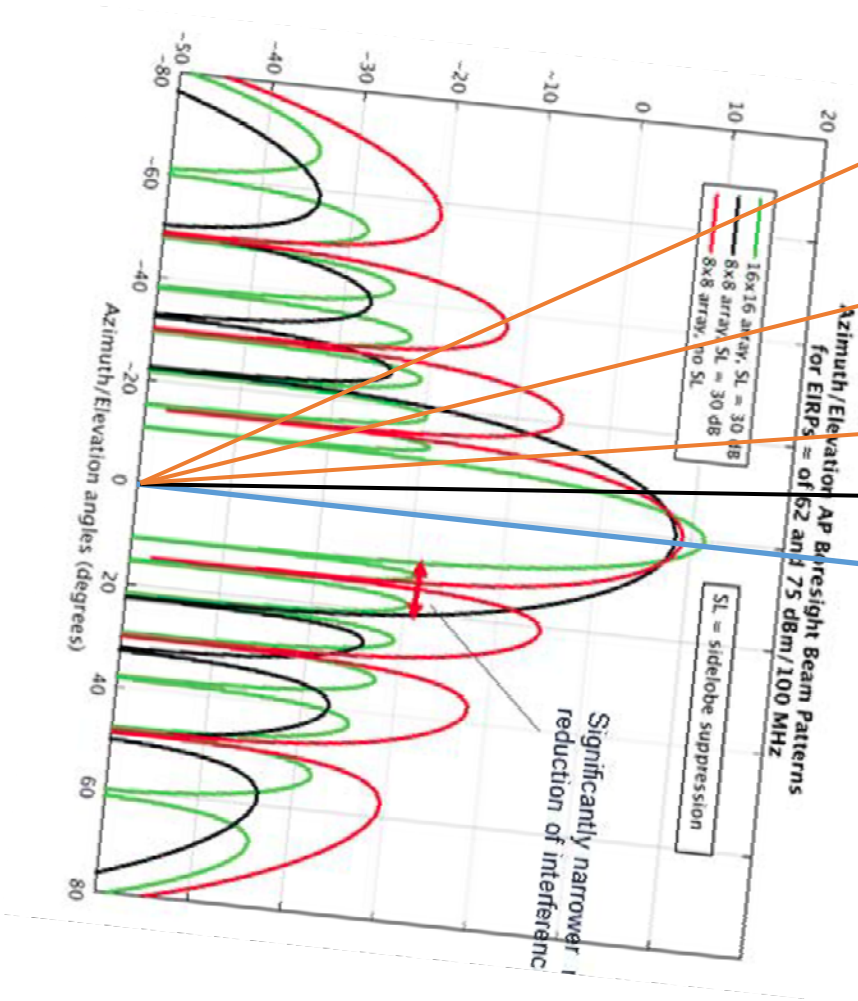
SES-15 beams (-2, -4, -6, -8, -10dB)



Viasat beams (-2, -4, -6, -8, -10 and -20dB)

The Solution? Impose reasonable constraints on UMFU

Adopt maximum Gain/EIRP as a function of elevation angle



>25° angle

15° angle

5° angle

8by8 array: -30 dB
16x16 array: -43 dB

8by8 array: -25 dB
16x16 array: -38 dB

8by8 array: -15 dB
16x16 array: -25 dB

Local horizon

6° downtilt

The antenna pattern is that contained in Exhibit B-7 of the Joint Filers June 1st letter