May 12, 2016

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

Re: *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

Dear Ms. Dortch:

On May 11th, 2016, AT&T Services Inc., ("AT&T"), Nokia ("Nokia"), Samsung Electronics America ("Samsung"), T-Mobile USA, Inc. ("T-Mobile") and Verizon ("Verizon") met with members of the Wireless Telecommunications Bureau, the International Bureau and the Office of Engineering and Technology to discuss the above-referenced proceeding. A full list of attendees at this meeting is attached hereto as Exhibit 1.

In this meeting, Nokia presented the results of its preliminary simulation to assess potential interference between terrestrial mobile broadband (fifth generation or "5G") and Fixed Satellite Service ("FSS") systems sharing the 28 GHz band. The discussion followed closely with the presentation that is attached as Exhibit 2.

Pursuant to the Commission's rules, this notice is being filed in the above-referenced docket for inclusion in the public record. Please contact me should you have any questions.

Respectfully submitted,

/s/ Stacey Black
Assistant Vice President – Federal Regulatory
AT&T Services, Inc.

/s/ Prakash Moorut
Spectrum Lead, North America
Nokia

/s/ John Hunter
Senior Director, Engineering & Technology Policy
T-Mobile USA, Inc.

/s/ Sanyogita Shamsunder
Director, Network Planning,
Verizon

/s/ Robert Kubik
Director, Public Policy, Engineering and Technology
Samsung Electronics America

EXHIBIT 1

Meeting Attendees

Wireless Telecommunications Bureau
- Charles Oliver
- Brian Regan
- Chris Helzer
- Matthew Pearl
- John Schauble
- Simon Banyai
- Stephen Buenzow (by phone)
- Tim Hilfiger (by phone)
- Nancy Zaczek (by phone)
- Catherine Schoedeer (by phone)

International Bureau
- Robert Nelson
- Jose Albuquerque

Office of Engineering and Technology
- Julius Knapp
- Michael Ha
- Nicholas Oros

AT&T
- Stacey Black
- Neeti Tandon
- Jack Wengryniuk (by phone)

Nokia
- Prakash Moorut (by phone)
- Eugene Visotsky (by phone)
- Jeffrey Marks

Samsung
- Rob Kubik

T-Mobile
- John Hunter

Verizon
- Charla Rath
- Greg Romano
- Sanyogita Shamsunder (by phone)
- Vishwanath Ramamurthi (by phone)

EXHIBIT 2

Presentation: FSS and 5G Coexistence Analysis at 28GHz
System-level Simulation results

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Nokia Networks

FSS and 5G Coexistence Analysis at 28GHz

System-level Simulation results

Eugene Visotsky, Kamil Bechta, Prakash Moorut

Nokia - Bell Labs

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Outline

- Interference from FSS towards 5G
- Interference from 5G APs towards FSS
- Interference from 5G UEs towards FSS

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Preliminaries
Definition of 5G protection criterion at the system level

- Link-level protection criterion:

  A 5G link (DL or UL) is "protected" from FSS Earth Station interference if $I_{FSS}/N_{thermal} < TH\ (dB)$, where $N_{thermal}$ includes NF (5 dB)

  - ➢ Results are generated for $TH = -12.2,\ -6,\ 0\ dB$

- System-level protection distance criterion:
  - ➢ Minimum distance between an FSS Earth Station and the ***nearest*** 5G AP, such that 95% of the DL/UL links attached to the ***nearest*** 5G AP are "protected"

- How should FSS earth station be positioned/oriented relative to the 5G system?
  - ➢ *For the current results, FSS Earth Station is pointed at the center of the 5G system layout*

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Evaluation scenario and methodology

Simulation parameters		Comments
Methodology	• FSS transmitter placed at a certain distance away from the 5G system edge • FSS transmitter in azimuth is pointing at the center of the 5G system layout • 5G UL interference calculations are averaged over many FSS transmitter positions around the 'victim' 5G system and the 5G UEs attached to the AP nearest to the FSS Earth Station	• Statistical methodology • Output is the percentage of UL links with satisfied 5G protection criterion attached to the AP *nearest* to the FSS Earth Station as a function of the FSS distance to that site • FSS Earth Station antenna pattern in the horizontal plain is displayed in the following slides
5G System layout	3GPP-defined 19-site (57 sectors) system, ISD = 200m	Shown on the next slide
5G AP antenna configuration	• 64 (8x8) cross-polarized elements • Element antenna gain =5 dBi	• Total number of elements = 128 • Max AP array gain = 23 dBi • 4-bit azimuth and 4-bit elevation codebooks used for steering the array at the AP
FSS-to-5G AP pathloss model	Free space pathloss + 20 dB additional attenuation	
5G AP receiver NF	5 dB	
5G AP antenna height	10m AGL	3GPP Urban Micro (UMi) scenario

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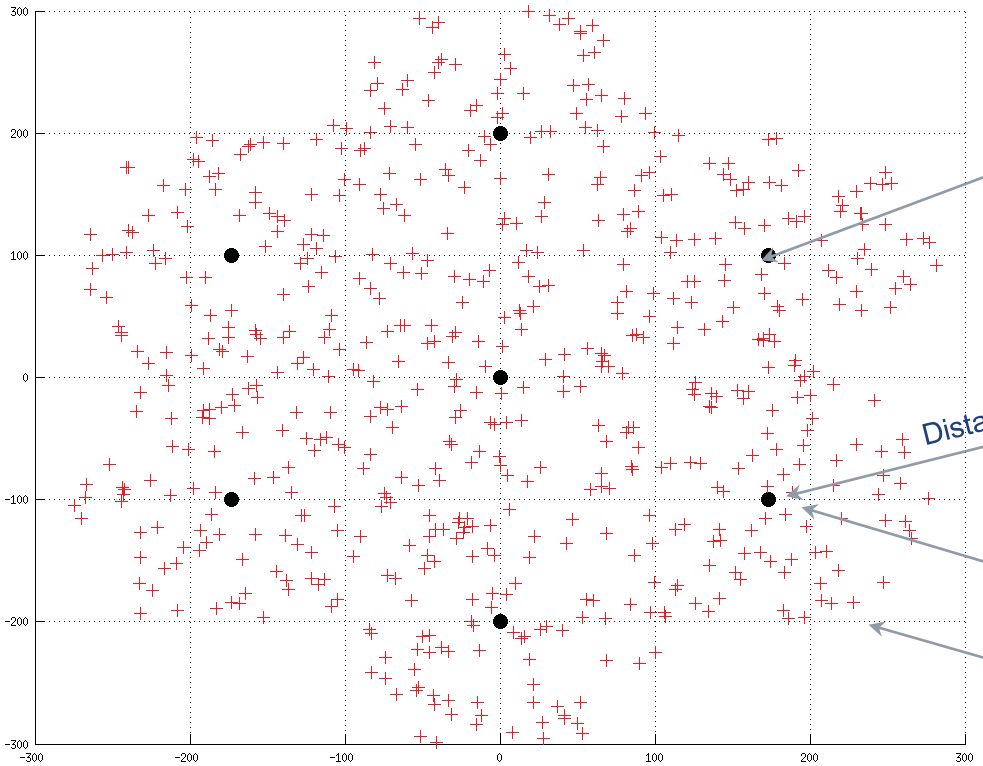
5G System layout example (7-sites)



System layout stats:
AP density = 29 APs/km^2
ISD = 200 m

5G APs (3 sectors)

Distance from system edge

FSS Transmitter

AP nearest to the FSS Earth Station ('***Victim***' AP)

UEs (90 UEs per AP)

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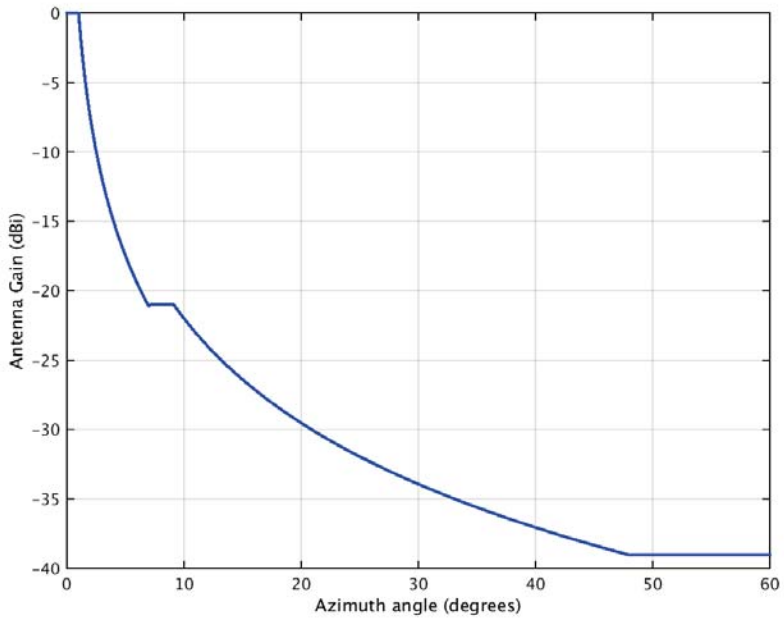
FSS Earth Station parameters

Parameter	Value
EIRP density towards horizon (dBm/MHz)	12.2 (Class 1), 24.1 (Class 2), 48.0 (Class 3)
Antenna height	10m AGL

FSS Earth Station pattern in the azimuth plane



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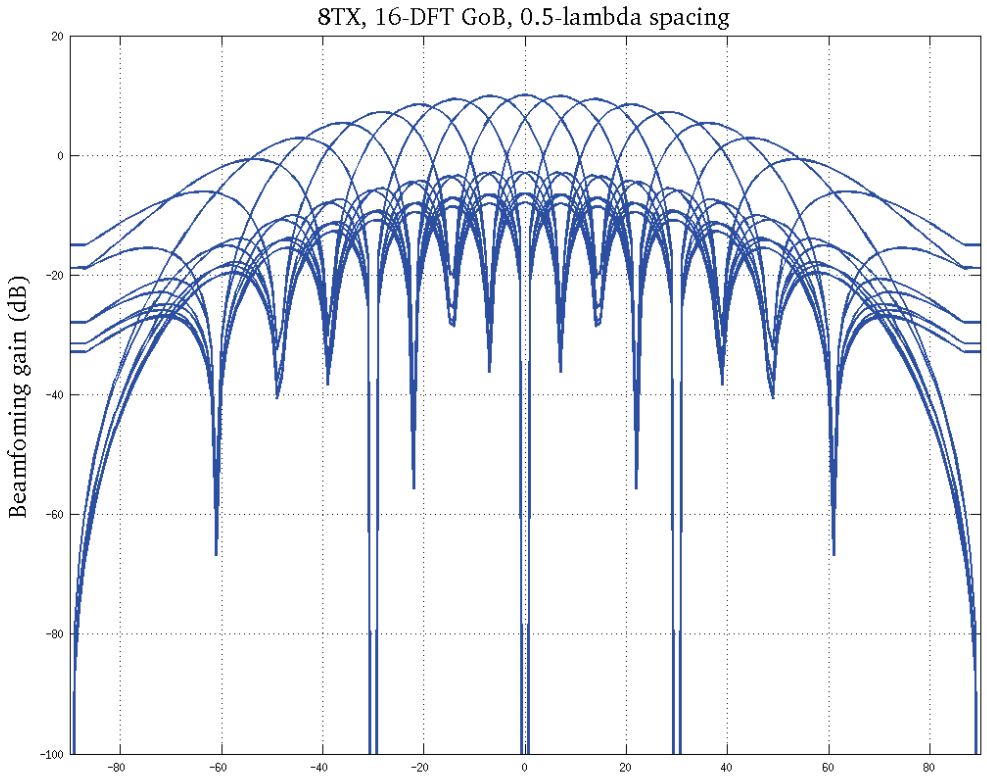
5G AP Antenna Pattern



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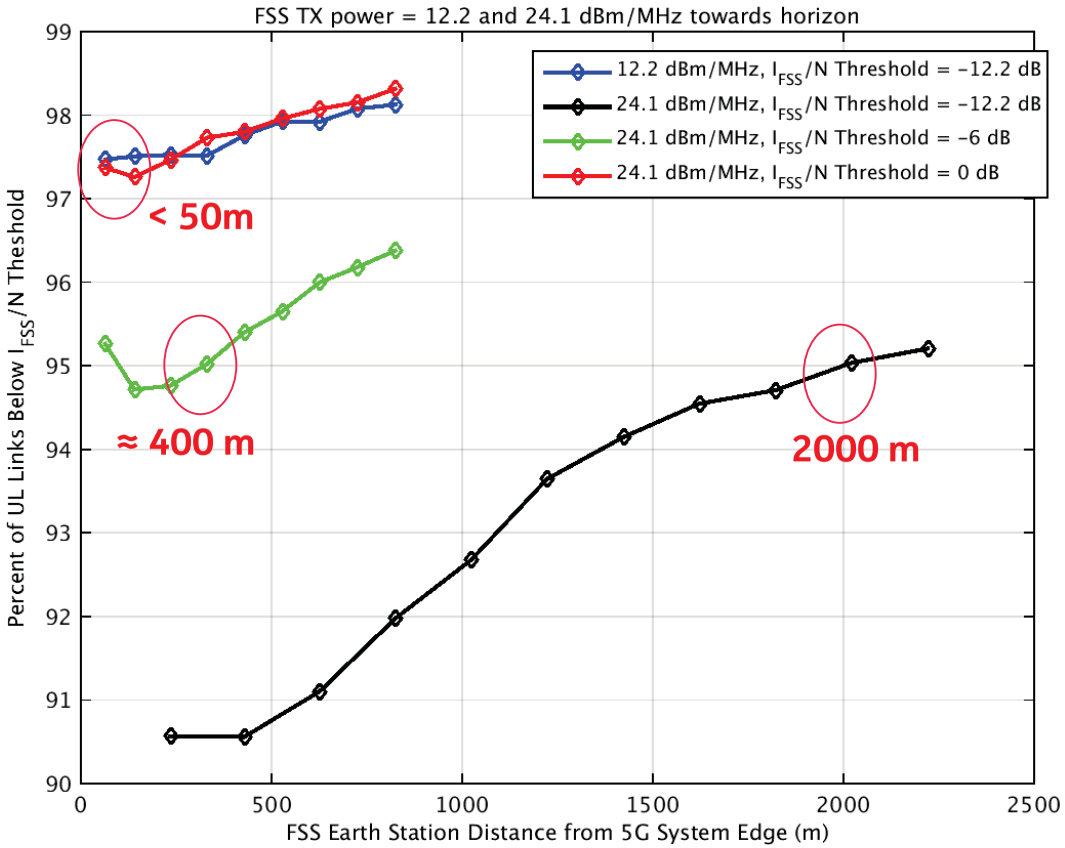
Initial simulation results for Class 1 and Class 2 Earth Stations



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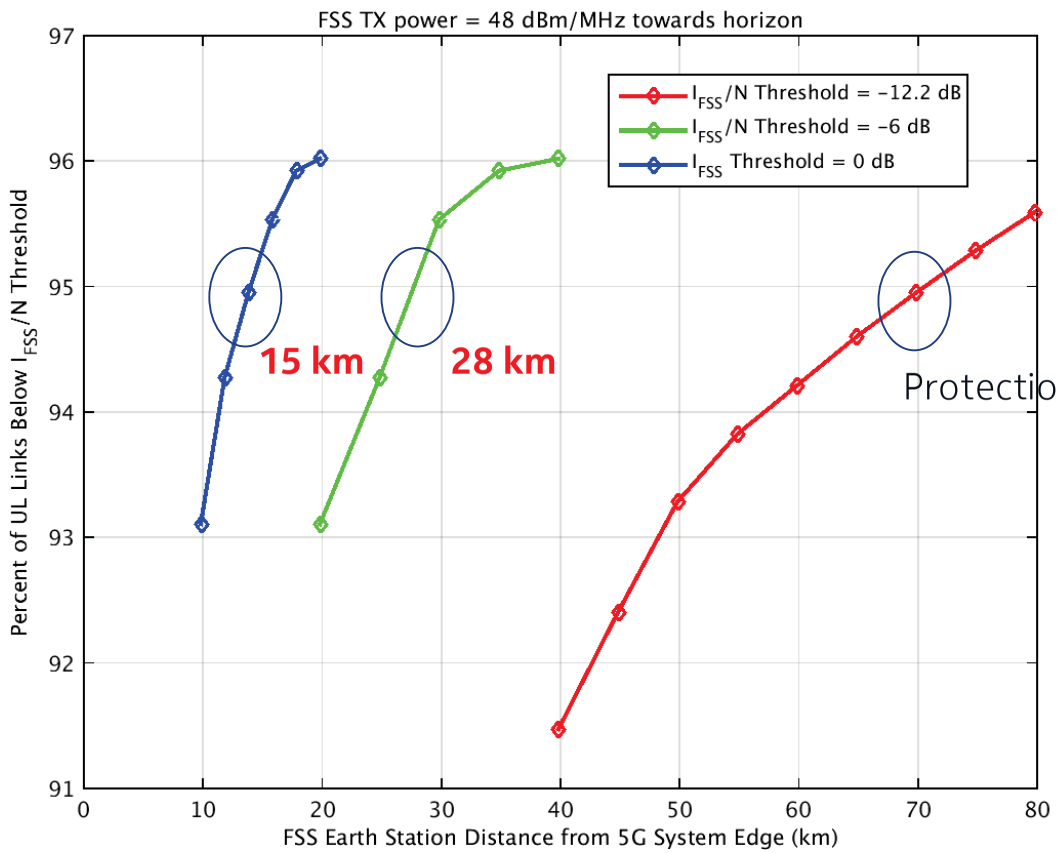
Initial simulation results for Class 3 Earth Stations



Protection distance ≈ **70 km!**

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Results summary

Earth Station Class	Required UL Protection Distance		
	$TH = -12.2\ dB$	$TH = -6\ dB$	$TH = 0\ dB$
Class 1	< 50 m	< 50 m	< 50 m
Class 2	1500 m	400 m	< 50 m
Class 3	70 km	28 km	15 km

Observations

- Co existence results sensitive to system protection thresholds
- Range of co ordination distances dependent upon the earth station class type.

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Next Steps

- Alternative channel model (cmWave AP-AP)

Link direction	AP-to-UE		AP-to-AP		UE-to-UE	
Link type	LOS	NLOS	LOS	NLOS	LOS	NLOS
Path Loss Exponent n	2.1	3.3	2.1	3.5	2.1	3.3
Shadow Fading X	4.9 dB	7.6 dB	4.2 dB	7.9 dB	5.0 dB	7.6 dB

$$PL[dB](d) = 20\log_{10}\left(\frac{4\pi d_o}{\lambda}\right) + 10n\log_{10}(d/d_o) + X$$

  - LoS vs. NLoS probability according to 3GPP UMa/RMa

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Outline

- Interference from FSS towards 5G
- Interference from 5G APs towards FSS
- Interference from 5G UEs towards FSS

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Preliminaries

- FSS protection criterion: $I_{5G}/N_{thermal} < -12.2\ dB$

  NT = 650K: $N_{thermal} = -198.6 + 10\log_{10} 650 = -170.5\ dBm/Hz \Rightarrow \boldsymbol{I_{5G} < -183\ dBm/Hz}$

  NT = 1000K: $N_{thermal} = -198.6 + 10\log_{10} 1000 = -168.6\ dBm/Hz \Rightarrow \boldsymbol{I_{5G} < -181\ dBm/Hz}$

- Space Station Parameters

Earth Station Class	Parameter	Value
Class 1	Elevation angle (degrees)	30
	Orbit distance (km)	36000
	Max Space Station antenna gain (dBi)	60 (***57 dBi used***)
Class 2	Elevation angle (degrees)	14.6
	Orbit distance (km)	36000
	Max Space Station antenna gain (dBi)	60 (***57 dBi used***)
Class 3	Elevation angle (degrees)	5
	Orbit distance (km)	1000
	Max Space Station antenna gain (dBi)	30 (***27 dBi used***)

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Evaluation scenario and methodology

Simulation parameters		Comments
Methodology	Average receiver power (dBm/Hz) ***per sector*** is computed at the space station receiver Average receive power is calculated by averaging over all DL transmissions in the system	• Given an interference protection criterion, this can be used to compute the number of ***simultaneously*** active sectors • Needs to be translated to AP density under certain assumptions
5G System layout	3GPP-defined 19-site (57 sectors) system, ISD = 200m	
5G AP antenna configuration	• 64 (8x8) cross-polarized elements • Element antenna gain =5 dBi • ***12 degree mechanical downtilt***	• Total number of elements = 128 • Max AP array gain = 23 dBi • 4-bit azimuth and 4-bit elevation codebooks used for steering the array at the AP • Codebooks are DFT vector-based with ***side-lobe control***
5G AP-to-FSS (space station) pathloss model	NLoS: Free space pathloss + ***20 dB + 4 dB*** LoS: Free space pathloss + ***4 dB***	• 20 dB models NLoS clutter and ***vegetation*** losses • 4 dB models 1 dB atmospheric loss + 3 dB polarization loss
5G AP TX power	***39 dBm/100 MHz/per sector (EIRP = 62 dBm/100 MHz)***	

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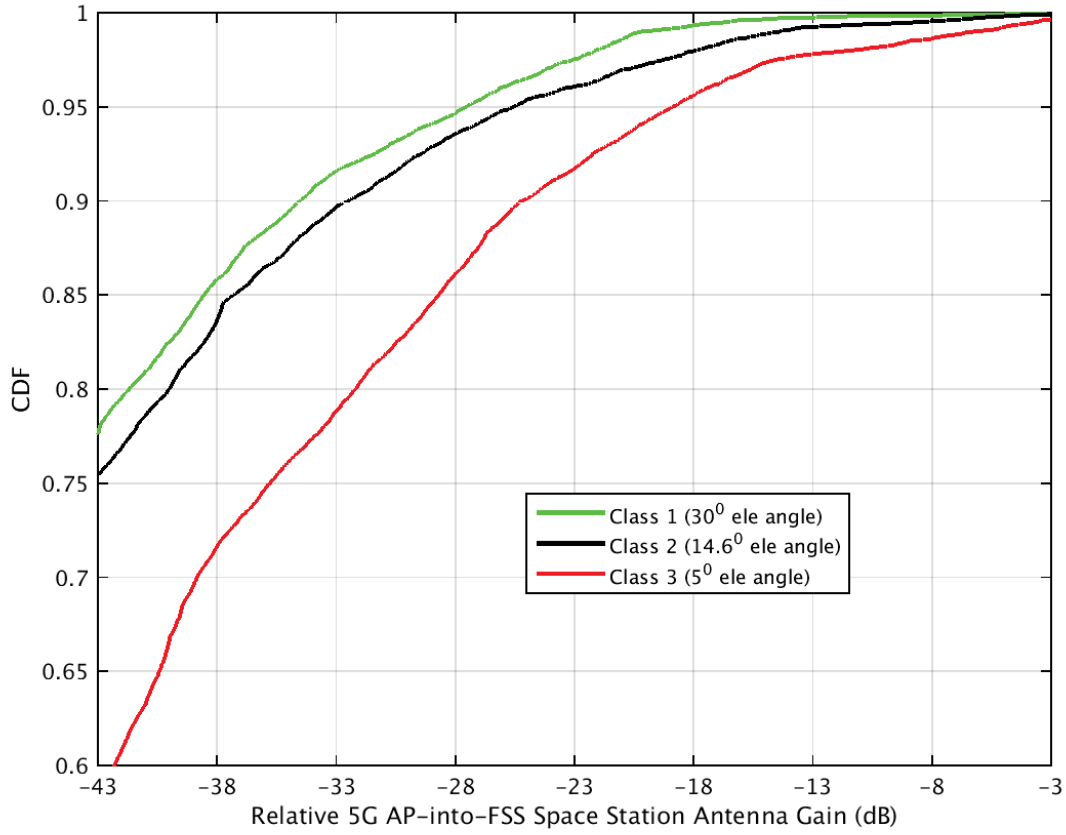
5G AP into FSS antenna gains



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Preliminary results - Number of simultaneously transmitting 5G sectors

Earth Station Class, 5G AP -> FSS LoS/NLoS channel mix	Average normalized antenna gain towards the Space Station (dB)	Average receive power (dBm/Hz) at Space Station from a single 5G sector	Number of *simultaneously* transmitting 5G sectors					
			NT = 650K			NT = 1000K		
			$TH = -12.2\ dB$	$TH = -6\ dB$	$TH = 0\ dB$	$TH = -12.2\ dB$	$TH = -6\ dB$	$TH = 0\ dB$
Class 1, Rural/Urban (50% LoS/50% NLoS)	-47 dB	-223 dBm/Hz	~11300	~45200	~180800	~17900	~71600	~286400
Class 1, Urban (25% LoS/75% NLoS)		-226 dBm/Hz	~22500	~90000	~360000	~35600	~142400	~569600
Class 1, Urban (10% LoS/90% NLoS)		-230 dBm/Hz	~56600	~226400	~905600	~89700	~358800	~1435200
Class 2, Rural/Urban (50% LoS/50% NLoS)	-35 dB	-213 dBm/Hz	~1100	~4400	~17600	~1700	~6800	~27200
Class 2, Urban (25% LoS/75% NLoS)		-216 dBm/Hz	~2300	~9200	~36800	~3600	~14400	~57600
Class 2, Urban (10% LoS/90% NLoS)		-220 dBm/Hz	~5700	~22800	~91200	~9000	~36000	~144000
Class 3, Rural /Urban(50% LoS/50% NLoS)	-22 dB	-211 dBm/Hz	~700	~2800	~11200	~1100	~4400	~17600
Class 3, Urban (25% LoS/75% NLoS)		-214 dBm/Hz	~1400	~5600	~22400	~2200	~8800	~35200
Class 3, Urban (10% LoS/90% NLoS)		-218 dBm/Hz	~3600	~14400	~57600	~5700	~22800	~91200

Assumptions: AP downtilt = 12 degrees, side-lobe suppression, NLoS probability > 50% which accounts for the vegetation/foliage loss

Note:

- A realistic network loading factor will increase total # of active 5G APs that can be supported

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Outline

- Interference from FSS towards 5G
- Interference from 5G APs towards FSS
- Interference from 5G UEs towards FSS

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Evaluation scenario and methodology

Simulation parameters		Comments
Methodology	Average receiver power (dBm/Hz) ***per UE*** is computed at the space station receiver Average receive power is calculated by averaging over all UL UE transmissions in the system ***Only outdoor UEs are considered***	• Given an interference protection criterion, this can be used to compute the number of ***simultaneously*** active ***outdoor*** UEs • Results translated into the total number of UL active UEs in the system
5G System layout	3GPP-defined 19-site (57 sectors) system, ISD = 200m	
5G UE antenna configuration	• 16 (4x4) cross-polarized elements • Element antenna gain =5 dBi • ***0 degree mechanical downtilt*** • ***Optimized orientation in azimuth towards the serving sector***	• Total number of elements = 32 • Max UE array gain = 17 dBi • 3-bit azimuth and 3-bit elevation codebooks used for steering the array at the UE • Codebooks are DFT vector-based
5G UE-to-FSS (space station) pathloss model	NLoS: Free space pathloss + ***20 dB + 4 dB*** LoS: Free space pathloss + ***4 dB***	• 20 dB models NLoS clutter and ***vegetation*** losses • 4 dB models 1 dB atmospheric loss + 3 dB polarization loss
5G UE TX BW	***100 MHz***	• 100 MHz carrier BW assumed • UL UEs transmissions are scheduled per 100 MHz
5G UE TX power	***26 dBm/100 MHz (EIRP = 43 dBm/100 MHz)***	• With UL carrier aggregation, UE EIRP/100 MHz will be reduced

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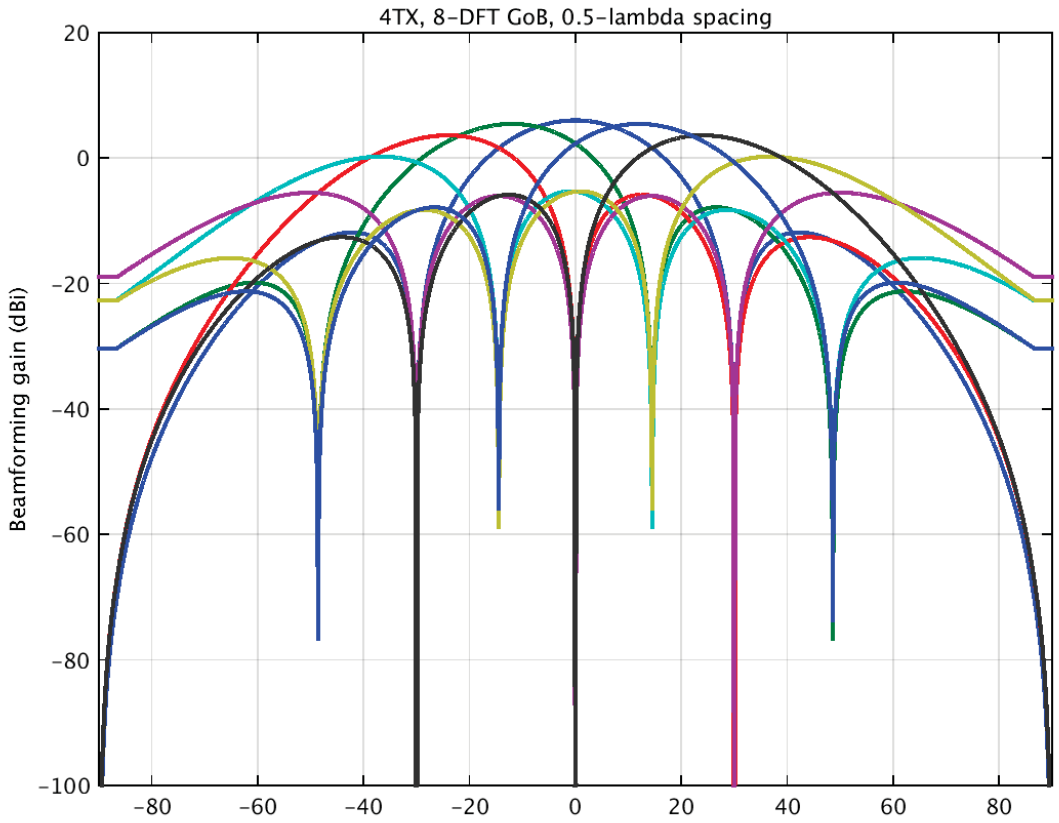
5G UE Antenna Pattern



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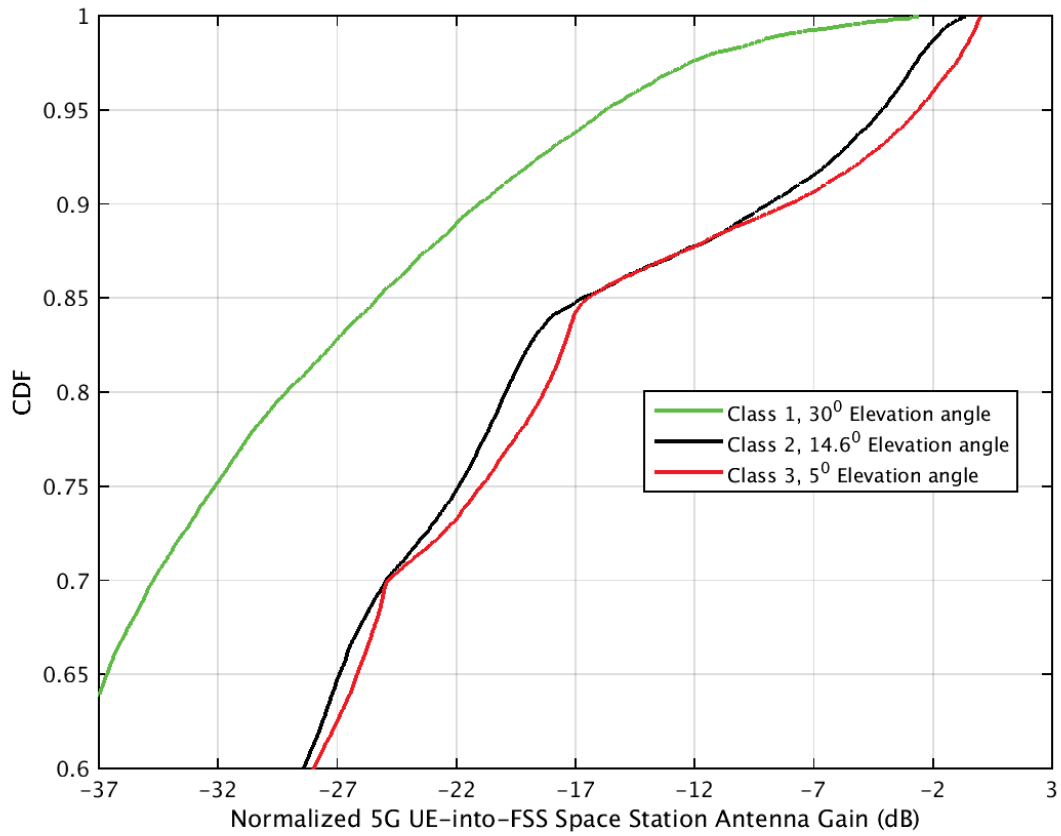
5G UE into FSS antenna gains



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Preliminary results - Number of simultaneously transmitting outdoor 5G UEs

Earth Station Class, 5G UE -> FSS LoS/NLoS channel mix	Average normalized antenna gain towards the Space Station (dB)	Average receive power (dBm/Hz) at Space Station from a single 5G UE	Number of *simultaneously* transmitting *outdoor* 5G UEs					
			NT = 650K			NT = 1000K		
			$TH = -12.2\ dB$	$TH = -6\ dB$	$TH = 0\ dB$	$TH = -12.2\ dB$	$TH = -6\ dB$	$TH = 0\ dB$
Class 1, Rural/Urban: 25% LoS/75% NLoS	-22 dB	-225 dBm/Hz	~17900	~71600	~286400	~28300	~113200	~452800
Class 1, Urban: 10% LoS/90% NLoS	-22 dB	-228 dBm/Hz	~35700	~142800	~571200	~56600	~226400	~905600
Class 1, 100% NLoS	-22 dB	-238 dBm/Hz	~392700	~1570800	~6283200	~622600	~2490400	~9961600
Class 2, Rural/Urban: 25% LoS/75% NLoS	-14 dB	-217 dBm/Hz	~2800	~11200	~44800	~4400	~17600	~70400
Class 2, Urban: 10% LoS/90% NLoS	-14 dB	-220 dBm/Hz	~5700	~22800	~91200	~9000	~36000	~144000
Class 2, 100% NLoS	-14 dB	-230 dBm/Hz	~62700	~250800	~1003200	~99000	~396000	~1584000
Class 3, Rural /Urban: 25% LoS/75% NLoS	-12 dB	-223 dBm/Hz	~11300	~45200	~180800	~17900	~71600	~286400
Class 3, Urban: 10% LoS/90% NLoS	-12 dB	-227 dBm/Hz	~28400	~113600	~454400	~45000	~180000	~720000
Class 3, 100% NLoS	-12 dB	-237 dBm/Hz	~312400	~1249600	~4998400	~495000	~1980000	~7920000

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Preliminary results - Number of active outdoor 5G UEs

Earth Station Class, 5G UE -> FSS LoS/NLoS channel mix	Average normalized antenna gain towards the Space Station (dB)	Average receive power (dBm/Hz) at Space Station from a single 5G UE	Number of *active outdoor* 5G UEs					
			NT = 650K			NT = 1000K		
			$TH = -12.2\ dB$	$TH = -6\ dB$	$TH = 0\ dB$	$TH = -12.2\ dB$	$TH = -6\ dB$	$TH = 0\ dB$
Class 1, Rural/Urban: 25% LoS/75% NLoS	-22 dB	-225 dBm/Hz	~179000	~716000	~2864000	~283000	~1132000	~4528000
Class 1, Urban: 10% LoS/90% NLoS	-22 dB	-228 dBm/Hz	~357000	~1428000	~5712000	~566000	~2264000	~9056000
Class 1, 100% NLoS	-22 dB	-238 dBm/Hz	~3927000	~15708000	~62832000	~6226000	~24904000	~99616000
Class 2, Rural/Urban: 25% LoS/75% NLoS	-14 dB	-217 dBm/Hz	~28000	~112000	~448000	~44000	~176000	~704000
Class 2, Urban: 10% LoS/90% NLoS	-14 dB	-220 dBm/Hz	~57000	~228000	~912000	~90000	~360000	~1440000
Class 2, 100% NLoS	-14 dB	-230 dBm/Hz	~627000	~2508000	~10032000	~990000	~3960000	~15840000
Class 3, Rural /Urban: 25% LoS/75% NLoS	-12 dB	-223 dBm/Hz	~113000	~452000	~1808000	~179000	~716000	~2864000
Class 3, Urban: 10% LoS/90% NLoS	-12 dB	-227 dBm/Hz	~284000	~1136000	~4544000	~450000	~1800000	~7200000
Class 3, 100% NLoS	-12 dB	-237 dBm/Hz	~3124000	~12496000	~49984000	~4950000	~19800000	~79200000

Active UEs: UEs with buffered UL data and in a scheduling queue

Assumption:

- 10 active UEs per cell
- Single UE per scheduling instance => 10X factor to convert from transmitting to active UEs

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Preliminary results - Total number of simultaneously transmitting 5G UEs

Earth Station Class, 5G UE -> FSS LoS/NLoS channel mix	Average normalized antenna gain towards the Space Station (dB)	Average receive power (dBm/Hz) at Space Station from a single 5G UE	Total number of simultaneously transmitting 5G UEs					
			NT = 650K			NT = 1000K		
			$TH = -12.2\ dB$	$TH = -6\ dB$	$TH = 0\ dB$	$TH = -12.2\ dB$	$TH = -6\ dB$	$TH = 0\ dB$
Class 1, Rural/Urban: 25% LoS/75% NLoS	-22 dB	-225 dBm/Hz	~89500	~358000	~1432000	~141500	~566000	~2264000
Class 1, Urban: 10% LoS/90% NLoS	-22 dB	-228 dBm/Hz	~178500	~714000	~2856000	~283000	~1132000	~4528000
Class 1, 100% NLoS	-22 dB	-238 dBm/Hz	~1963500	~7854000	~31416000	~3113000	~12452000	~49808000
Class 2, Rural/Urban: 25% LoS/75% NLoS	-14 dB	-217 dBm/Hz	~14000	~56000	~224000	~22000	~88000	~352000
Class 2, Urban: 10% LoS/90% NLoS	-14 dB	-220 dBm/Hz	~28500	~114000	~456000	~45000	~180000	~720000
Class 2, 100% NLoS	-14 dB	-230 dBm/Hz	~313500	~1254000	~5016000	~495000	~1980000	~7920000
Class 3, Rural /Urban: 25% LoS/75% NLoS	-12 dB	-223 dBm/Hz	~56500	~226000	~904000	~89500	~358000	~1432000
Class 3, Urban: 10% LoS/90% NLoS	-12 dB	-227 dBm/Hz	~142000	~568000	~2272000	~225000	~900000	~3600000
Class 3, 100% NLoS	-12 dB	-237 dBm/Hz	~1562000	~6248000	~24992000	~2475000	~9900000	~39600000

Assuming outdoor to indoor UEs ratio of 20% to 80% as in 3GPP UMi => 5X factor

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Preliminary results - Total number of active 5G UEs

Earth Station Class, 5G UE -> FSS LoS/NLoS channel mix	Average normalized antenna gain towards the Space Station (dB)	Average receive power (dBm/Hz) at Space Station from a single 5G UE	Total number of active 5G UEs					
			NT = 650K			NT = 1000K		
			$TH = -12.2\ dB$	$TH = -6\ dB$	$TH = 0\ dB$	$TH = -12.2\ dB$	$TH = -6\ dB$	$TH = 0\ dB$
Class 1, Rural/Urban: 25% LoS/75% NLoS	-22 dB	-225 dBm/Hz	~895000	~3580000	~14320000	~1415000	~5660000	~22640000
Class 1, Urban: 10% LoS/90% NLoS	-22 dB	-228 dBm/Hz	~1785000	~7140000	~28560000	~2830000	~11320000	~45280000
Class 1, 100% NLoS	-22 dB	-238 dBm/Hz	~19635000	~78540000	~314160000	~31130000	~124520000	~498080000
Class 2, Rural/Urban: 25% LoS/75% NLoS	-14 dB	-217 dBm/Hz	~140000	~560000	~2240000	~220000	~880000	~3520000
Class 2, Urban: 10% LoS/90% NLoS	-14 dB	-220 dBm/Hz	~285000	~1140000	~4560000	~450000	~1800000	~7200000
Class 2, 100% NLoS	-14 dB	-230 dBm/Hz	~3135000	~12540000	~50160000	~4950000	~19800000	~79200000
Class 3, Rural /Urban: 25% LoS/75% NLoS	-12 dB	-223 dBm/Hz	~565000	~2260000	~9040000	~895000	~3580000	~14320000
Class 3, Urban: 10% LoS/90% NLoS	-12 dB	-227 dBm/Hz	~1420000	~5680000	~22720000	~2250000	~9000000	~36000000
Class 3, 100% NLoS	-12 dB	-237 dBm/Hz	~15620000	~62480000	~249920000	~24750000	~99000000	~396000000

Active UEs: UEs with buffered UL data and in a scheduling queue

Assumption:

- 10 active UEs per cell
- Single UE per scheduling instance => 10X factor to convert from transmitting to active UEs

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Next steps & Observations

- Results show a range of values dependent upon the underlying assumptions
- Most sensitive parameters -- Path loss and system protection criteria
  - Consider NLoS channel conditions for FSS-into-5G interference calculations
  - I/N = -6dB or I/N = 0 dB, - results in 4X and 16X increase in the number of simultaneously transmitting sectors or UEs
- FSS beam size varies in diameter on the ground from one system to another.
  - Only the 5G APs/UEs within the FSS beam diameter should be considered for aggregate interference analysis
- All 5G sectors or UEs simultaneously transmitting is unlikely in actual networks
  - A realistic network loading factor will increase total # of active 5G APs that can be supported
  - Only scheduled UEs will contribute to aggregate interference on the UL.
    - 5G Systems expected to schedule < 4 simultaneous UEs per sector (RF beamforming limitation).
    - Activity factor for UEs is going to be much less as opposed to BS.
- Indoor APs/UEs will have further building penetration losses and will not contribute to aggregate interference.
- Consider other losses specific to UE (e.g., body loss).
- All UEs were assumed to transmit at maximum EIRP of 43dBm/100MHz in the simulations. Power control was not modeled. Also, if UEs transmit on bandwidth higher than 100MHz, then number of UEs would be higher.
- So, total number of active UEs deployed will be much larger.

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