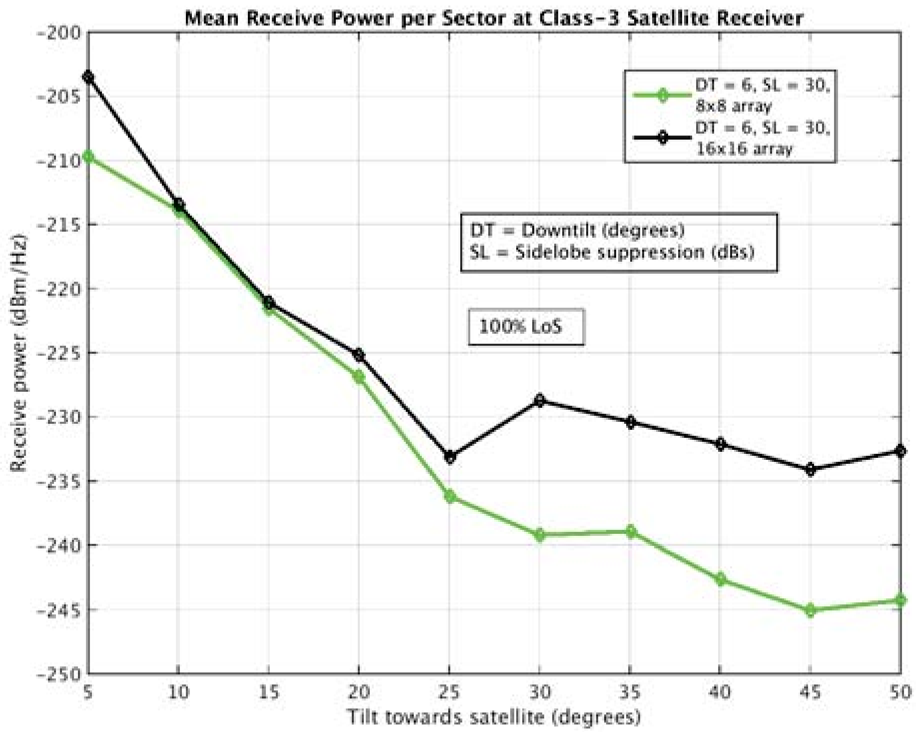
Mean 5G received interference power per sector, EIRP = 62 and 75 dBm/100 MHz

Class-3 Space Station (SS) interference example



Note: Mean interference power plot generated for d_orbit = 8000 km, 100% LoS; For other orbits and LoS/NLoS mixes, the relative shape of the 8x8 and 16x16 curves will remain the same.

Effects of increasing EIRP from 62 to 75 dBm/100 MHz

- Slight interference increase in the elevation angle range < 10 degrees
- No increase in the elevation angle range between 10 and 25 degrees

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Number of simultaneously transmitting 5G sectors: EIRP = 62 dBm/100MHz

Space Station Class, 5G AP -> FSS LoS/NLoS channel mix	Average normalized antenna gain towards the Space Station (dB) @min elevation angle	Average receive power at Space Station from a single 5G sector (dBm/Hz) @min elevation angle	Number of *simultaneously* transmitting 5G sectors		
			$TH = -12.2\ dB$	$TH = -6\ dB$	$TH = 0\ dB$
Class 1, Rural/Urban (50% LoS/50% NLoS)	-34	-213	2000	8000	32000
Class 1, Urban (25% LoS/75% NLoS)		-216	3800	15200	60800
Class 1, Urban (10% LoS/90% NLoS)		-220	9000	36000	144000
Class 2, Rural/Urban (50% LoS/50% NLoS)	-34	-213	1200	4800	19200
Class 2, Urban (25% LoS/75% NLoS)		-216	2300	9200	36800
Class 2, Urban (10% LoS/90% NLoS)		-220	5400	21600	86400
Class 3, Rural /Urban(50% LoS/50% NLoS)	-22	-217	2200	8800	35200
Class 3, Urban (25% LoS/75% NLoS)		-219	4400	17600	70400
Class 3, Urban (10% LoS/90% NLoS)		-223	10000	40000	160000

Assumptions: AP downtilt = 6 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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Number of simultaneously transmitting 5G sectors: EIRP = 75 dBm/100MHz

Space Station Class, 5G AP -> FSS LoS/NLoS channel mix	Average normalized antenna gain towards the Space Station (dB) @min elevation angle	Average receive power at Space Station from a single 5G sector (dBm/Hz) @min elevation angle	Number of simultaneously transmitting 5G sectors		
			$TH = -12.2\ dB$	$TH = -6\ dB$	$TH = 0\ dB$
Class 1, Rural/Urban (50% LoS/50% NLoS)	-48	-213	2000	8000	32000
Class 1, Urban (25% LoS/75% NLoS)		-216	3800	15200	60800
Class 1, Urban (10% LoS/90% NLoS)		-220	9000	36000	144000
Class 2, Rural/Urban (50% LoS/50% NLoS)	-48	-213	1200	4800	19200
Class 2, Urban (25% LoS/75% NLoS)		-216	2300	9200	36800
Class 2, Urban (10% LoS/90% NLoS)		-220	5400	21600	86400
Class 3, Rural /Urban(50% LoS/50% NLoS)	-29	-211	600	2400	9600
Class 3, Urban (25% LoS/75% NLoS)		-214	1300	5200	20800
Class 3, Urban (10% LoS/90% NLoS)		-218	3000	12000	48000

Assumptions: AP downtilt = 6 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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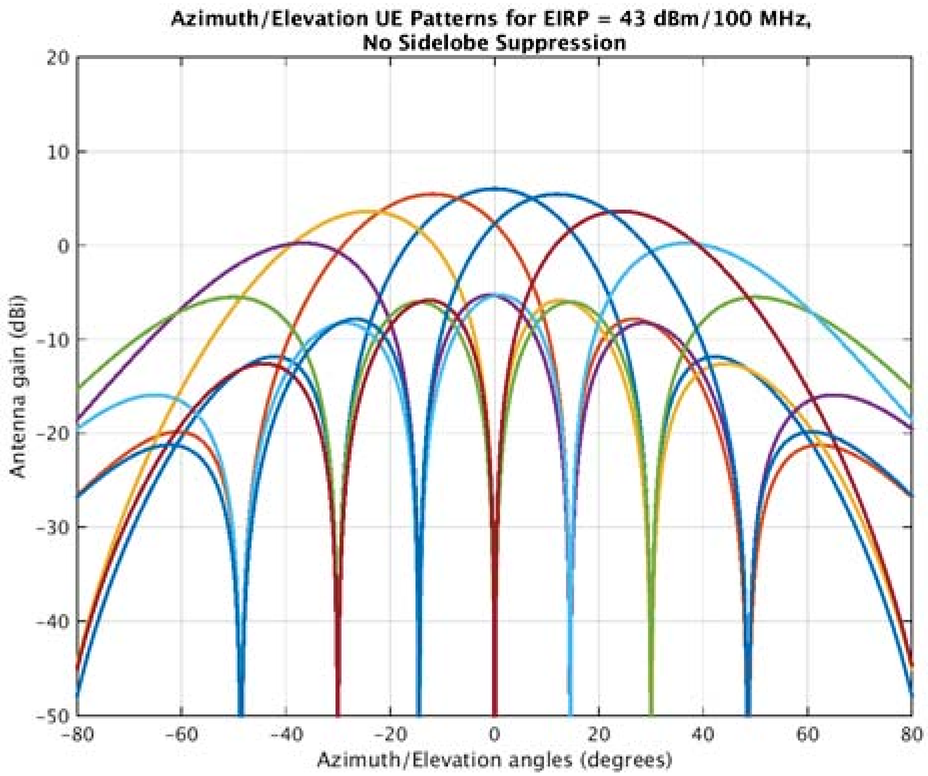
5G UE Beam Patterns, EIRP = 43 dBm/100 MHz



16 cross-polarized elements (4x4)
TX power per cross-polarized element = 14 dBm/100 MHz
Element antenna gain = 5 dBi
Max AP array gain = 6 + 6 + 5 = 17 dBi
Max EIRP = 14 + 10*log10(16) + 17 = 43 dBm/100 MHz
8 horizontal and elevation beams used for steering to the APs

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Average AP array discrimination towards satellite per SS Class

Space Station Class, 5G AP -> FSS LoS/NLoS channel mix	BS EIRP = 62 dBm/100 MHz (8x8 array) Average normalized antenna gain towards the Space Station (dB)@min elevation angle	BS EIRP = 75 dBm/100 MHz (16x16 array) Average normalized antenna gain towards the Space Station (dB)@min elevation angle
Class 1 (min elevation angle = 15º)	-34	-48
Class 2 (min elevation angle = 15º)	-34	-48
Class 3 (min elevation angle = 5º)	-22	-29

Average UE array discrimination towards satellite per SS Class

Space Station Class, 5G AP -> FSS LoS/NLoS channel mix	UE EIRP = 43 dBm/100 MHz (4x4 array) Average normalized antenna gain towards the Space Station (dB)@min elevation angle
Class 1 (min elevation angle = 30º)	-22
Class 2 (min elevation angle = 15º)	-14
Class 3 (min elevation angle = 5º)	-12

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Exhibit C:
Power Distribution for Mobile Networks

In 2013, AT&T submitted a study to the ITU providing a snapshot of the power used in its 3GPP UMTS/HSPA+ and LTE network in the United States.[14] The study considered a network covering approximately 1000 km^2 comprised of approximately 900 cell sites, with over 3500 sectors individually measured and tracked for power level measurements of base station and UE transmit levels. The region involved a mix of terrain types, including hilly regions, and included key portions of an urban area and surrounding suburban areas. Measurements were performed on a "per sector" basis gathered over a typical operation day in late June of 2013 from 14:00 to 18:00 hours at up to 100 ms intervals.

Data showing the power distribution of sectors for BSs in a combined urban, suburban and rural setting are shown below in Table 1:

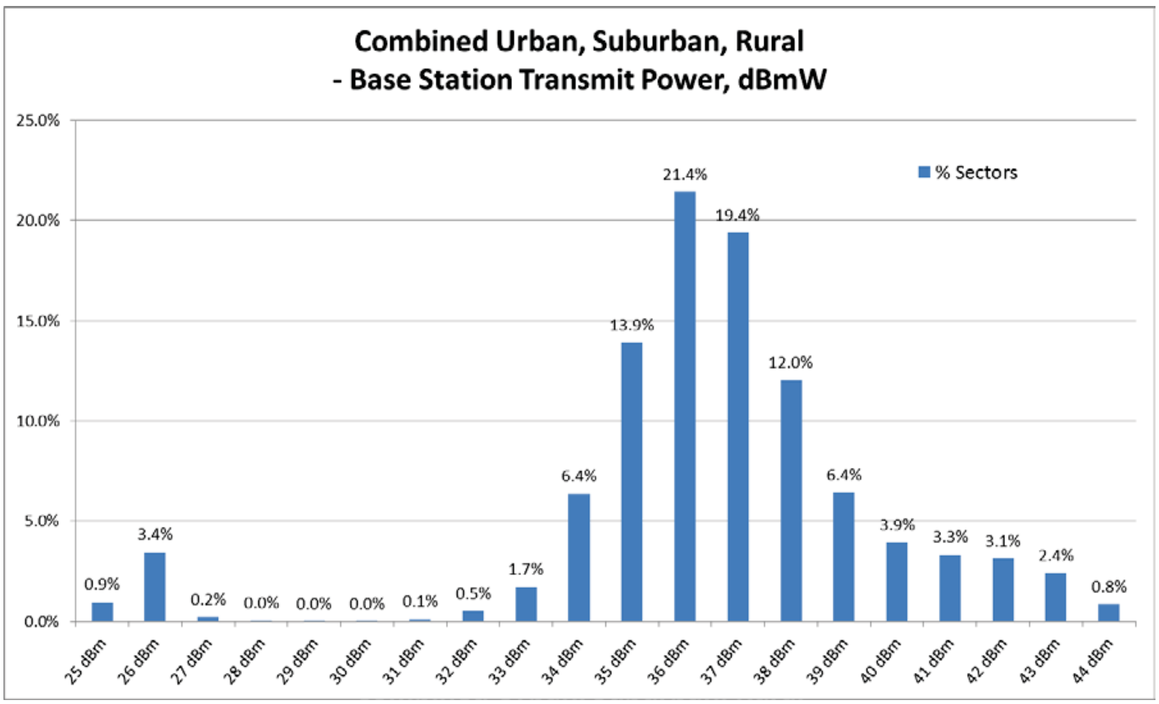

Table 1

As shown, only 0.8% of the time is the BS sector operating at full power; over 90% of the time the sector is radiating at half power or less, and 13.2% of the time it is 10 dB or more below maximum power. The distribution of power levels for UEs is shown in Table 2, and shows even lower typical powers:

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[14] System Design Information And Dynamic Data Measurements Of Operating Characteristics For A Commercial IMT Mobile Broadband System In Consideration Of Sharing Study Parameters, Document 5D/395-E (July 3, 2013); *available at*: http://www.itu.int/md/R12-WP5D-C-0395/en (requires TIES account).

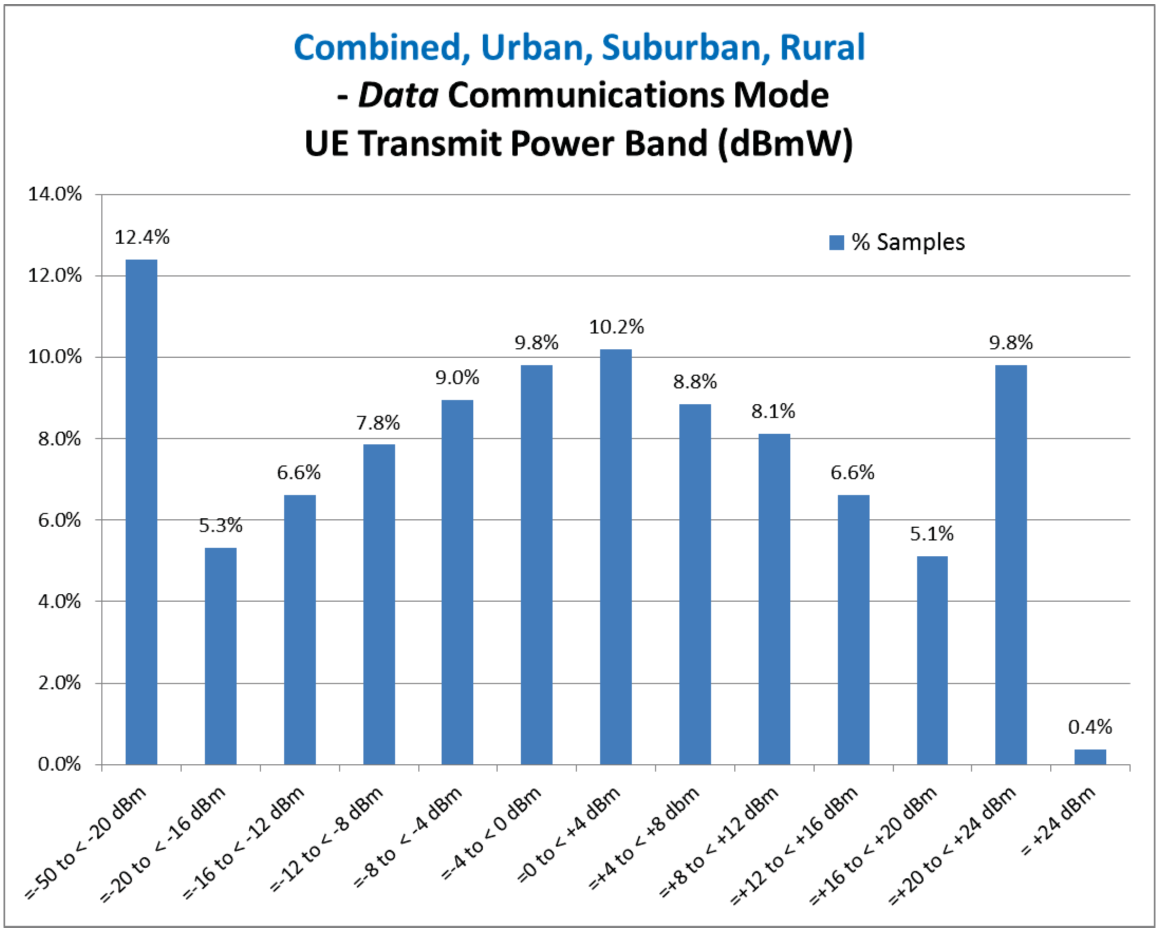


Table 2

The data in Table 2 shows that UE operates at half power or less almost 90% of the time, and 10 dB down almost 80% of the time.

Exhibit D:
Estimate of FSS beam area

The earth-to-satellite link (i.e. uplink) comprises of an earth station transmitting towards the satellite with a directional transmit (Tx) antenna , and a satellite receiving the signal with a directional (typically parabolic) receiver (Rx) antenna. The Rx antenna on board the satellite forms a spot where the solid angle formed by the Rx beam subtends the surface of the earth; this is typically known as a spot-beam. This area covered by the Satellite RX antenna is dependent on the antenna gain. The table below shows some examples of satellite antennas and the respective Half-Power beam widths (HPBW) represented by α_{spot} as one-half of the HPBW. The calculation assumes a pattern from a parabolic antenna.

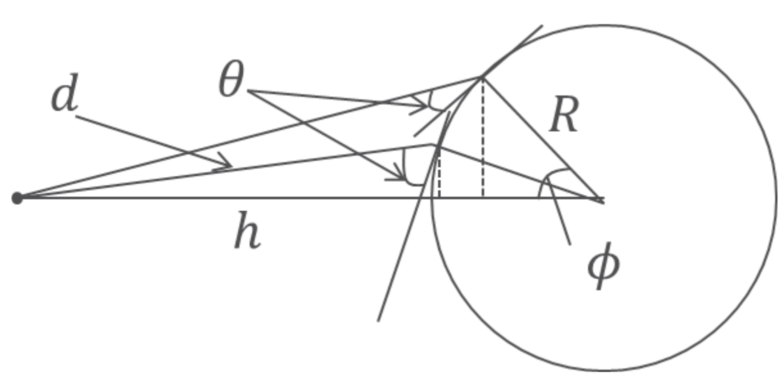
	Class 1	Class 2	Class 3	Class 4
Antenna gain (dBi)	60	60	30	50
α_{spot} (degrees)	0.0875	0.0875	2.86	0.28
HPBW (degrees)	0.175	0.175	5.71	0.56

Figure 2 Relationship between antenna gain and HPBW for the four satellite classes

The covered area is determined by the location of the Satellite relative to the Earth Station. The following describes a simplified calculation of the area in the spot-beam around the Earth Station.

The Satellite is located over the equator and is furthermore assumed to be at a position at the same longitude as the Earth Station. The covered area may be approximated as an ellipse on the Earth's surface, subtending a solid angle equivalent to the geometry of the beam pattern.

The angle of arrival, or angle over the horizon "θ", and the distance "d", can be calculated with the model showed in the picture below.



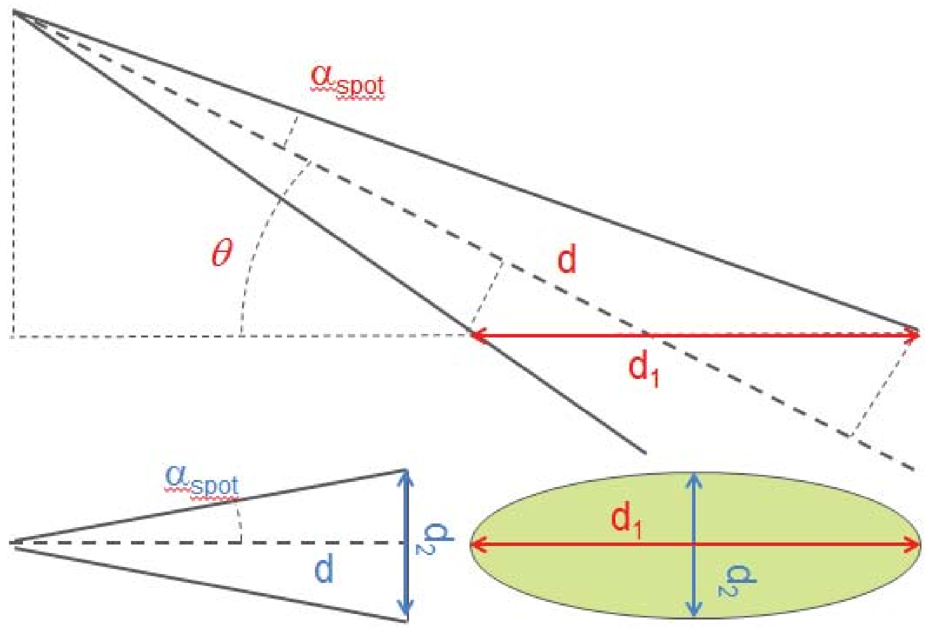
R = Radius of Earth

ϕ = the latitude of the Earth Station h = the altitude of the satellite over the equator

d = distance between the Satellite and the Earth Station

θ =elevation angle to the satellite

(a)



$2\alpha_{spot}$ = HPBW of the satellite RX antenna

(b)

Figure 3 Geometrical relationship between the angles and the area of the spot-beam: (a) Orthogonal view to earth; (b) azimuth and elevation in regard to spot-beam area.

The area covered by the Satellite RX antenna beam on the earth's surface is defined by the area of the ellipse defined by the model below. The d_1 and d_2 is the distance the ellipse covers in North-South and East-West directions, respectively.

Using this model, the coverage areas for the Satellite RX antenna can be estimated.

The estimated areas for the example antennas are shown in picture above with the model can be found in Table 3.

		Class 1	Class 2	Class 3	Class 4
Antenna Gain	dBi	60	60	30	50
HPBW	degrees	0.175	0.175	5.71	0.56
Satellite-to-earth-station d	km	37000	37000	11000	37000
Beam coverage area	km^2	~11,000	~11,000	~1,200,000	~147,000

Table 3 Beam Coverage Areas

The covered area is highly dependent on the antenna gain and the distance to the satellite.

Exhibit E:
Updated FSS into UL 5G Interference Analysis for 28 GHz

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Updated FSS into UL 5G Interference Analysis at 28GHz

System-level simulation results with RMa/UMa terrestrial channel models

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Nokia - Bell Labs

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 5G system and the 5G UEs attached to the 'victim' AP	• Statistical methodology • Output is the percentage of UL links with satisfied 5G protection criterion attached to the 'victim' AP 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 • ***6 degree mechanical downtilt*** • 16 horizontal/vertical beams with ***side-lobe control***	• Total number of elements = 128 • Max AP array gain = 23 dBi
FSS-to-5G AP pathloss model	1. 3GPP UMa@28 GHz 2. 3GPP RMa@28 GHz	Urban-macro model Rural-macro model
5G AP receiver NF	5 dB	
5G AP antenna height	10m AGL	3GPP Urban Micro (UMi) scenario

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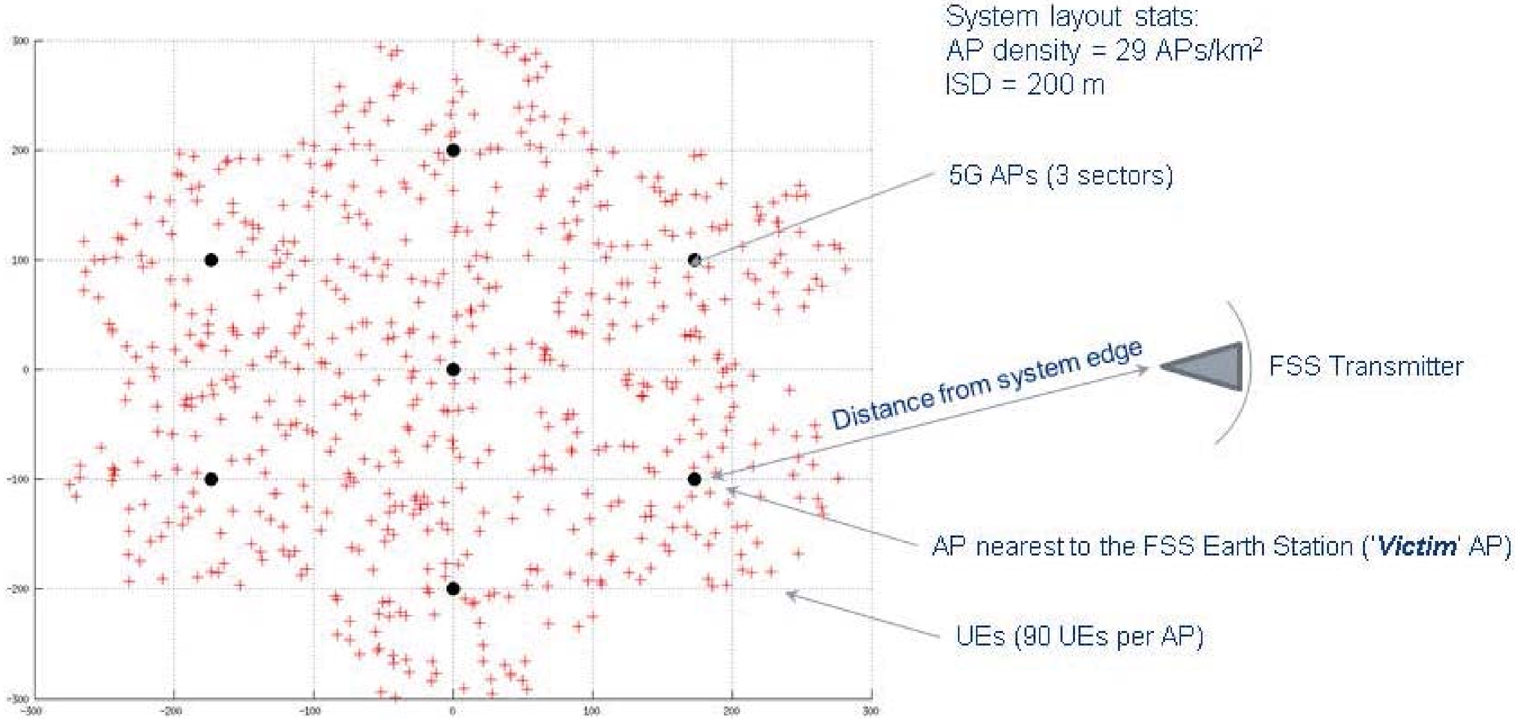
5G System layout example (7-sites)



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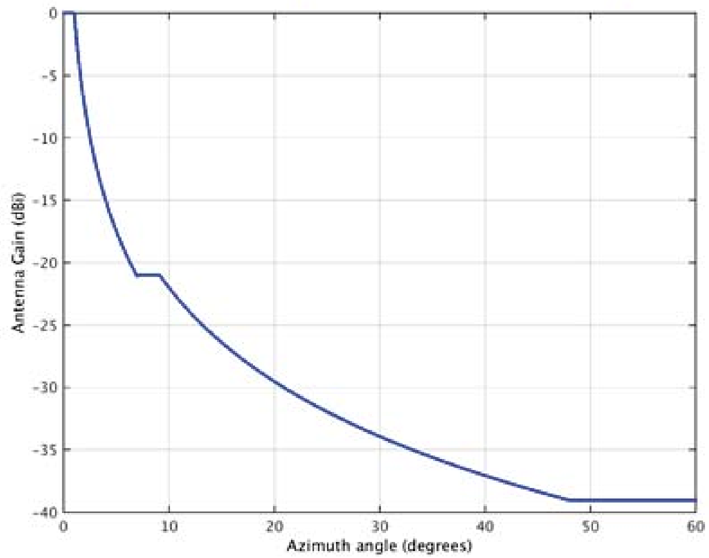
FSS Earth Station parameters

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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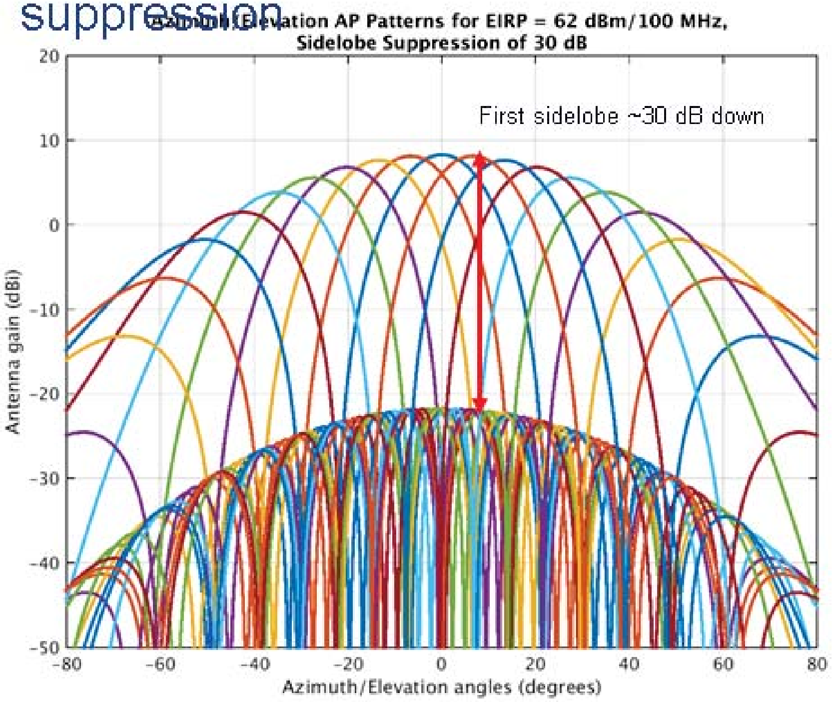
5G AP Beam patterns, EIRP = 62 dBm/100 MHz, 30 dB sidelobe suppression



- 64 cross-polarized elements (8x8)
- TX power per cross-polarized element = 21 dBm/100 MHz
- Element antenna gain = 5 dBi
- Max AP array gain = 9 + 9 + 5 = 23 dBi
- Max EIRP = 21 + 10*log10(64) + 23 = 62 dBm/100 MHz
- 16 horizontal and elevation beams used for steering to the UEs
- Chebychev window used for sidelobe suppression

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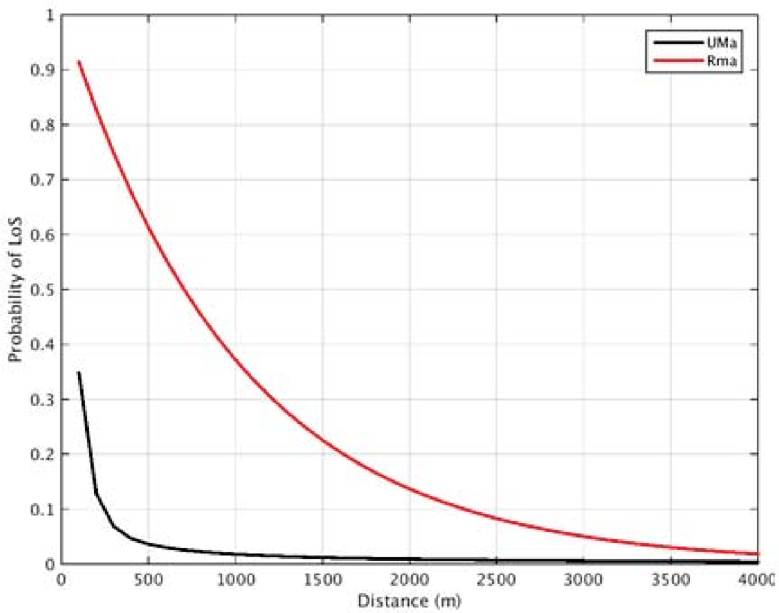
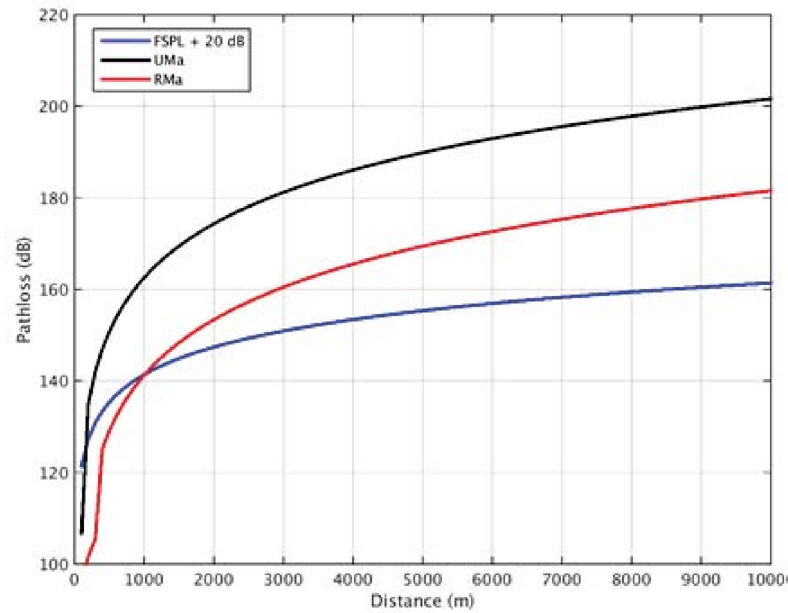
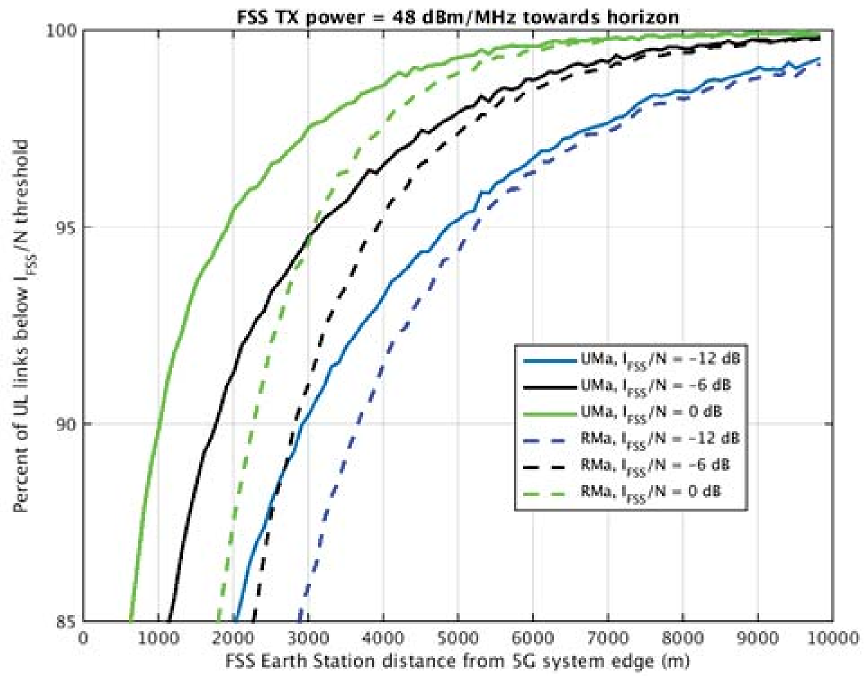
Terrestrial channel models

- LoS/NLoS mix according to UMa/RMa channel models in 3GPP TR 38.900
- LoS vs. NLoS probability according to UMa/RMa channel models in 3GPP TR 38.900





Simulation results for Class 3 Earth Stations



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Results summary

Earth Station Class	Required UL Protection Distance (m)					
	UMa			RMa		
	$TH = -12.2\ dB$	$TH = -6\ dB$	$TH = 0\ dB$	$TH = -12.2\ dB$	$TH = -6\ dB$	$TH = 0\ dB$
Class 3	4900	3000	2000	5100	4000	3000

Observations

- Co-existence results sensitive to system protection thresholds
- Range of coordination distances dependent upon the earth station class type
- Worst-case distance separation ~5km under RMa channel model

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