Effects of 5G NR Beamforming on Transmit Power in Spectrum Sharing

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INTRODUCTION

- Massive MIMO (multiple input, multiple output) technology plays a key role in 5G networks today, boosting throughput and capacity by enabling user-specific beamforming of the data channel, and thus Active antenna systems (AAS) has been adopted in 5G networks [1].
- AAS in 5G enable directional control of radiated gain from gNodeB (gNB) to user equipment (UE) via advanced beamforming capabilities for enhanced coverage and capacity: coarse synchronization signal block (SSB) beams and refined shared channel beams [2].
- Therefore, accurate modelling of the AAS is essential for analyzing the spectrum sharing feasibility of terrestrial network with other in-band or adjacent band incumbent services.

Goal:

- To investigate the effects of 5G beamforming on transmit power in spectrum sharing.
- What matters in the context of interference is the power radiated by the gNB towards the incumbents, i.e., above the horizon.
- To understand the average Effective Isotropic Radiated Power (EIRP) over different beamforming directions.

METHODOLOGY

- Create a 3D probabilistic model of energy emanating from a 5G gNB using Monte-Carlo simulations:
  - ✓ Should be 3GPP specific, focusing on downlink transmissions.
  - ✓ Should include AAS, beamforming procedures and codebooks as specified in the standard.
- Conducting real-world measurements around 5G gNB deployment to inform the developed simulator with the observations.

1) 5G NR Advanced Antenna Panel Configuration

- Antenna modeling decisions, including input data and parameters, can be broadly classified into physical and operational antenna configurations, referred to as antenna ports [3].

1.1) Antenna element configuration

Table 1: Antenna element parameters.

Antenna Element	Characteristics
Frequency Range	3700-3980 MHz
Carrier Frequency	3.75 GHz
Half power beam width (HPBW) (azimuth, elevation)	(90, 60 degree)
Antenna element gain	5.3 dBi

1.2) Antenna array configuration

Table 2: AAS array parameters.

Antenna Array Parameters	Characteristics
Antenna Element	NR antenna element
Subarray	3 ver. Ant. Ele.
Subarray panel	4-by-8 matrix
Ant. Ele. Spacing	58 mm in El. 44 mm in Az.
Panel down-tilt	0 degrees

1.3) SSB & PMI beam configuration

Table 3: Type 1 Single Panel : Based on 38.214 v15.3 Table 5.2.2.2.1-2

Number of CSI-RS antenna ports	(N1,N2)	2*N1*N2 = # of CSI ports	(O1,O2)	N1*O1	N2*O2	N1*O1*N2*O2=Ac (Bitmap in SinglePanel n1-n2)
4	(2,1)	2*2*1 = 4	(4,1)	2*4=8	1*1=1	2*4*1*1 = 8
8	(2,2)	2*2*2 = 8	(4,4)	2*4=8	2*4=8	2*4*2*4 = 64
	(4,1)	2*4*1 = 8	(4,1)	4*4=16	1*1=1	4*4*1*1 = 16
12	(3,2)	2*3*2 = 12	(4,4)	3*4=12	2*4=8	3*4*2*4 = 96
	(6,1)	2*6*1 = 12	(4,1)	6*4=24	1*1=1	6*4*1*1 = 24
16	(4,2)	2*4*2 = 16	(4,4)	4*4=16	2*4=8	4*4*2*4 = 128
	(8,1)	2*8*1 = 16	(4,1)	8*4=32	1*1=1	8*4*1*1 = 32
24	(4,3)	2*4*3 = 24	(4,4)	4*4=16	3*4=12	4*4*3*4 = 192
	(6,2)	2*6*2 = 24	(4,4)	6*4=24	2*4=8	6*4*2*4 = 192
	(12,1)	2*12*1 = 24	(4,1)	12*4=48	1*1=1	12*4*1*1 = 48
32	(4,4)	2*4*4 = 32	(4,4)	4*4=16	4*4=16	4*4*4*4 = 256
	(8,2)	2*8*2 = 32	(4,4)	8*4=32	2*4=8	8*4*2*4 = 256
	(16,1)	2*16*1 = 32	(4,1)	16*4=64	1*1=1	16*4*1*1 = 64

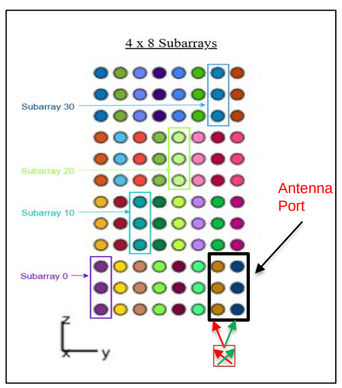

Figure 2: ITU AAS array of subarrays configuration.

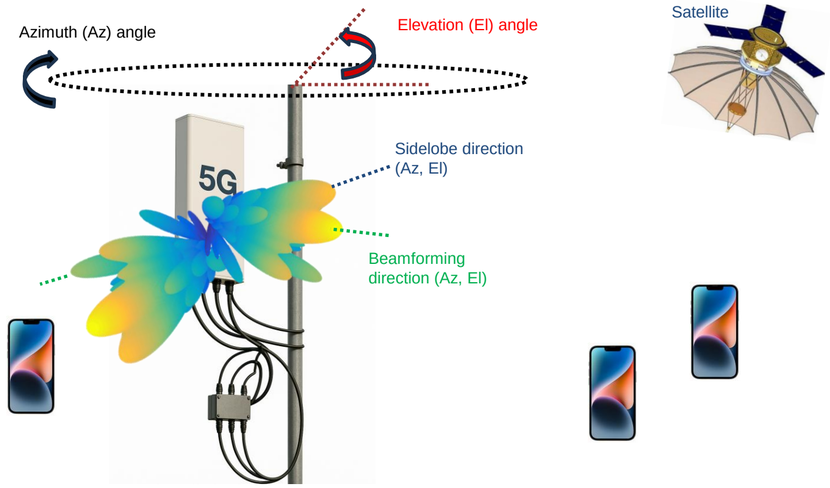

Figure 1: Illustration of 5G gNB deployment.

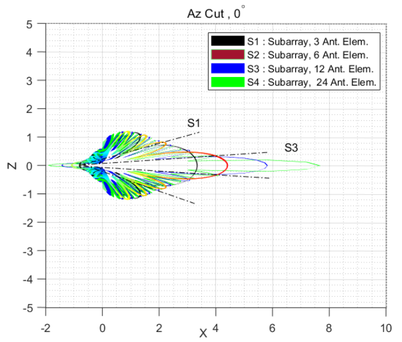

Figure 3: Power radiation in Cartesian coordinates at XZ-plane (Az Cut 0 degree).

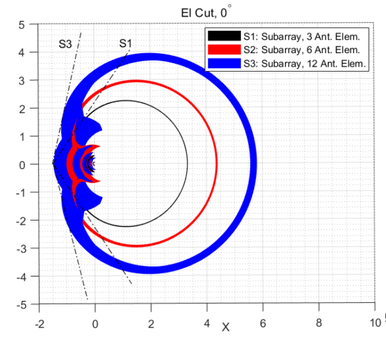

Figure 4: Power radiation in Cartesian coordinates at YX-plane (El Cut 0 degree).

○ Choose the panel size depending on the deployment needs.

Real-world 5G gNB deployment

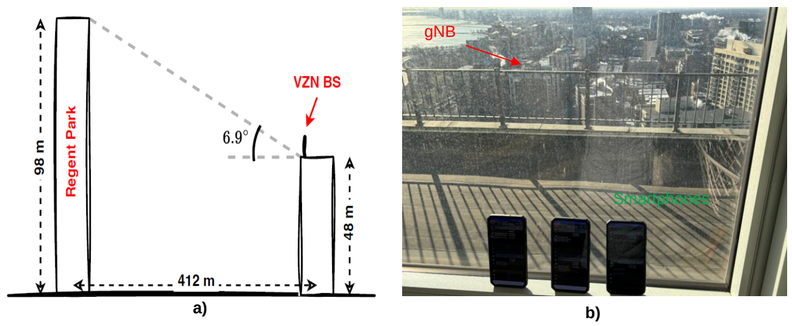

Figure 5: Illustration of real-world deployment a), and measurement setup b).

Acknowledgement

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References

[1] Document 5D/701-E, "Antenna Pattern Measurements of sub-6GHz commercial AAS Base Stations and Antenna Pattern Model for Sharing Studies", 31 May 2021, ITU

[2] 5G: Study on channel model for frequencies from 0.5 to 100 GHz, 3GPP TR38.901 Version 14.0.0 Release 14.

[3] Morais, Douglas H. "5G NR overview and physical layer." Key 5G/5G-Advanced Physical Layer Technologies: Enabling Mobile and Fixed Wireless Access. Cham: Springer International Publishing, 2024. 233-321.

RESULTS & DISCUSSION

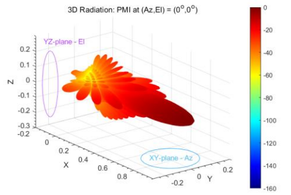

Figure 6: 3D-radiation for antenna panel shown in Fig.2.

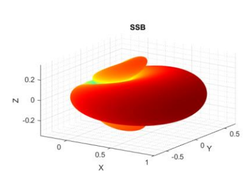

Figure 7: 3D-radiation for SSB.

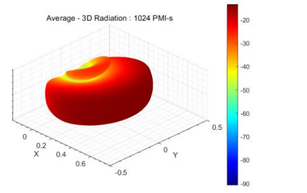

Figure 8: Average 3D-radiation for all SSB & PMIs.

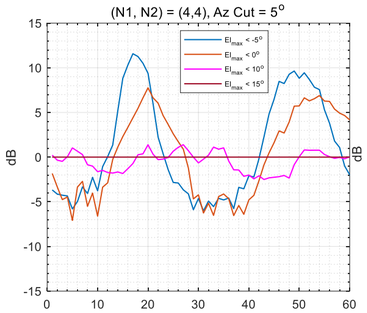

Figure 9: Average power for subset of PMIs filtered by El, at Az Cut 5 degree.

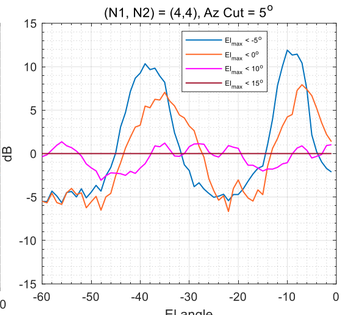

Figure 10: Average power for subset of PMIs filtered by El, at Az Cut 5 degree.

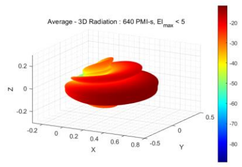

Figure 11: Average 3D-radiation for subset of PMIs filtered by El .

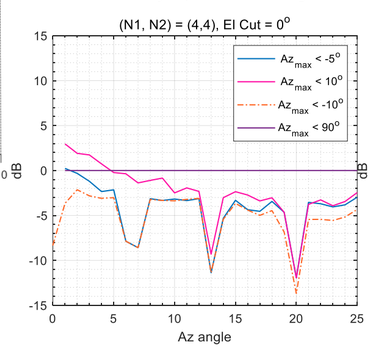

Figure 12: Average 3D-radiation for subset of PMIs filtered by Az, at El Cut 0 degree.

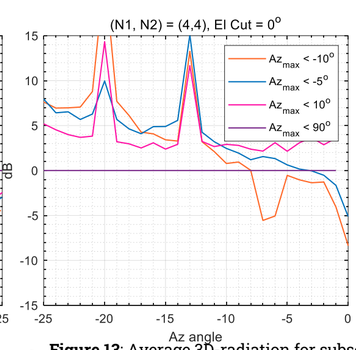

Figure 13: Average 3D-radiation for subset of PMIs filtered by Az, at El Cut 0 degree.

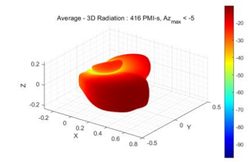

Figure 14: Average 3D-radiation for subset of PMIs filtered by Az .

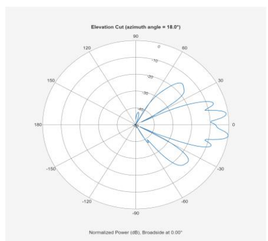

Figure 17: PMI (1,16,3,1) with RI(3) observed at top floor.

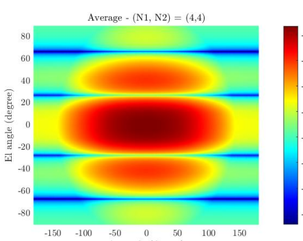

Figure 15: Average 3D radiation – (N1, N2) : (4,4), Layer = 1 .

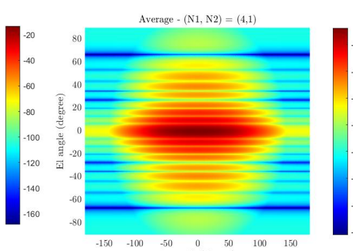

Figure 16: Average 3D radiation – (N1, N2) : (4,1), Layer = 1 .

Conclusion and Discussion

- ○ Interference from a gNB does not depend on the worst-case beamforming direction, but on the variety of beamforming directions, i.e., by averaging across different beamforming directions.
- ○ Physical AAS design plays a critical role on the 3D radiation.
- ○ Nulling out a group of PMIs at a given El direction, does not ensure reduced radiation over all the El plane. In addition, this can be a threat at some other (El, Az) directions.
- ○ Development of more comprehensive schemes for proper control of gNB radiated power at any given (El, Az) direction are a future work.