Cells Sweeping
A New Paradigm for Cells Deployment

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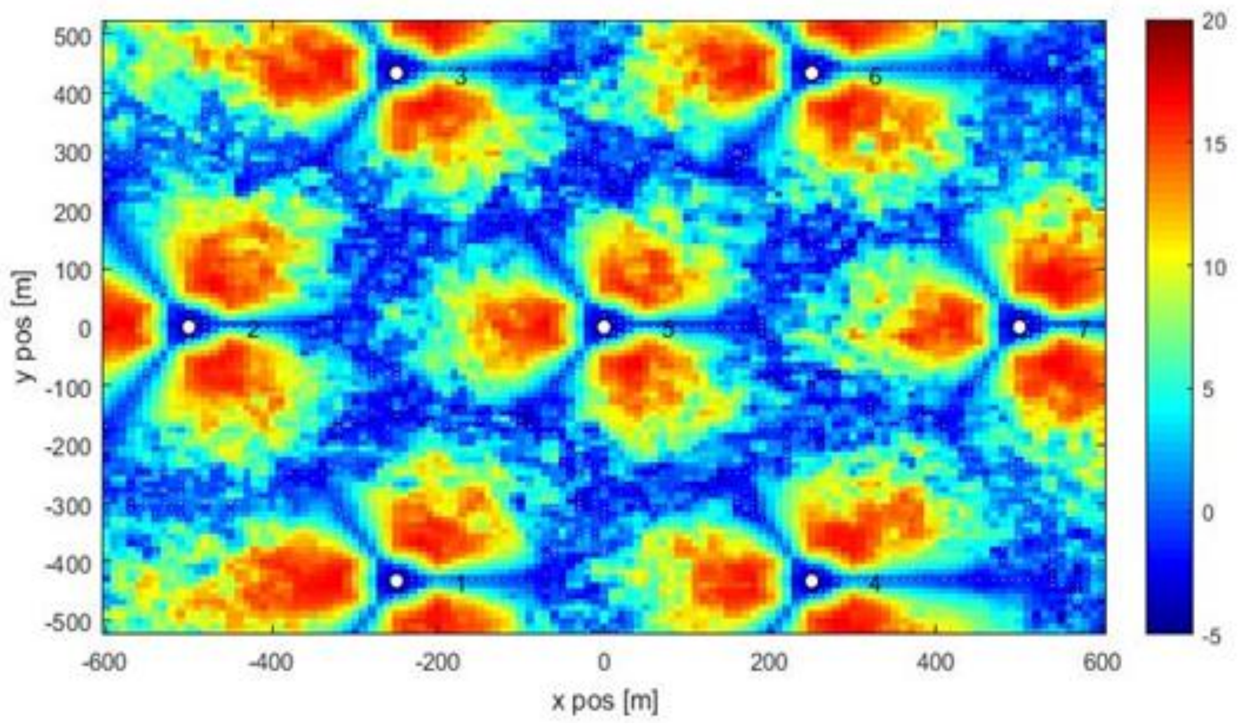
Radio Access Network Techniques for 6G workshop
Supported by DCMS and UK SPF
1st July 2021

Problem – Coverage is Patchy & Non-Uniform

- Coverage imbalance / dead-spots is an inherent problem in cellular systems
- Typical sectored antennas do not favour users at the cell edges of same site!



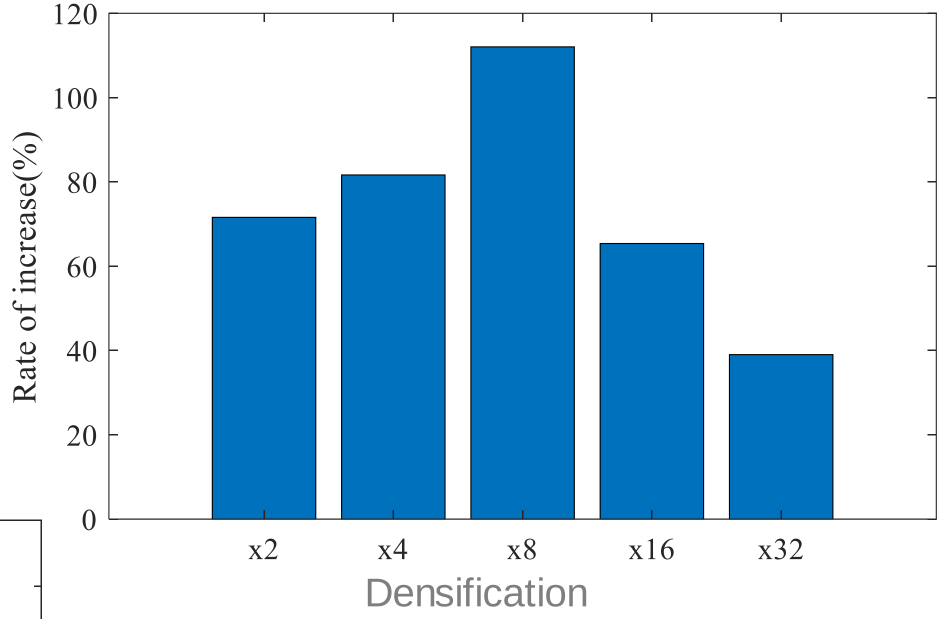
Wideband SINR 2D Geographic heat map

7 Sites, 3 sectors
BS Tx Power: 46 dBm
System Bandwidth: 10 MHz
Path Loss Model: 3GPP Urban Macro
BS Antennas Model:
(Berger 2D as per 3GPP TS 36.942)
Shadowing: Claussen (Correlated)
Inter-site Distance: 500 m
Fading: Typical Urban, 5 km/h
Carrier Freq: 2.1 GHz
Frequency reuse factor: 1

Red → High SINR
Blue → Low SINR

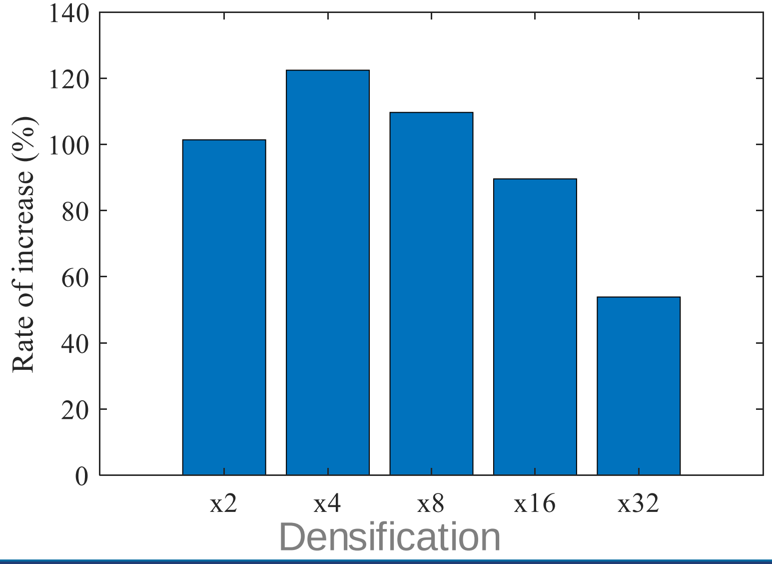
Densification is Not Always the Answer !

Area spectral efficiency

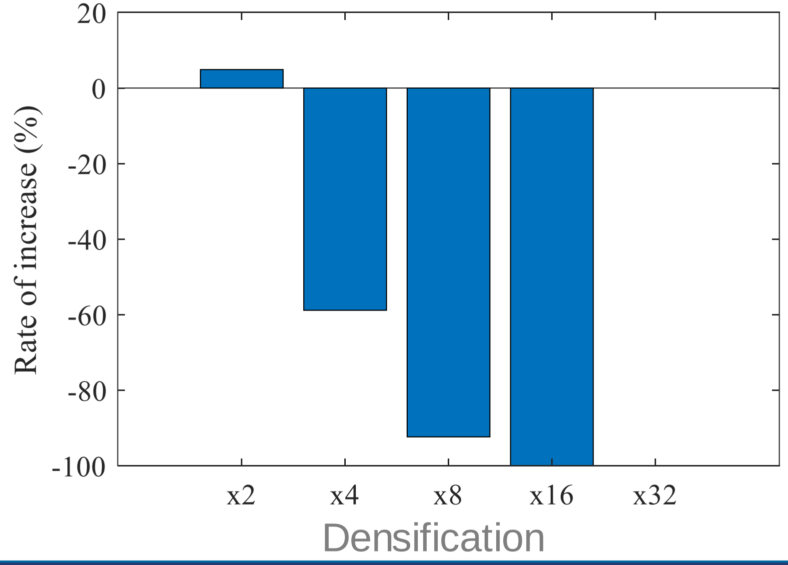


Parameter	Value
Standard	LTE
Frequency	2 GHz
Bandwidth	10 MHz
Waveform	OFDM
Transmission mode	LTE TM 1 SISO
Modulation/Coding	Adaptive, LTE CQI 1-15
Traffic model	Full buffer
Scheduler	Proportional fair

95^{th}-percentile (Cell-centre)

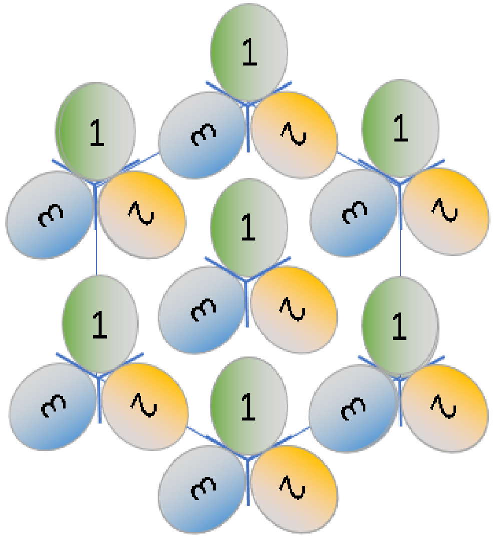


5^{th}-percentile (Cell-edge)

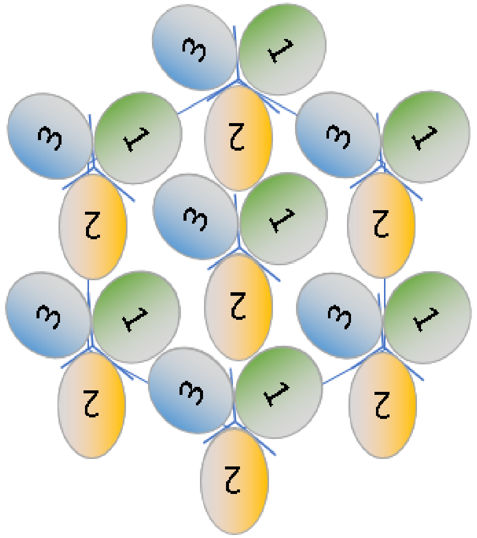


Proposed Solution - Autonomous Cells Sweeping

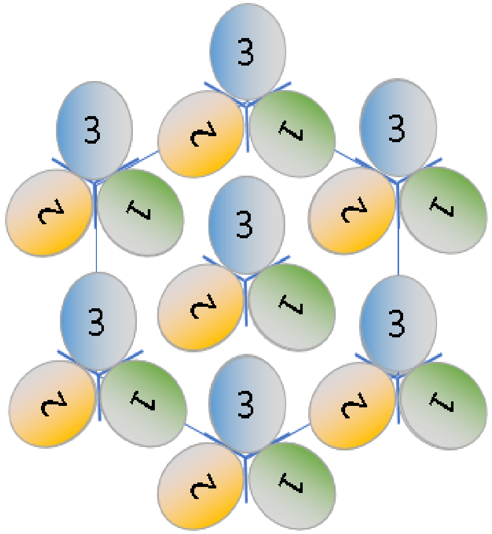
- Allow cells to start **Sweeping**: all cells sweep in Azimuth from 0 to 360 degrees to provide **Uniform Coverage**



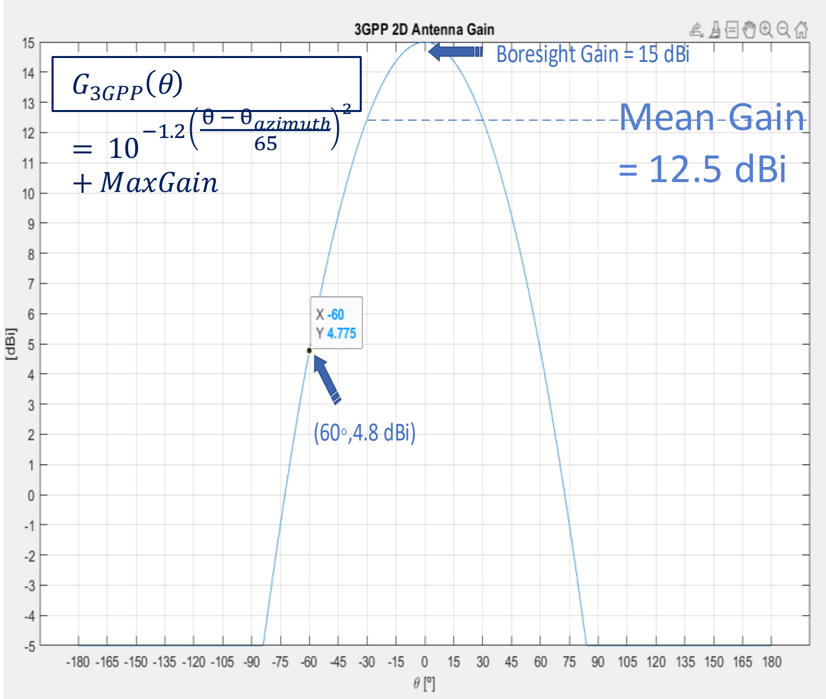
Initial State (Static)



After 60° Sweep



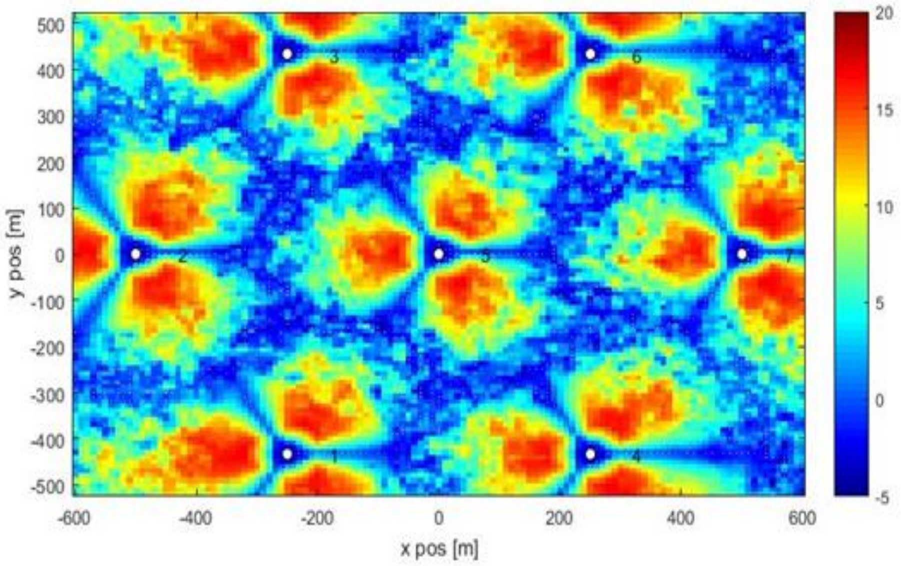
After 120° Sweep



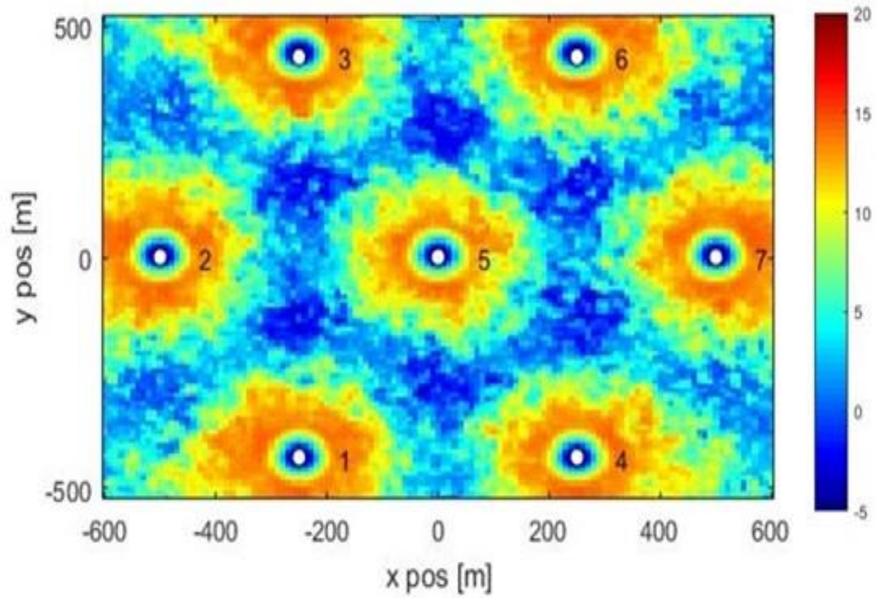
What happens with Autonomous Cells Sweeping ?

- More **Uniform Coverage** is achieved, coverage dead-spots are reduced
- Cell-edge (5th percentile) throughput is significantly enhanced

Static Deployment



After Cells Sweeping over 360°



A. Quddus, A. Mohamed, R. Borralho, M. Khalily, and R. Tafazolli, “Electrically Rotating Base Station Sectors for Uniform Coverage and Cell Edge performance in Mobile Wireless / Cellular Systems,” Patent filled, Application Number 2005722.0.

System Level Simulation Assumptions

Configuration:

- 7 Sites with 3 sectors each (i.e. 21 cells)
- eNodeB TxPower: 46 dBm
- 50 users/cell
- 400 TTI simulation
- 30 laps of full sweeps
- System Bandwidth: 10 MHz

Configuration:

- **Path Loss Model:** "TS 36.942" Path Loss Model
- **Base Station Antenna Model:** Berger – 2D
- **Shadowing Model:** Claussen
- **Inter-site Distance:** 500 m
- **Traffic Model:** full Buffer
- **Fast Fading Model:** Typical Urban (TU), 5 km/h
- **LTE TM1:** SISO

Wideband SINR and Proportional Fair (PF) UE Throughput Results

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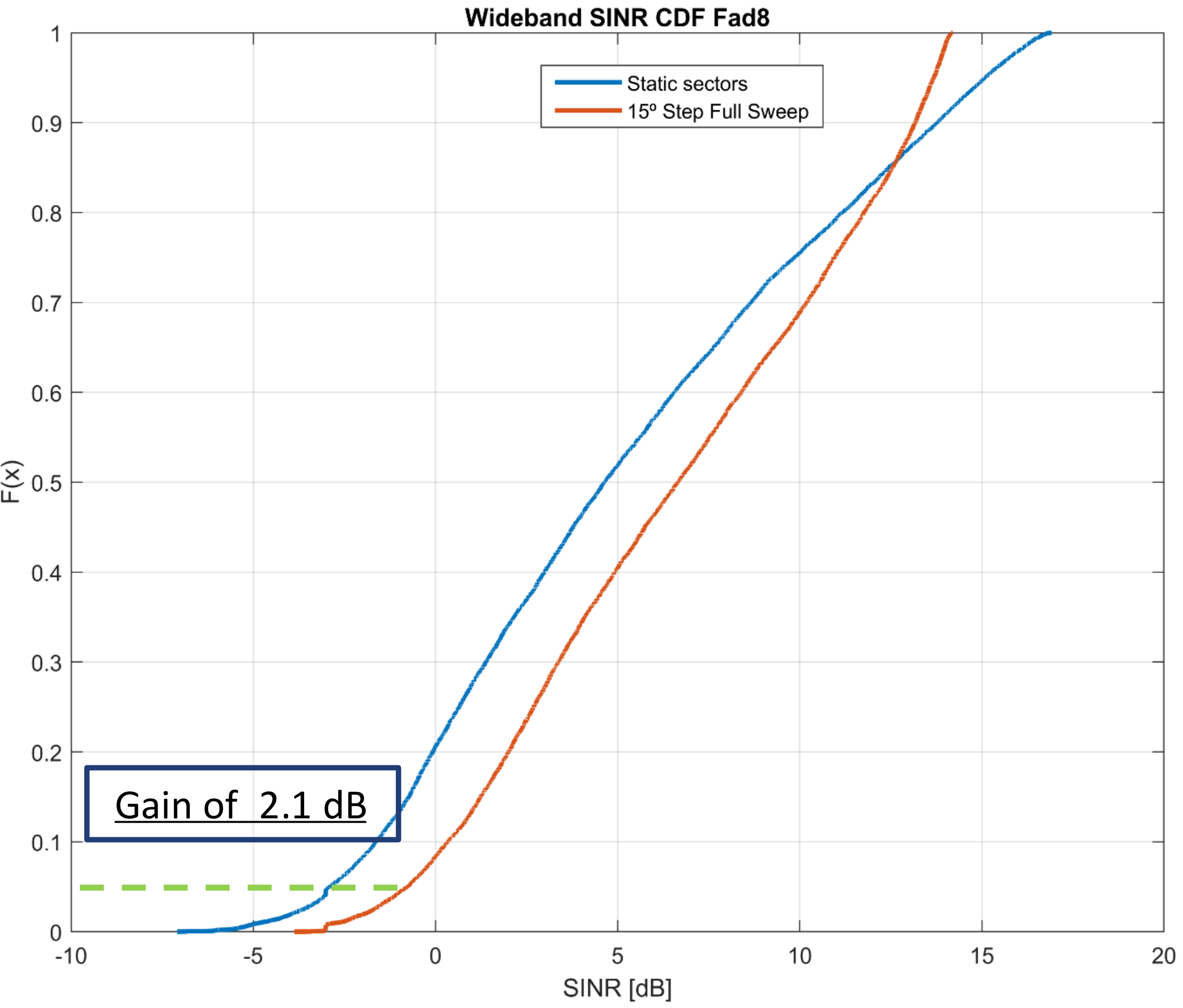
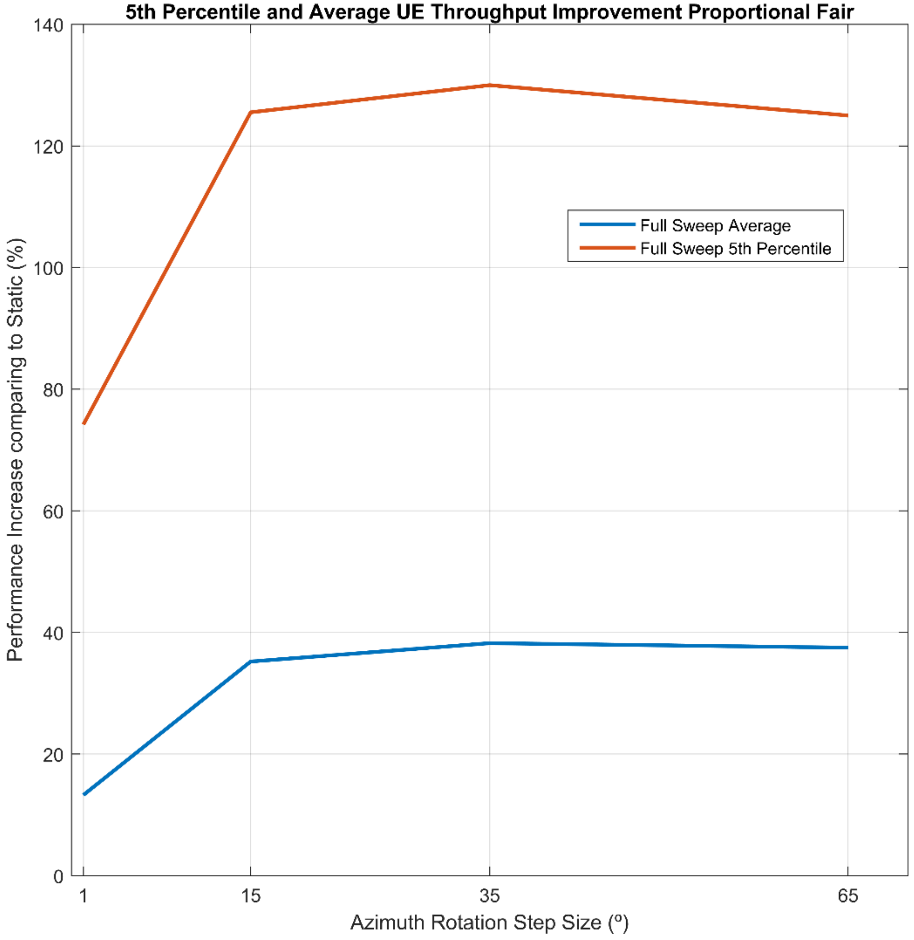


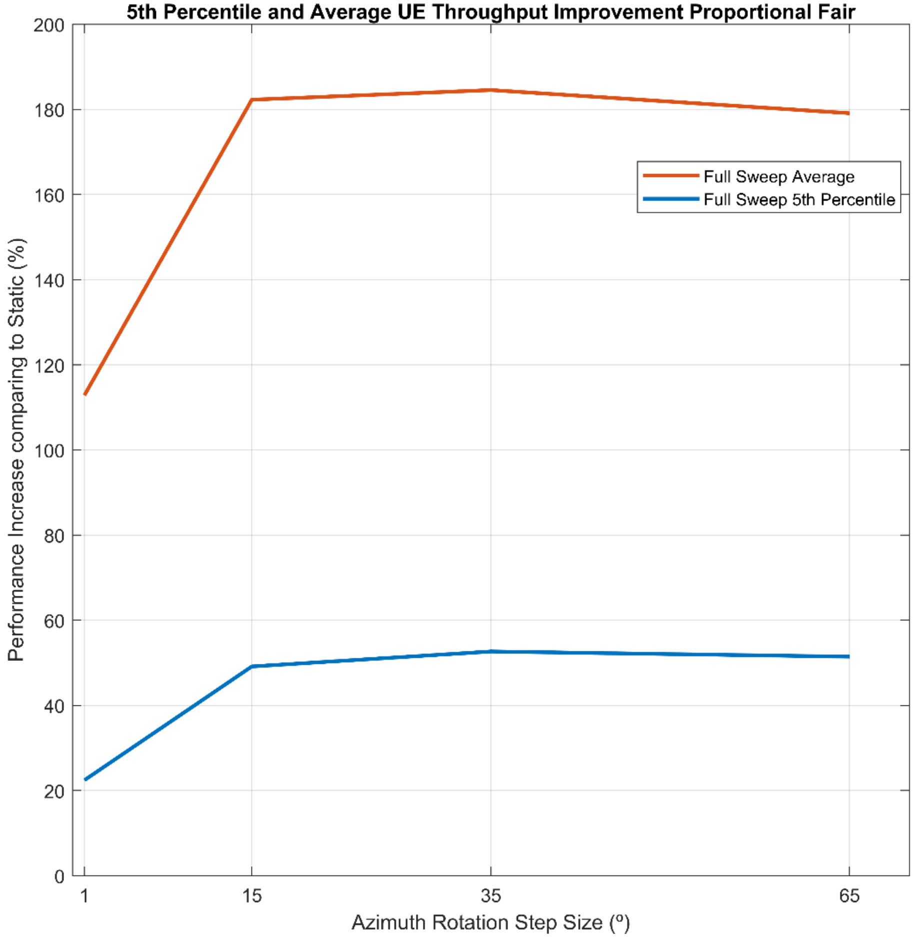
Throughput with Proportional Fair [Mbps]						
Metrics		Full Sweep				Static
		1°/TTI	15°/TTI	35°/TTI	65°/TTI	
%ile	5	0.1162 +74.2%	0.1504 +125.5%	0.1534 +130%	0.1501 +125%	0.0667
	50	0.3483 +14.5%	0.4309 +41.6%	0.4396 +44.5%	0.4389 +44.3%	0.3042
	95	0.7574 +6%	0.8611 +20.5%	0.8743 +22.3%	0.8625 +20.7%	0.7145
Average		0.3867 +13.3%	0.4616 +35.2%	0.4719 +38.2%	0.4694 +37.5%	0.3414

Standard deviation of Shadowing: 8 dB

Gains increase with Shadowing

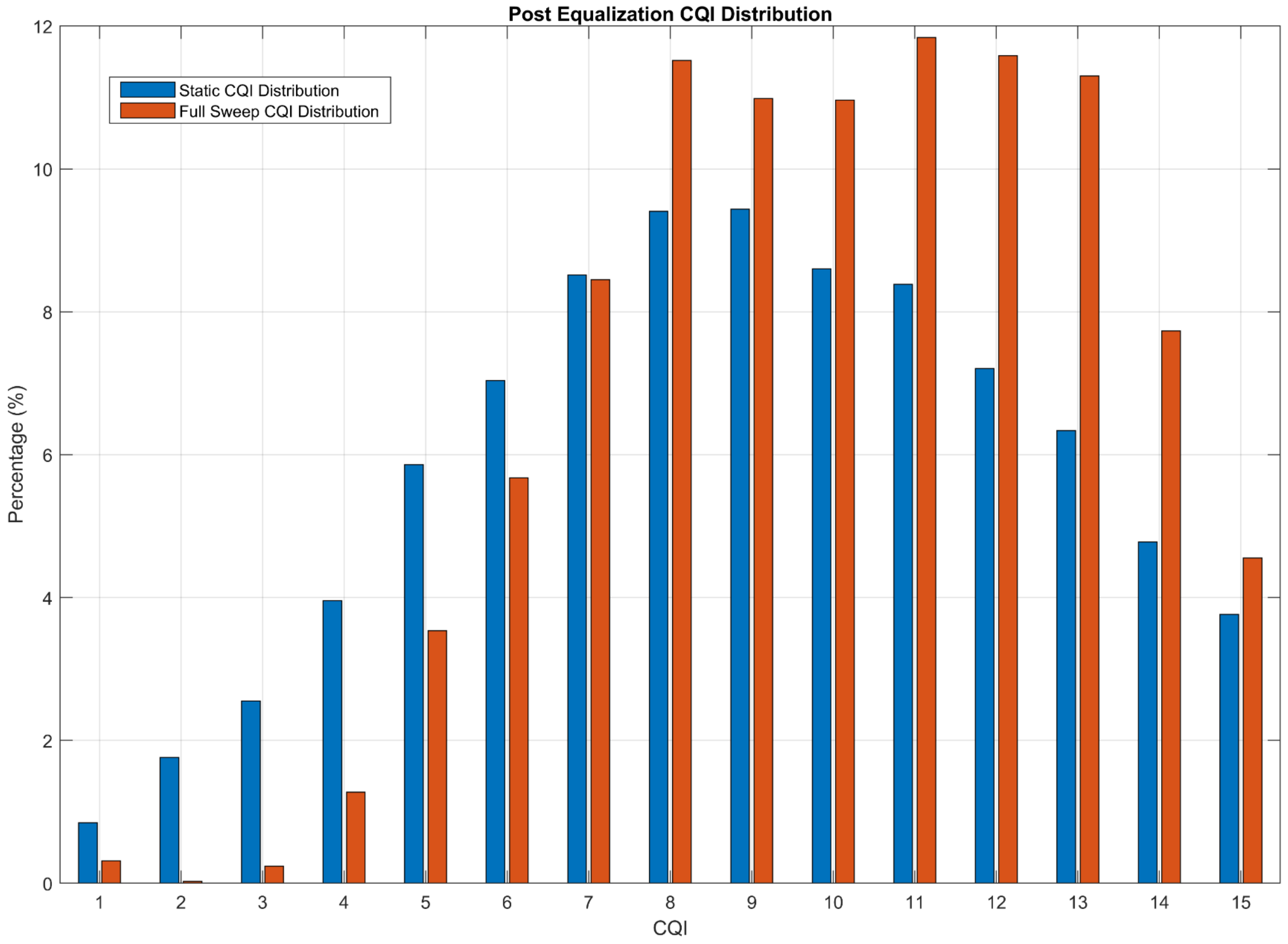


Standard deviation of Shadowing: 8 dB



Standard deviation of Shadowing: 12 dB

Modulation Coding Index (MCI) Distribution

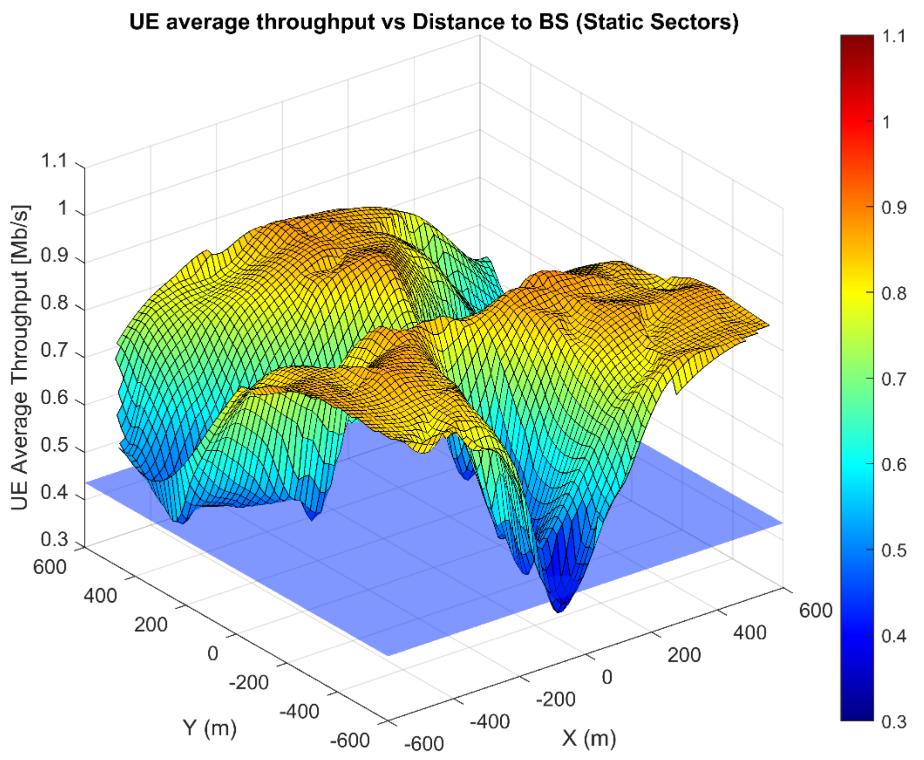


Standard deviation of Shadowing: 8 dB

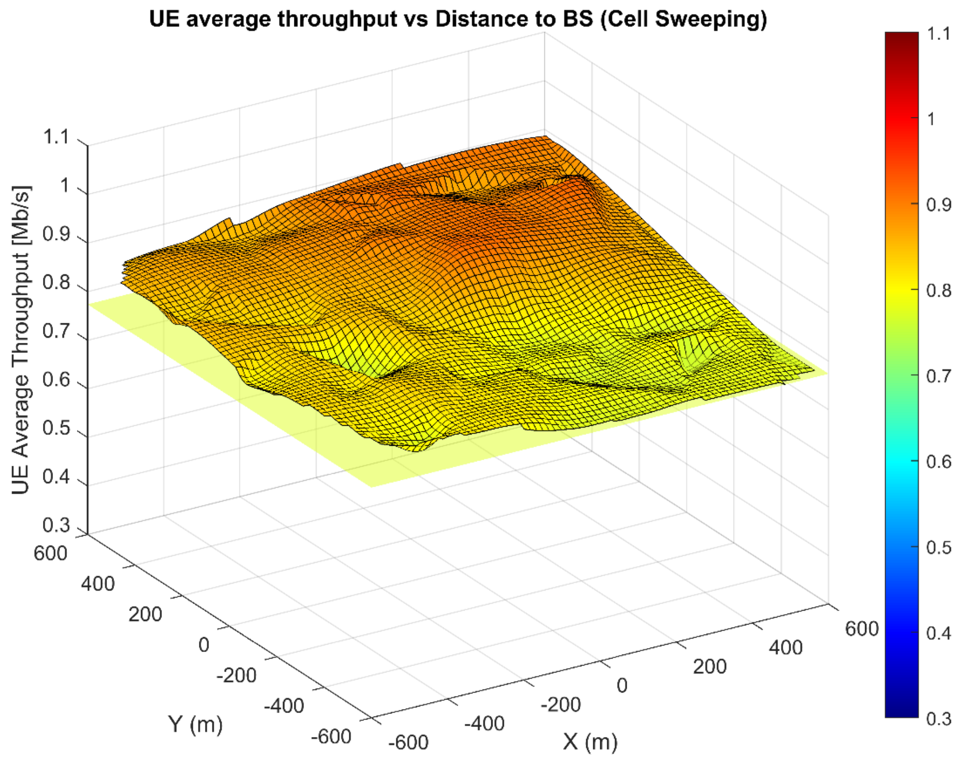
Channel Quality Indicator (CQI)			
5th Percentile		Mean	
Static	Full Sweep	Static	Full Sweep
3	5 (+2)	8	10 (+2)

Mod / Cod CQI Index	Modulation	Code Rate
1	QPSK	0.101449
2	QPSK	0.101449
3	QPSK	0.162319
4	QPSK	0.318841
5	QPSK	0.442210
6	QPSK	0.568116
7	16QAM	0.365217
8	16QAM	0.469565
9	16QAM	0.563768
10	64QAM	0.484058
11	64QAM	0.600000
12	64QAM	0.692754
13	64QAM	0.760870
14	64QAM	0.888406
15	64QAM	0.888406

Throughput Distribution



Static



Cell Sweeping

Standard deviation of Shadowing: 8 dB

Realistic LTE Link Budget with Cell Sweeping

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Downlink Parameter	Value [units]
Data Rate	1 Mb/s
Tx Power	46 dBm
BS Antenna Gain Boresight	15 dBi
Cable Loss	2 dB
Receiver Sensitivity	- 106.5 dBm
Interference Margin	4 dB
UE Antenna Gain	0 dBi
Cell Sweeping Gain (@ 5th percentile of SINR)	0 dB [Static Deployment] 2.1 dB [Cell Sweeping]
Maximum Allowable Path Loss	161.5 dB [Static Deployment] 163.6 dB [Cell Sweeping]

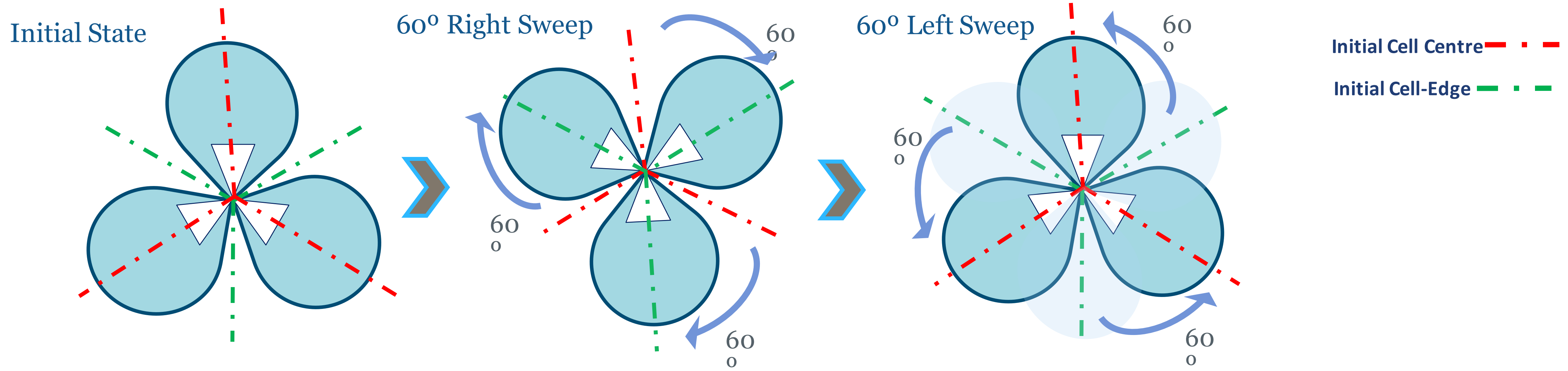
Okumara – Hata Propagation Model	Value [units]
Base Station Height	15 m
Mobile Station Height	1.5 m
Shadowing Standard Deviation	8 dB
Propagation Loss Exponent, n	3.7
Location / Cell Area Reliability	95 %
Fade Margin	8.8 dB
Carrier Frequency	2.1 GHz
Indoor Loss	18 dB
Cell Range, R	0.711 km [Static Deployment] 0.809 km [Cell Sweeping]

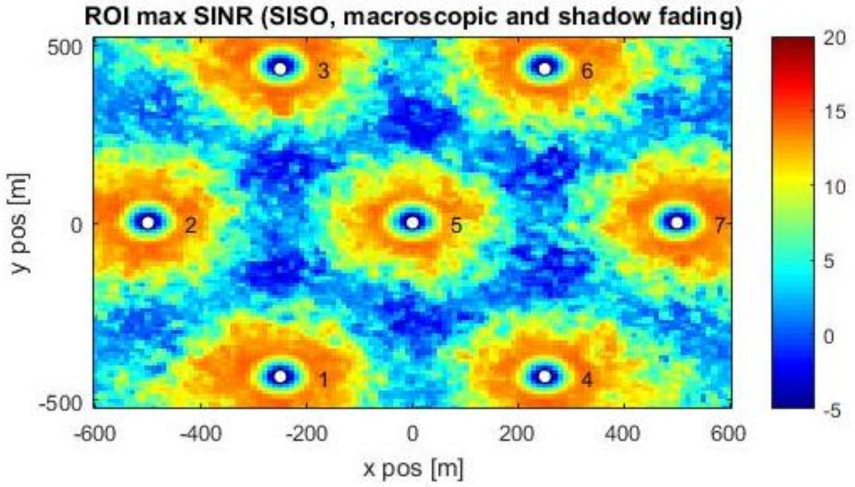
With cell sweeping, **98 metre (roughly 100 metres)** increase in cell-radius can be achieved which is about **14%** increase!

Impact on Network Dimensioning

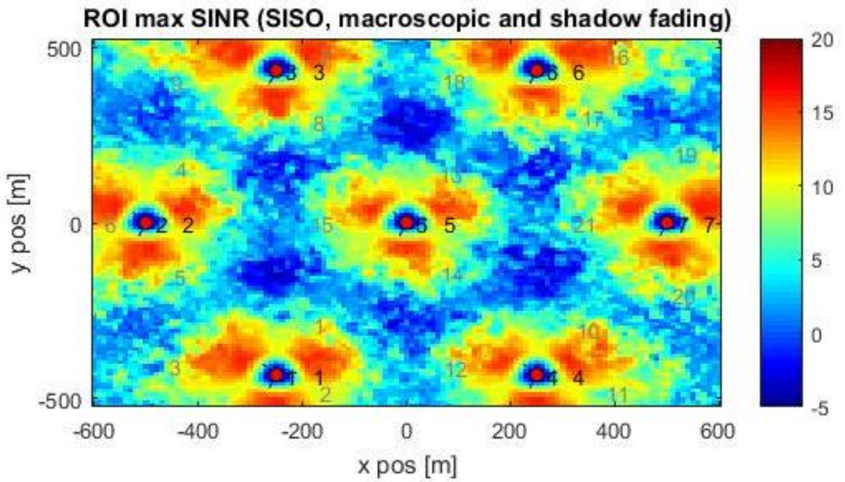
- **14%** increase in cell radius translates into roughly **30%** increase in cell area
- Hence, to cover a certain geographic area X square kilometres, **30%** less cells are required.
    - Direct cost savings to the operators
    - Reducing energy consumption
- It should be noted that this is the minimum increase, with advanced versions of cell sweeping, more gains are possible!

Some Practical Aspects – Partial Sweep





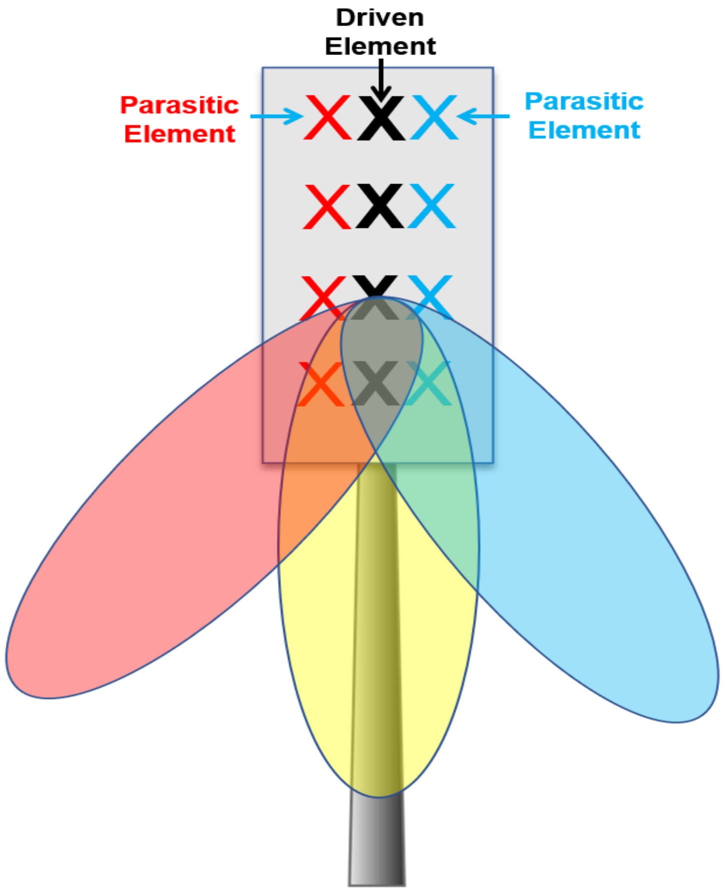
Full Sweep



60° Sweep

Cheap Practical Implementation – Electrically Steerable Antenna

- Our novel antenna design allows BS antennas to be **upgraded rather than replaced** in a cost-effective manner
- No need for complex feeding network design or addition of extra hardware
- We add parasitic elements on both sides close to the main structure of antenna to be excited by the fringing field of main structure
- We can use pin diodes to turn off and turn on these parasitic elements to shape the beam to either left or right of azimuth boresight



Conclusions

- Cell Sweeping is a novel cells deployment method that results in:
  - Uniform and fair distribution of capacity irrespective of user location
  - Cell edge problem is substantially reduced
  - Increase in cell-range and cell-area
  - Decrease in number of cells by a minimum of **30%**
  - Principle apply to MIMO / mmWave etc.
- What changes are required:
  - Upgrade Antennas to electrically sweeping beams
- Cell Sweeping does not affect the digital baseband, it is an RF level technique, hence applicable to existing cellular (3G / 4G / 5G), as well as to future networks.

Thank You