5G mmWave network field test with Phased array antenna

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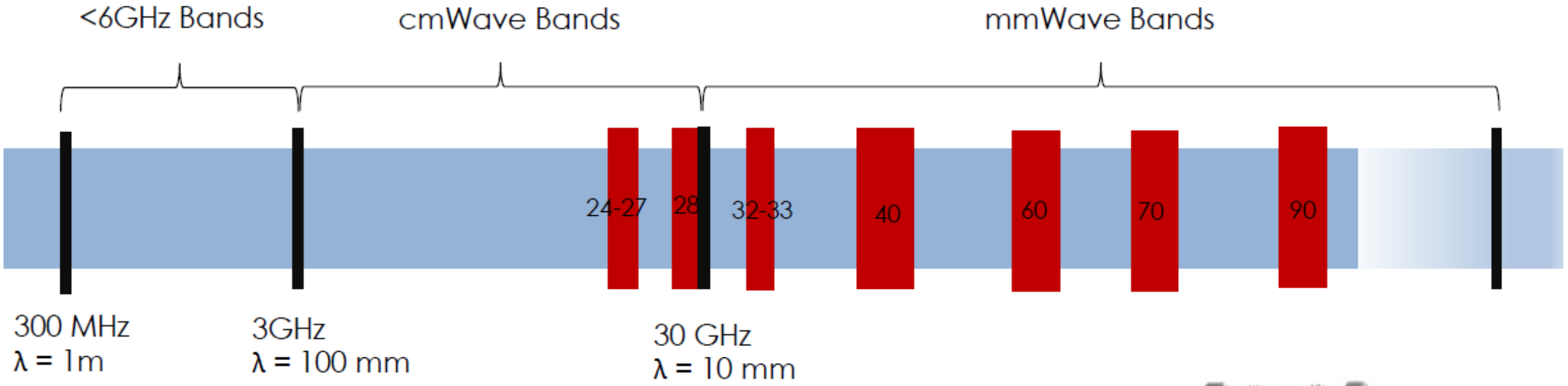
KEYSIGHT TECHNOLOGIES

Agenda

- 5G air interface technologies
- Phased array antenna brief intro
- mmWave 5G field test challenges
- Phased array based antenna receiver system
- 5G over the air demodulation/ cell scanning
- Keysight FieldFox overview

5G air interface technologies

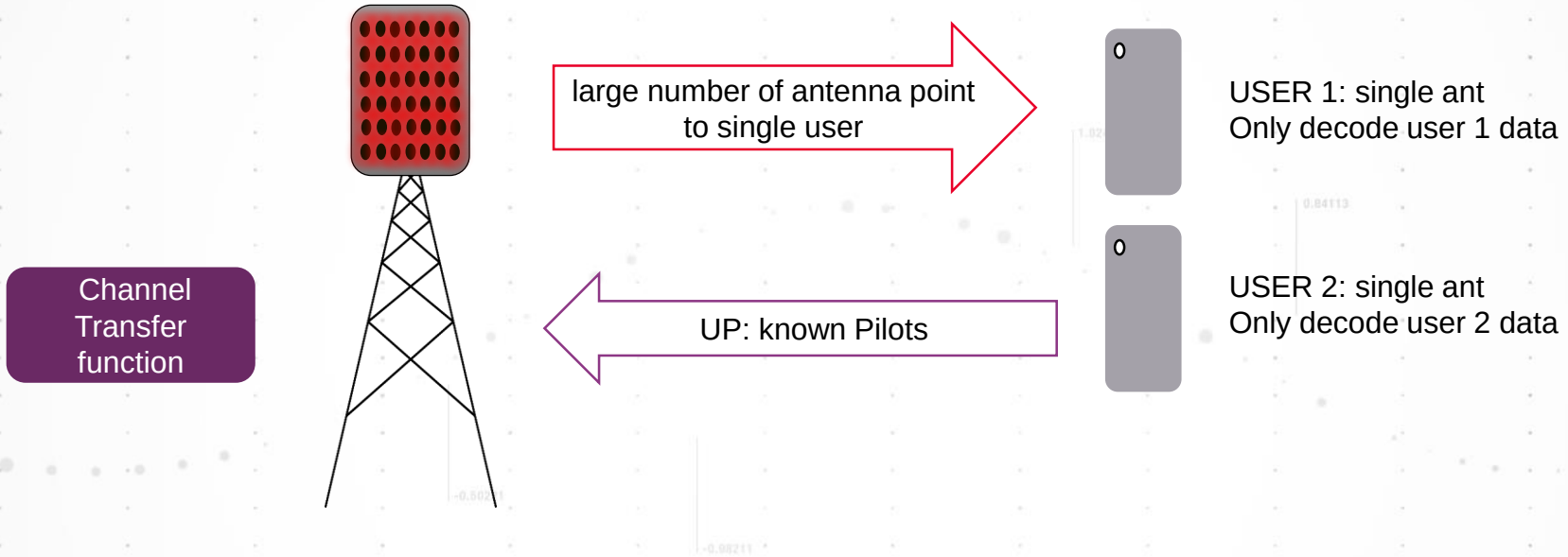
5G mmWave bands pose challenges in the field because there are many new obstructions compared to LTE.



Up to 50 GHz

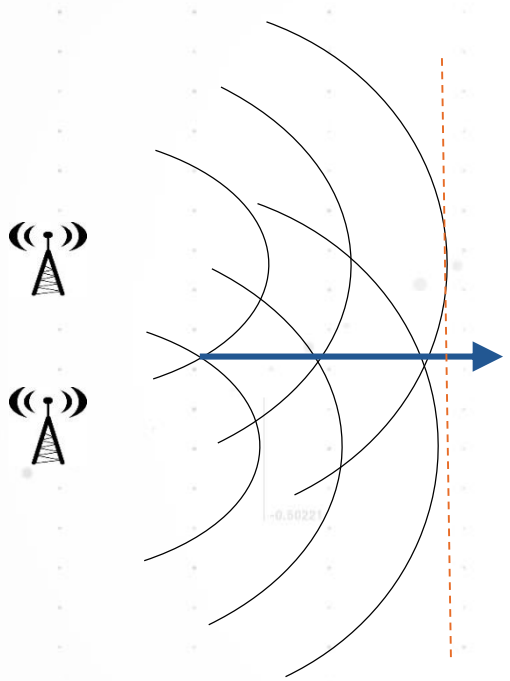
Massive MIMO

Multiuser MIMO when number of ant. >> number of UE

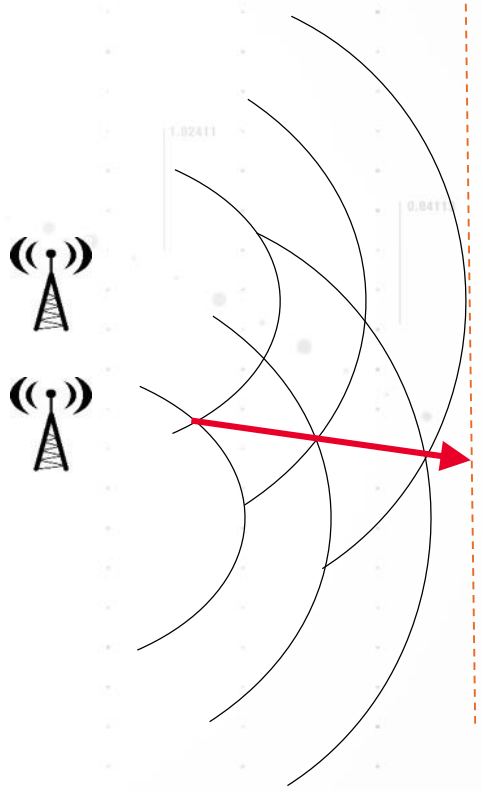


- Only BS keeps the channel information
- BS antenna number >> the number of UE
- Each antenna can be controlled (gain and phase)
- Dramatically improves SNR at UE, better overall capacity
- Channel noise can be reduced with increase of number of antenna

Beamforming occurs when you apply a delay to a signal, controlling the angle of the beam.

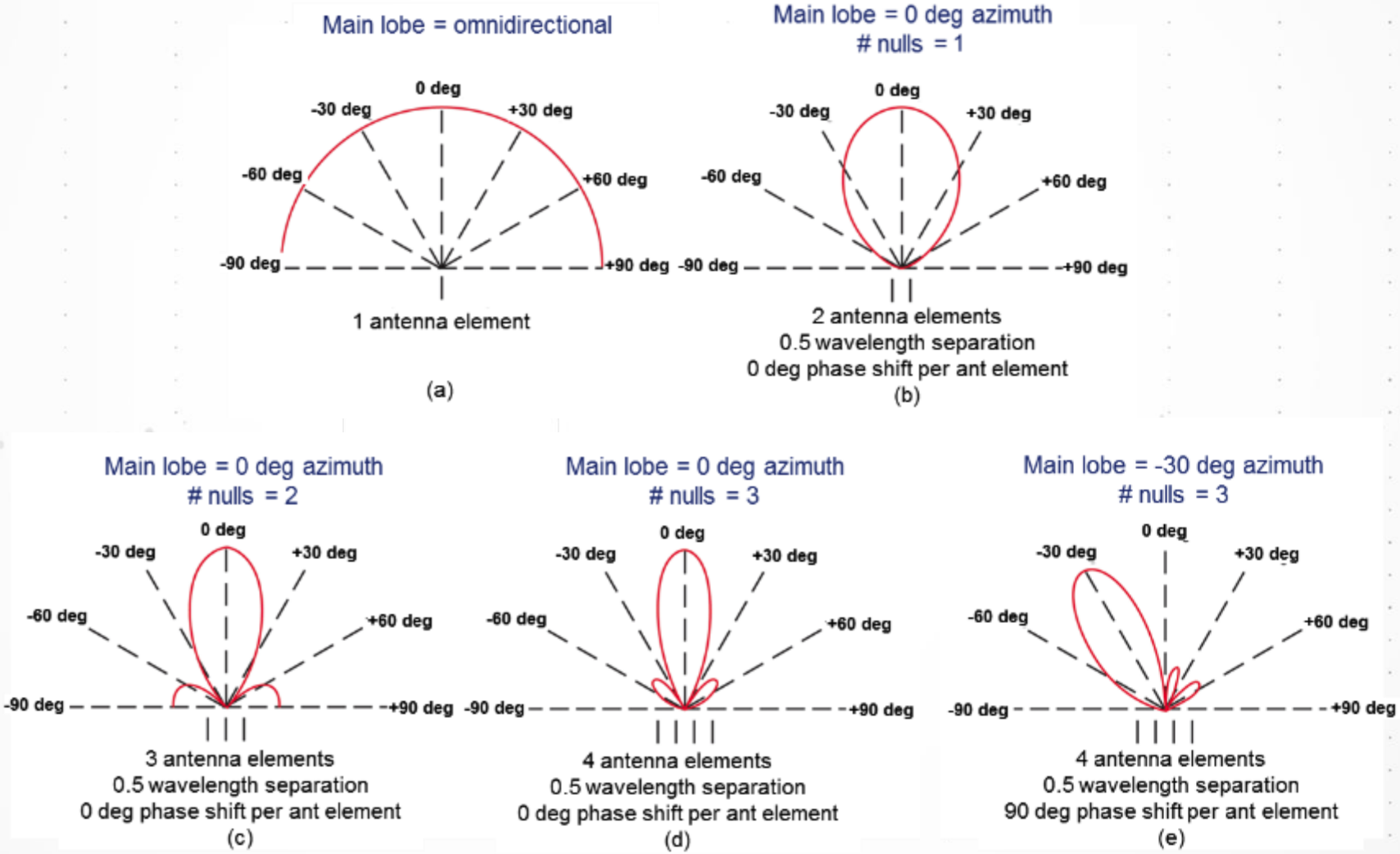


Delay = 0



Delay ≠ 0

Narrower beams have more elements which complicates antennas but improves directivity and the S/N ratio.



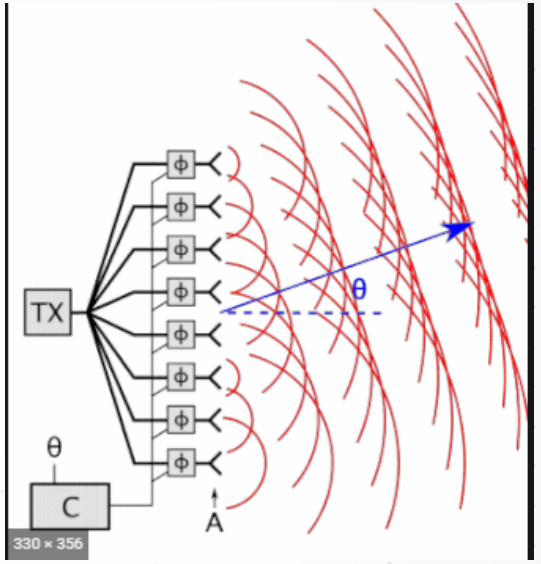
Phased array antenna overview

Phased array antenna overview

WHAT IS PHASED ARRAY ANTENNA

What is phased array antenna

- Multiple elements in an antenna
- Each element's phase and magnitude can be adjusted to create a beam of radio wave.
- The beam direction can be steered by changing phase of each element without physically moving antenna



Phased array antenna overview

TYPES OF BEAMFORMING

- **Analog beam forming:**

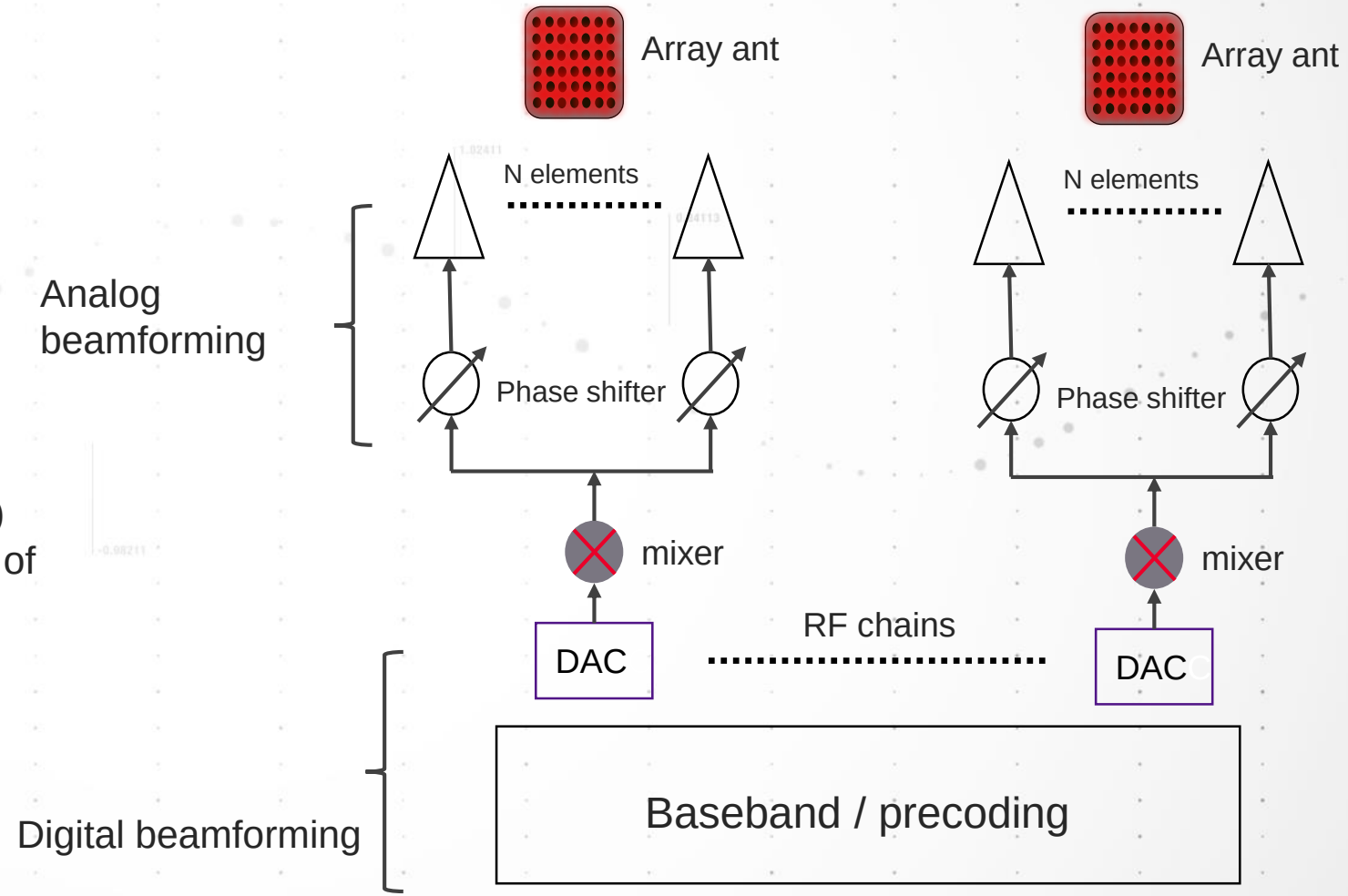
Phase and gain adjustment are adjusted on RF signal directly. One beam at a time.

- **Digital beam forming**

The signal is pre-coded (amplitude and phase modifications) in baseband processing before RF transmission. Multiple beams (one per each user) can be formed simultaneously from the same set of antenna elements. In the context of LTE/5G, MU-MIMO equals to digital beamforming

- **Hybrid beam forming**

Combine analog and digital beamforming



mmWave 5G field test challenges

Challenges to deploy 5G mmWave network

- mmWave band
  - Re-think of pass loss and link budget
  - Different deployment and optimization strategies
  - Engineers deal with uncharted territories to engineer network for terrestrial communications

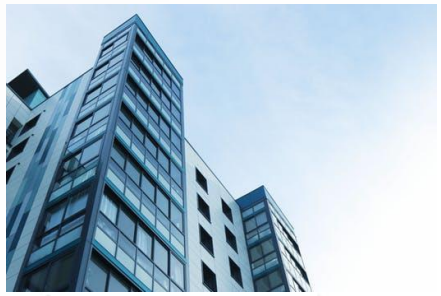
- Coverage test
  - Omni antenna doesn’t work well, not enough gain, not correlating with UE antenna.
  - Phased array antenna is the best choice to evaluate beam coverage
  - Horn antenna is a good alternative. But it is manual steering process

Phased array antenna based receiver system

Solution description

- Frequency: 28 GHz, 39 GHz (future)
- Measurement:
  - Multipath/ physical beam power measurement;
  - Multipath/reflection signal evaluation
  - Spectrum analysis
  - Real time spectrum analysis
  - Optional 5G TF control channel power and cell ID
  - Signal analysis with VSA software on PC/Tablet
  - Geo Tagging
  - Record and playback
- Solution components
  - FieldFox (spectrum analyzer, pre amp, RTSA,, 5G NR OTA), 28 GHz/ 64 element phased array antenna, cables and adapters, GPS.

5G mmWave air interface characterization challenges



Reflected signal

Direct path

Direct path

- 90 degree

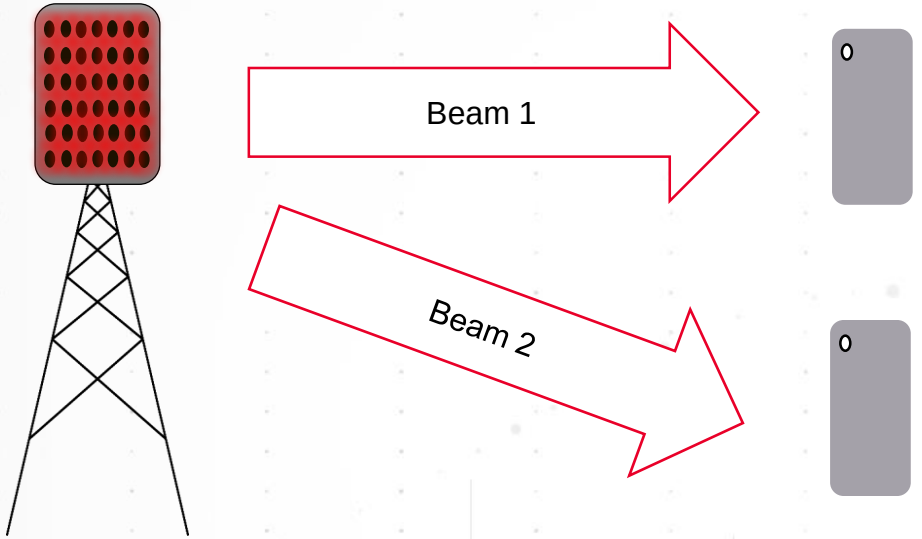
+ 90 degree

Power vs azimuth

Calibrated phased array

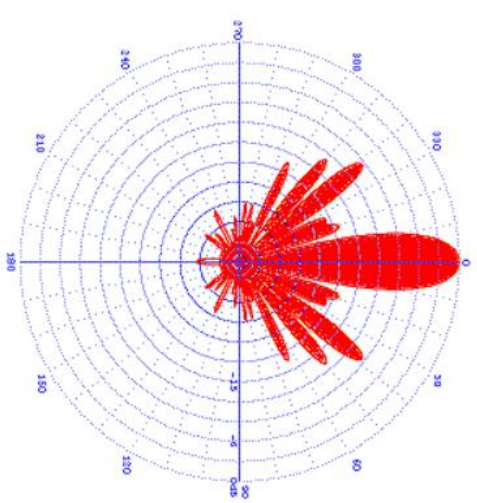
- Coverage test
  - Characterize mmWave beamformed signal from gNB, to efficiently harvest energy at UE side.
- Propagation model tuning
- Multipath evaluation
- Identify interferences from adjacent cells and reflected paths.

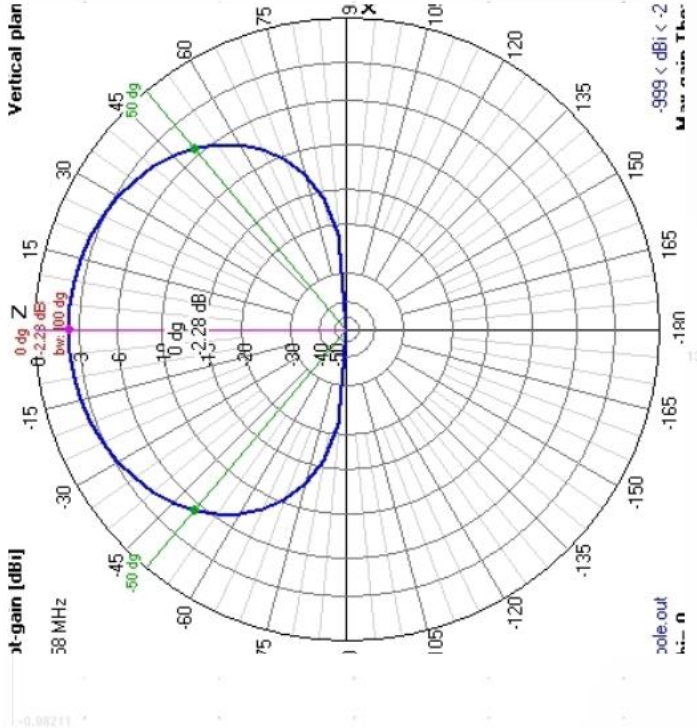
UE/CPE RF performance optimization



- Calibrated grade phased array antenna is to accurately characterize the power received at UE
- Configure test antenna to simulate UE antenna performance

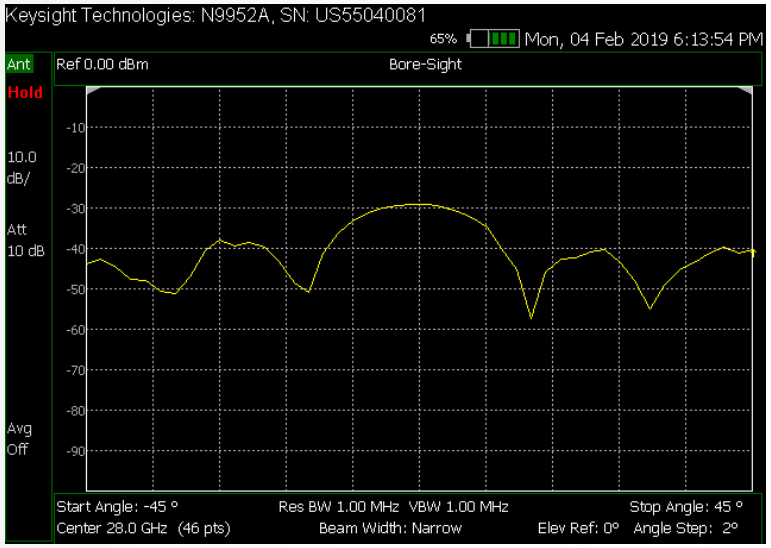
gNB RF parametric test over the air



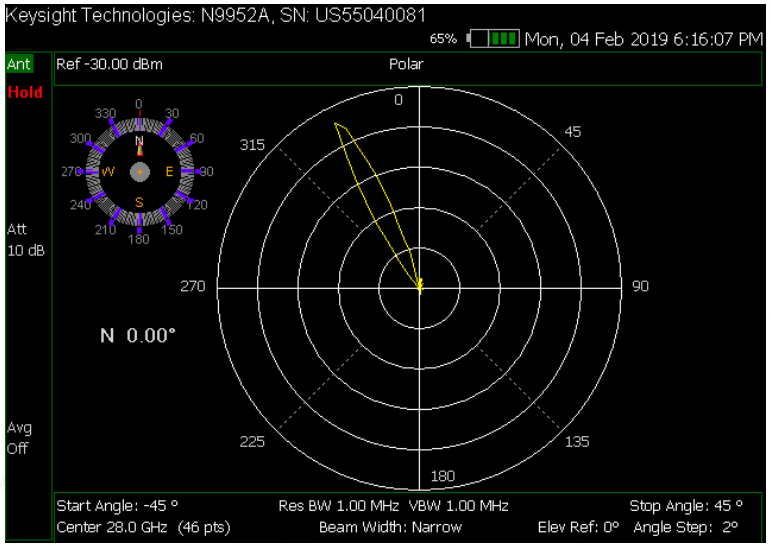


- Configure phased array as RF probe to “capture” all energy radiated from gNB.
- Measure estimated EIRP, TX Spurious, SEM etc..

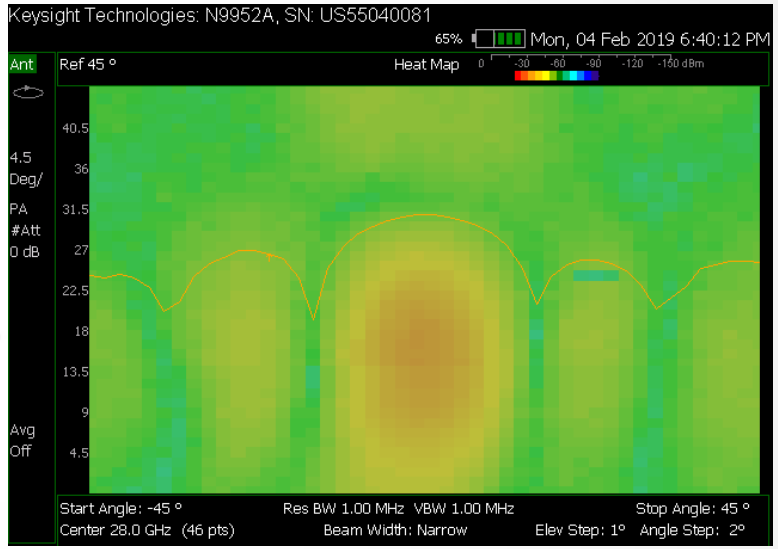
Phased Array Antenna measurements



Boresight scan

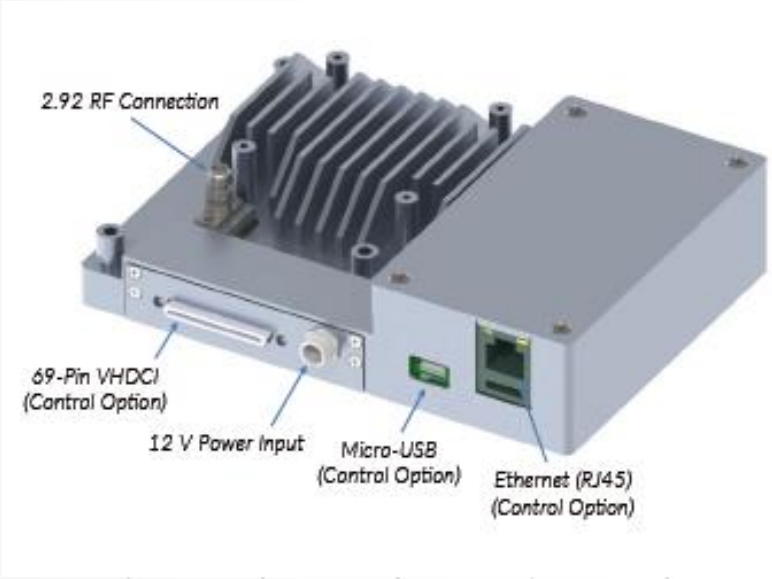


Polar scan



2D scan Heat map
(Azimuth vs elevation)

Antenna specification



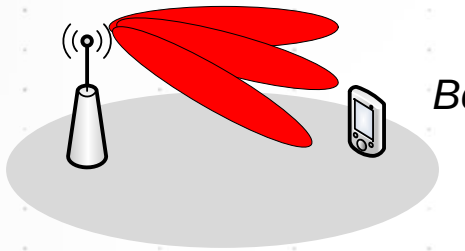
• Frequency	27.5 to 30 GHz
• EIRP	48 dBm (measured at boresight, P1 dB)
• G/T	>-7 dB/K (measured at boresight)
• Polarization	Linear (vertical)
• Beam Steering	Electronic
• Number Beams	Single radiation beam (can be broadened)
• 3 dB Beamwidths	Multiple beam widths, wide to narrow (16°)
• RF Interface	Half duplex (TDD), single 2.92 mm RF connector
• Size	4.25x6.0x1.55 inches
• Weight	1.1 pounds
• Supply Voltage	Single 12 or 18 VDC
• Peak Power	20 W DC (transmit) 15 W DC (receive)
• Control Interfaces	LVDS, Ethernet, USB

5G over the air demodulation/ cell scanning

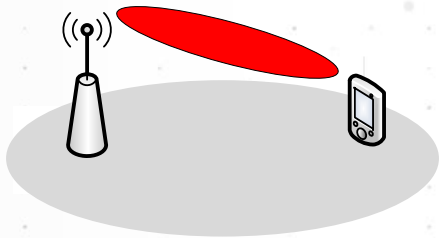
5G network access procedures

TRxP-wide coverage

UE-specific coverage

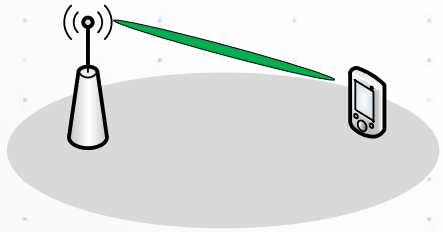


Beam-sweeping transmission



Beam-sweeping reception

UE-specific selected beam



UE-specific beamforming

Synchronization signals

System information

Basic information for all UEs

Random Access Channel

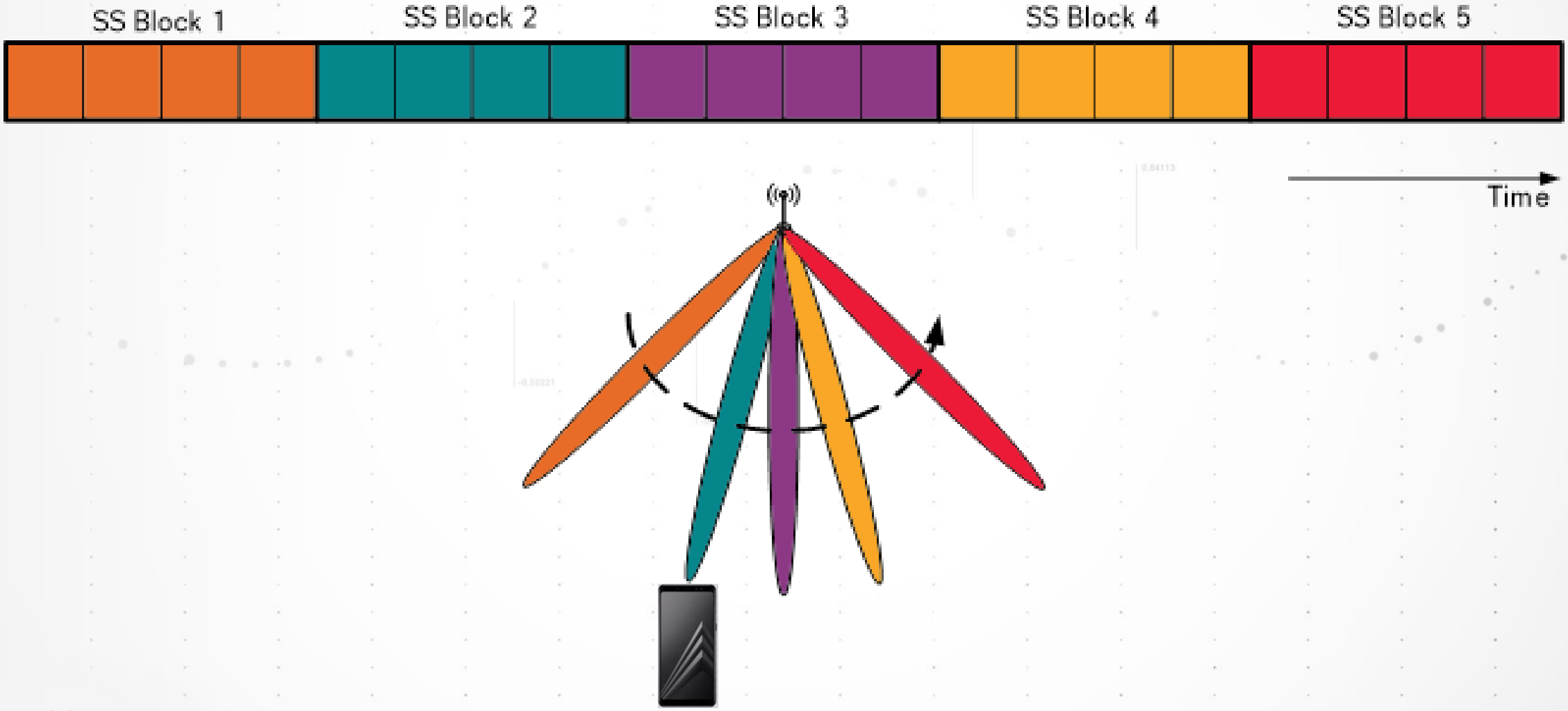
Random Access Response & system information

Required only for UEs after random access

Single-beam or Beam-sweeping

Data and control channels

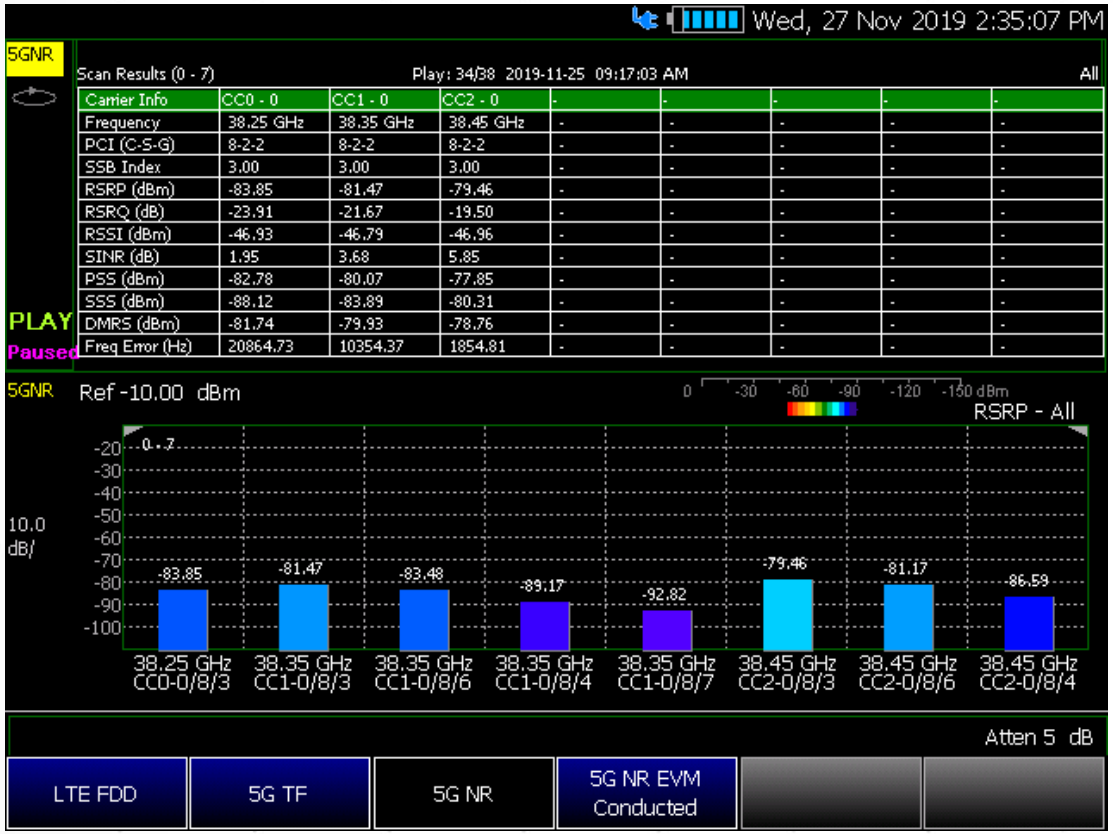
Each SSB block represents a different beam and angle, otherwise known as the beam index.



5G NR network scanning for coverage optimization

Cell site info

Beam index scanning



Carrier Info	CC0 - 0	CC1 - 0	CC2 - 0	-	-	-	-	-
Frequency	38.25 GHz	38.35 GHz	38.45 GHz	-	-	-	-	-
PCI (C-S-G)	8-2-2	8-2-2	8-2-2	-	-	-	-	-
SSB Index	3.00	3.00	3.00	-	-	-	-	-
RSRP (dBm)	-83.85	-81.47	-79.46	-	-	-	-	-
RSRQ (dB)	-23.91	-21.67	-19.50	-	-	-	-	-
RSSI (dBm)	-46.93	-46.79	-46.96	-	-	-	-	-
SINR (dB)	1.95	3.68	5.85	-	-	-	-	-
PSS (dBm)	-82.78	-80.07	-77.85	-	-	-	-	-
SSS (dBm)	-88.12	-83.89	-80.31	-	-	-	-	-
DMRS (dBm)	-81.74	-79.93	-78.76	-	-	-	-	-
Freq Error (Hz)	20864.73	10354.37	1854.81	-	-	-	-	-

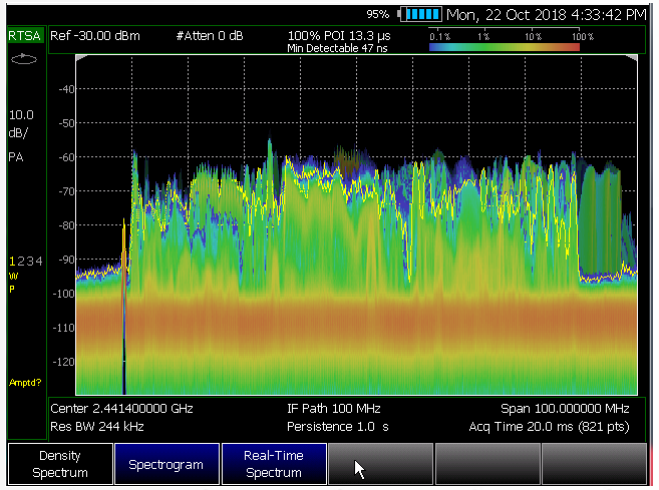
- FR1 and FR2
- PCI
- RSRP
- RSRQ
- PSS and SSS power
- SINR
- DMRS power and SINR
- SSB index (beam index)
- Frequency error
- EIRP
- SSB location/auto detection
- Top N cell scanning
- Top N component carrier scanning
- Demodulation bandwidth: 100 MHz

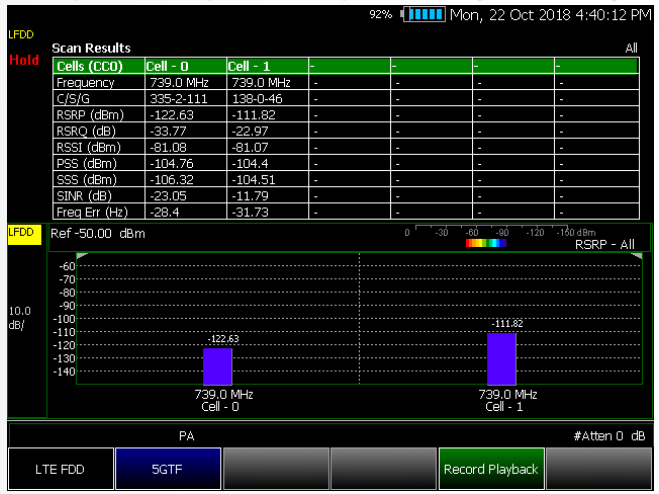
Wideband FieldFox introduction

Wideband FieldFox MW analyzer

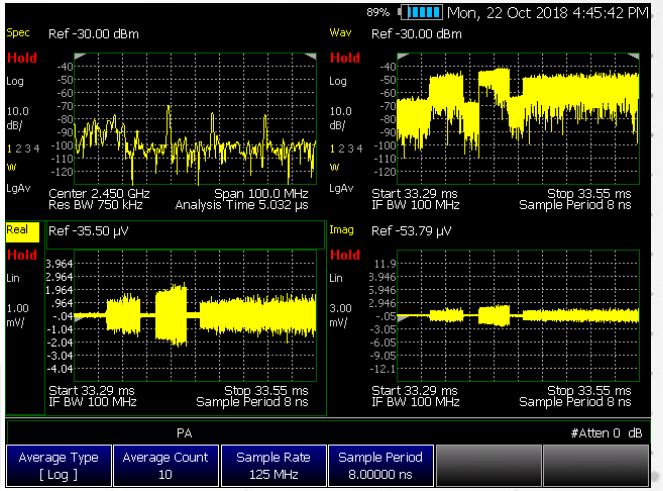
- Combo analyzer N9913/14/15/16/17/18B
- Spectrum analyzer N9933/34/35/36/37/38B
- Frequency range: 5kHz/30kHz to 26.5GHz
- Real time bandwidth: 10MHz (standard), 40 MHz and 100 MHz
- Functions: SA, VNA, RTSA, PM, independent CW source, CAT, TDR, channel scanner, NF, IQA, OTA, GNSS and many more;
- No vents and removable fan (no water or dust will get into FieldFox)
- LAN, USB and SD card.
- High capacity battery: 4 to 5 hr operation
- Meet Mil PRE 28800 F class

What is new





- DANL: -163 dBm (pre amp on)
- Improved phase noise 117 dBc @ 1GHz, 10kHz offset
- VNA system dynamic range: 117 dB better
- 100 MHz information bandwidth
- RTSA with real time bandwidth 100 MHz
- OTA demodulation on the box: LTE and 5G TF
- 5G NR demodulation via VSA
- 100 MHz IQ recording
- GNSS: GPS, GLONASS, Beidou, Galilieo
- And much more



FieldFox mmWave solutions

- N995X/6X:
  - 32, 44, 50 GHz
  - 10 MHz bandwidth
  - LTE and 5G TF demodulation
  - 5G NR FR1 control channel demodulation with VSA

- N991x/3xB + OML downconverter
  - WR 28 (24 to 40 GHz); WR15 (50 to 75 GHz); WR12 (60 to 90 GHz); WR 10 (75 to 110 GHz)
  - Wideband support: 40 / 100 MHz
  - LTE and 5G NR 100 MHz
  - 5G NR FR1 and FR2 demodulation with VSA

FieldFox Overview

CARRY PRECISION WITH YOU

For devices and components

1. Cable and antenna test
2. TDR
3. VNA / Time domain
4. Noise figure
5. Vector volt meter
6. Power meter
7. Extended Range Transmission Analysis (ERTA)
8. Tracking generator

For signal analysis

9. Spectrum analysis
10. Real time spectrum analysis
11. Time gating
12. Interference analysis
13. Channel scanner
14. Analog demodulation (AM/FM)
15. 5G OTA, LTE OTA
16. IQ Analyzer
17. Pulse Measurement with peak power sensor
18. Frequency counter
19. Keysight VSA 89600 link
20. Phased Array antenna control
21. EMF Measurement

Utilities

22. GNSS
23. DC voltage source
24. Secure erase
25. Mapping
26. Frequency extender up to 110 GHz

Summary

- 5G mm-Wave air interface is drastically different from sub 3 GHz;
- Implementing mm-Wave for terrestrial communication is new and challenging
- Engineers need to better understand the key factors which dominates the coverage
- Beam sweep of control channels makes the coverage and optimization more demanding.
- Network planning and deployment processes need to be adjusted for mm- Wave
- FieldFox with phased array antenna greatly improve the reliability of air interface measurement in mm-Wave band