Demystifying 5G & OTA Seminar

Mardi 18 juin 2019 - Vélizy-Villacoublay (78)

Conception et mesure d'antenne millimétrique 5G : Défis et perspectives

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Outline

- Introduction et motivation
- Projet FUI Mass-Start
- Antennes pour Small cell
- Antennes pour smartphone
  - Effet corps humain
- Conclusion and perspectives

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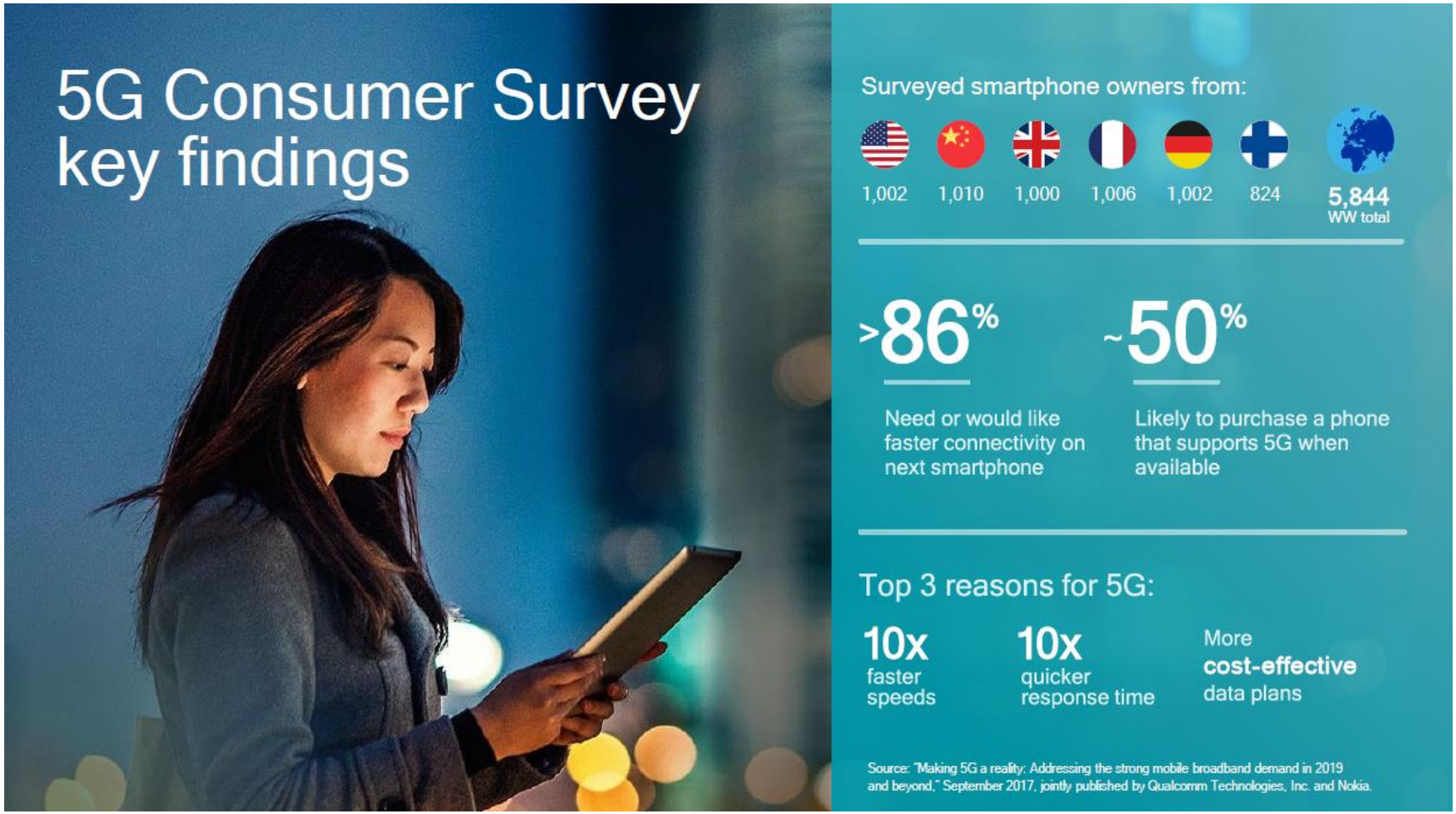
Motivation : 5G needs



« Make 5G mmWave a commercial reality… in your smartphone », Qualcomm

Motivation for mmW : Increasing data rate ?

- Channel capacity is defined as the maximum theorical datarate which the chanel can support

$$C = BW\ log_2(1 + SNR)$$

- Study of the technologies carrying the 5th generations of mobile communications :
  - High Frequency Antennas (10 GHz to 71 GHz)
  - MIMO and Massive MIMO

- Increase mobile network capacity thanks to network density, spectral efficiency and bandwidth

- Beamforming gain = 10*log(N_{ant}) dB

N_{ant} number of antenna

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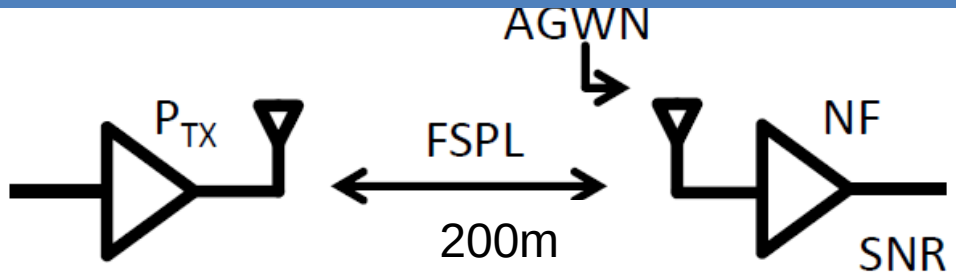
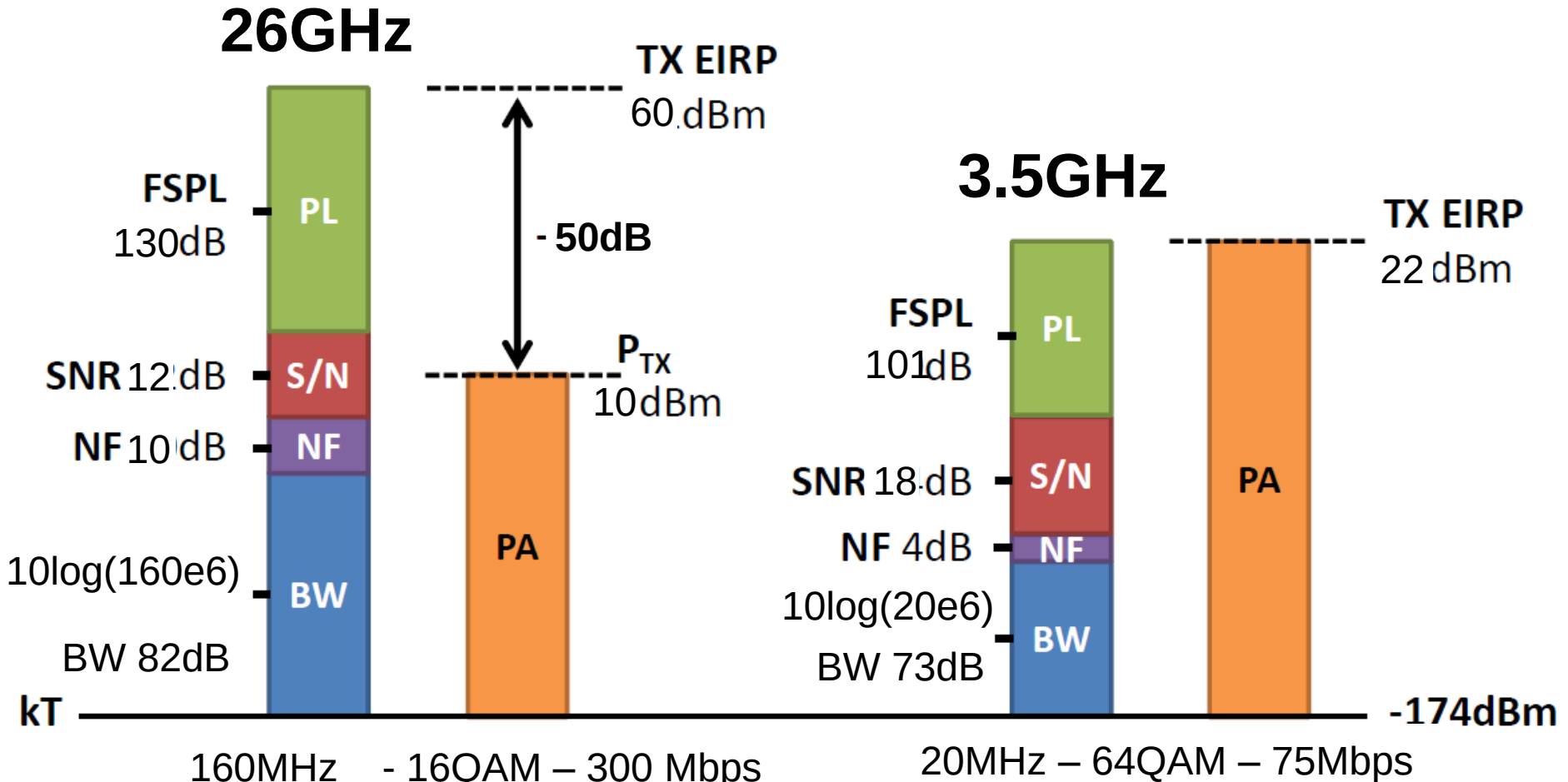
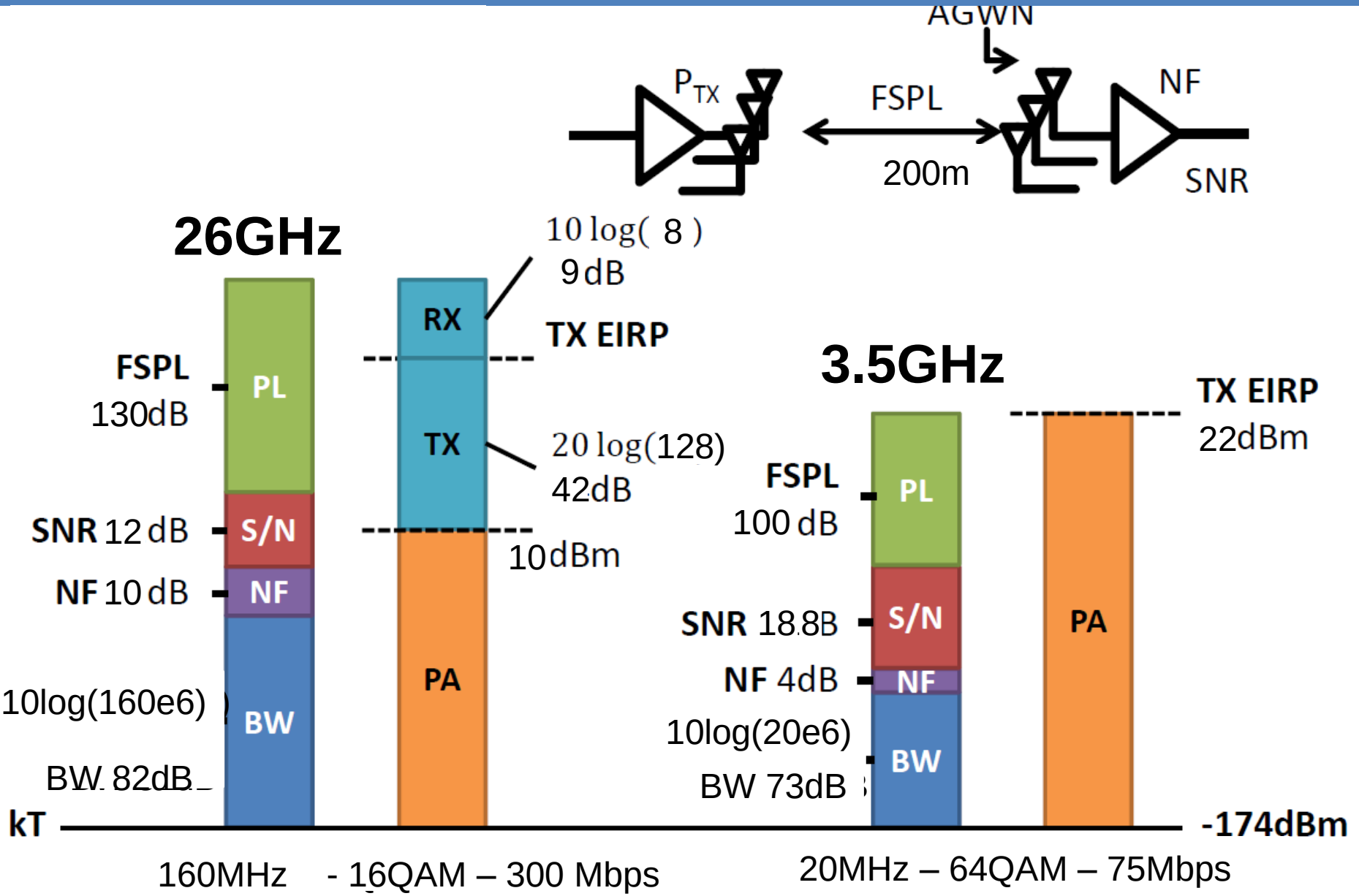




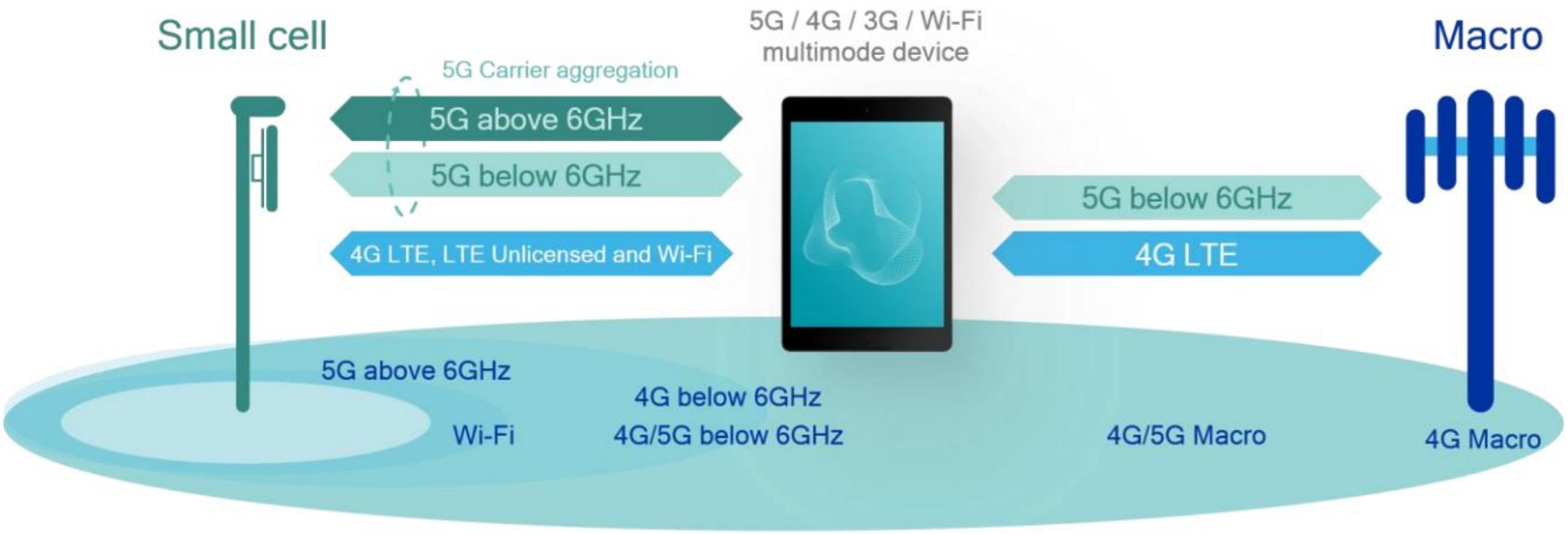
160MHz - 16QAM – 300 Mbps

20MHz – 64QAM – 75Mbps

Motivation : 5G requirements

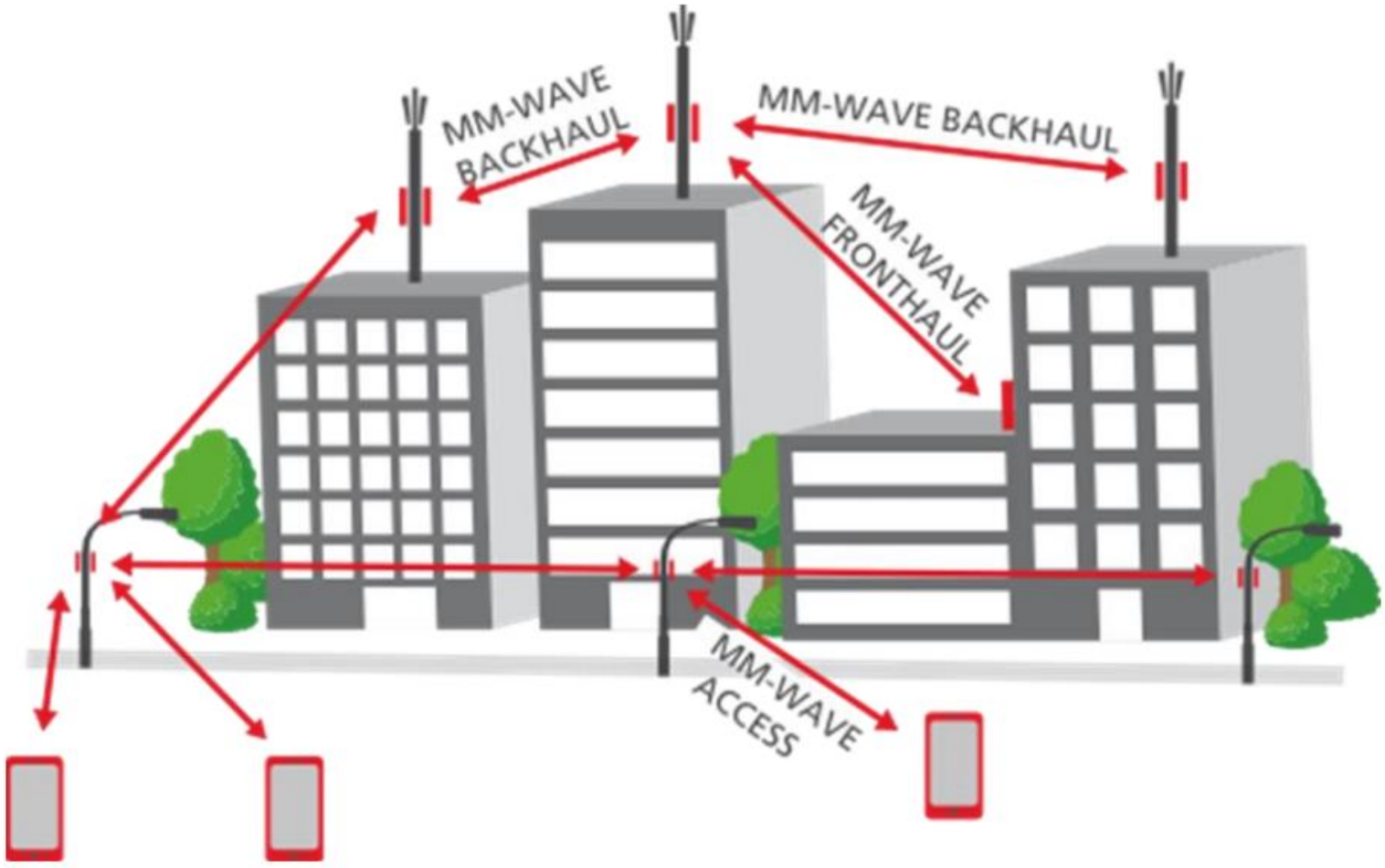


Motivation : Use case



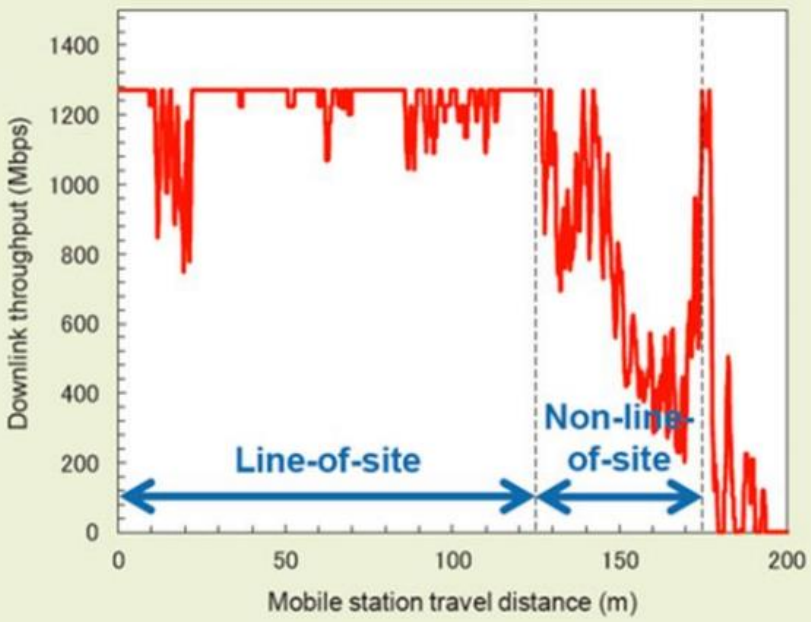
« Making 5G NR a reality », Qualcomm White paper

Motivation : Use case



Source: MiWeba

Motivation : 5G needs



Source: NTT Docomo Technical Journal, April 2016

Motivation : Increasing data rate ?

- Centimeters and Millimeters Wave have a low penetration capabilities
- Miniaturization thanks to smaller wavelength allows easier integration of multiple antennas (@26GHz, λ=10mm)
- MIMO technique as beamforming is **mandatory** at millimeter wave because of the higher attenuation in the channel.
- Handheld devices strongly impacted by user's interferences below 6 GHz, hand effect is expected to be more important at higher frequency.
- Impact of the user should be considered on the antenna efficiency and on the maximal gain that could be obtained in a beamforming configuration.

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Projet FUI Mass-Start

Open 5G Solution for Massive MIMO

Le projet ambitionne de développer une solution open source 5G pour le MIMO Massif. L'objectif est le développement d'une plateforme Hardware et Software, sur le principe du succès d'OAI en 4G (www.openairinterface.org).

Les principaux livrables matériels du projet sont les sous-systèmes radio et de traitement de bande de base compatibles 5G, leur intégration dans un démonstrateur de terminal 5G basé sur OAI et le réseau d'antennes permettant les expérimentations de bout en bout du lien MIMO Massif.

http://mass-start.fr

Projet FUI Mass-Start

Open 5G Solution for Massive MIMO

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Projet FUI Mass-Start

VIDEO

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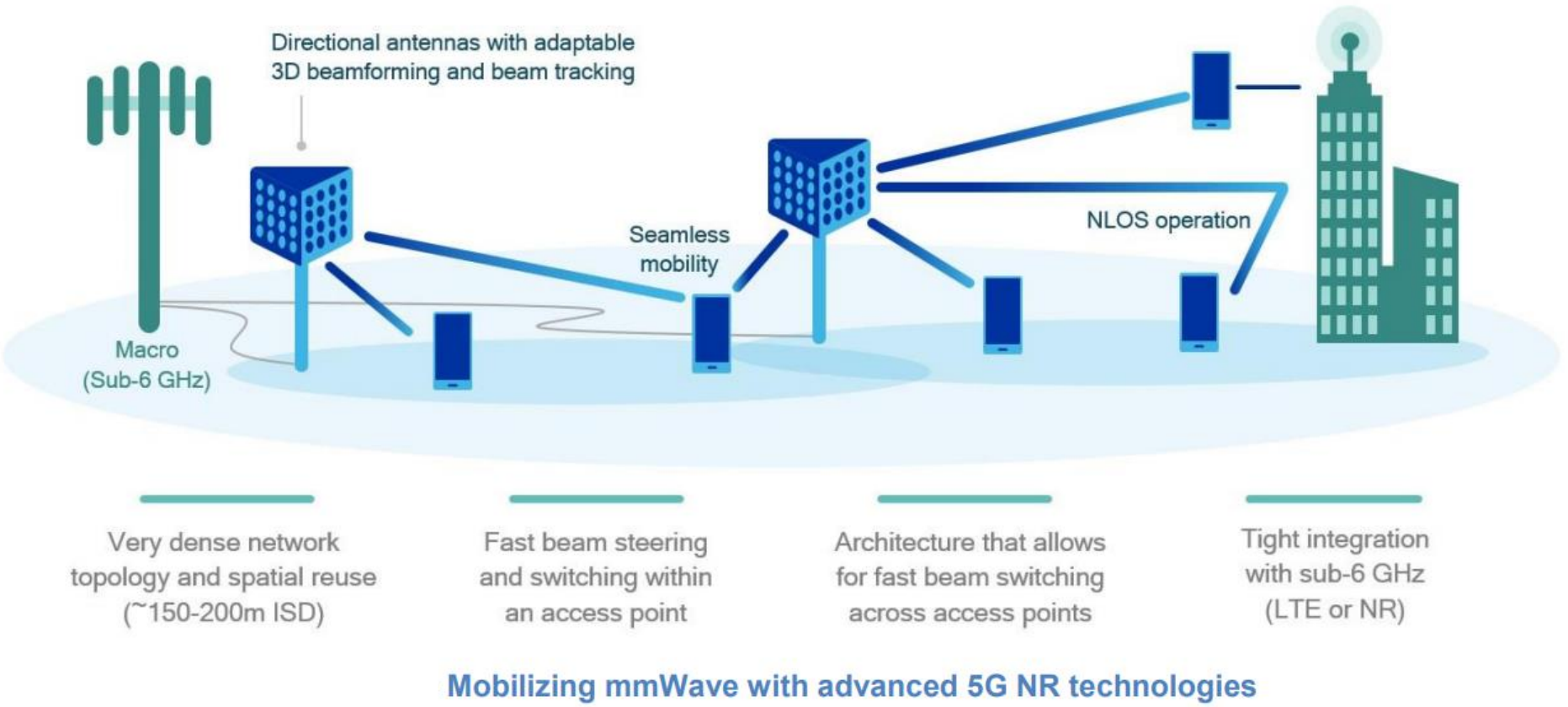
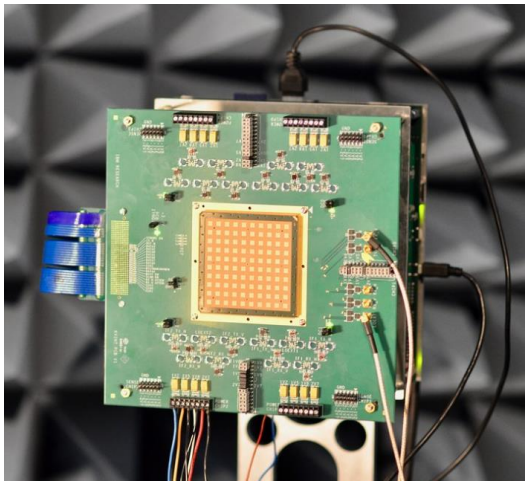
Small cell mmW system

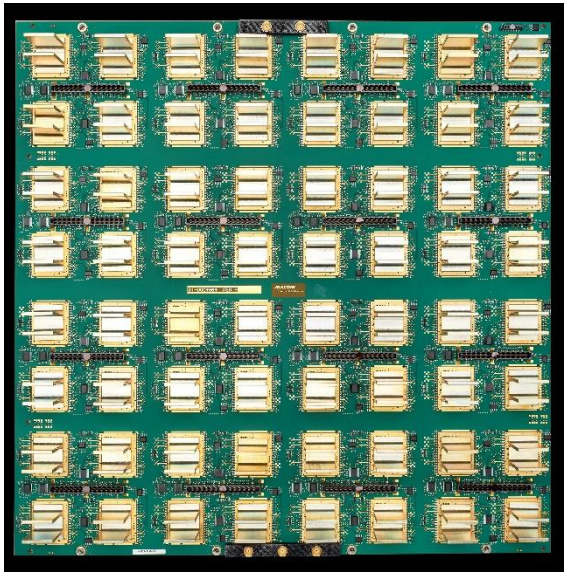


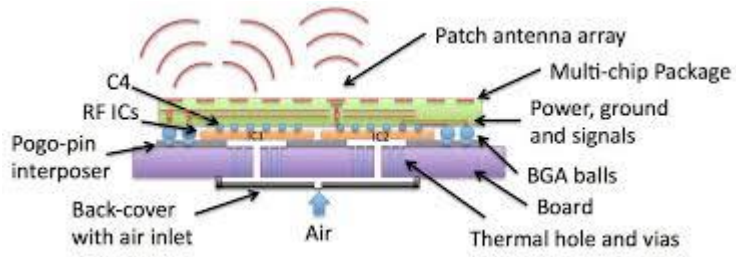
Mobilizing 5G NR Millimeter Wave: Network Coverage Simulation Studies for Global Cities, Qualcomm white paper

Needs : Small cell mmW

- AiP (antenna in Package) approach
- Direct antenna+ RF electronic integration
  -> OTA testing
- Classical antenna array with 0.5λ element distance, no challenge on bandwidth
- Heat issue : How to extract efficiently the heat ?
- **Mainly an integration problem**

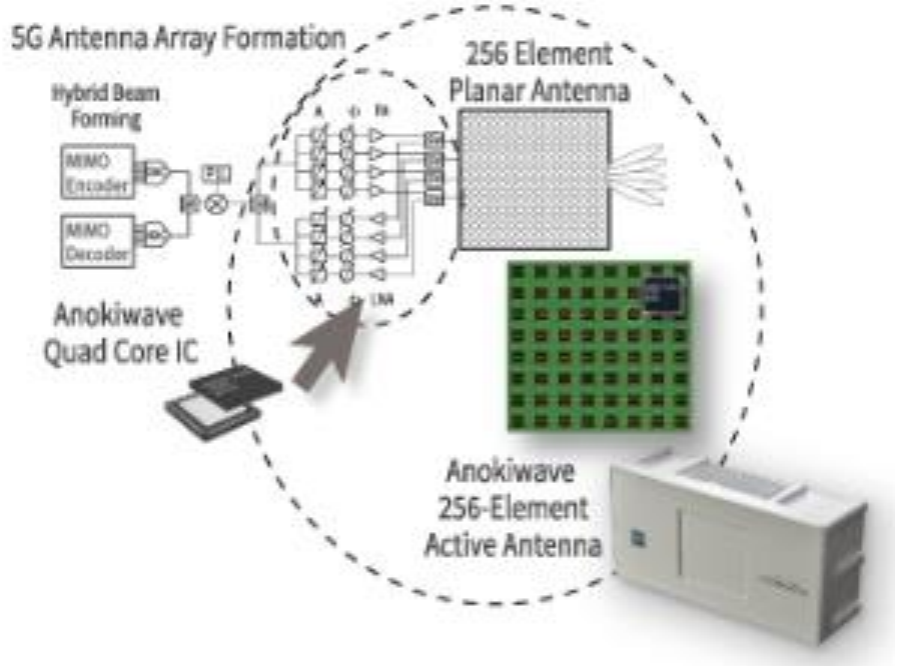






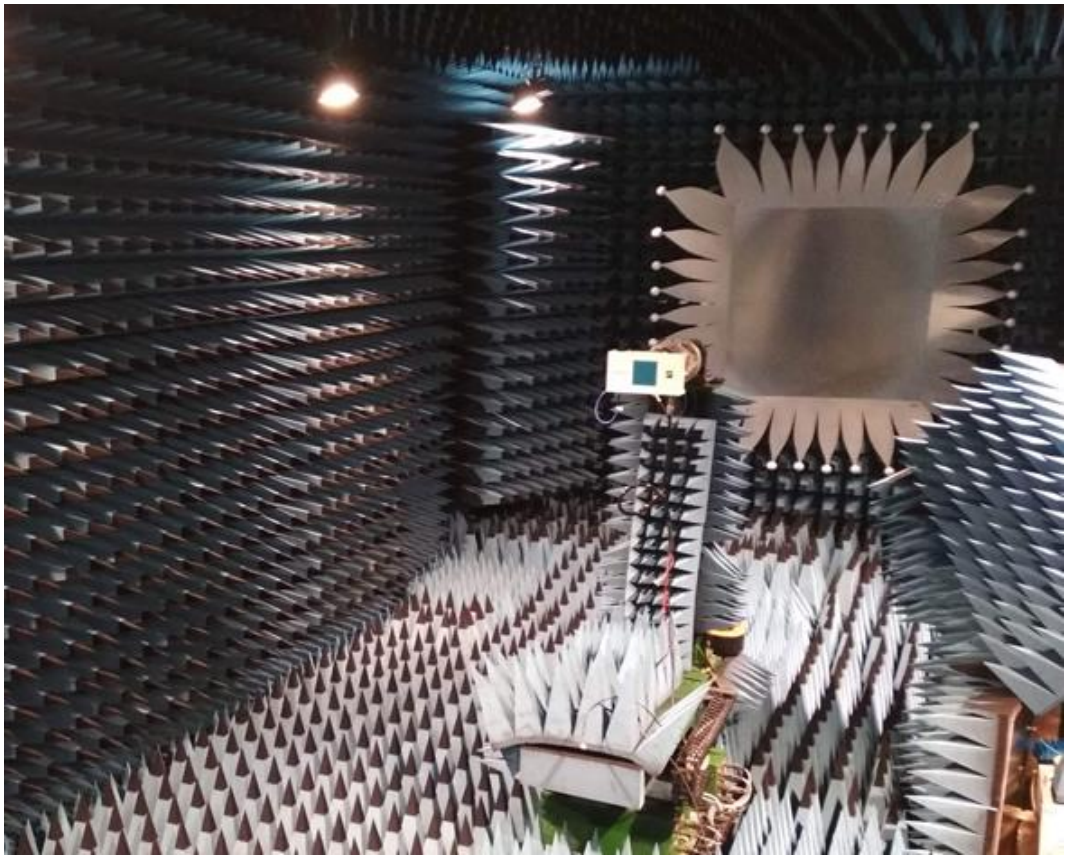
Source Macom

Small cell mmW system



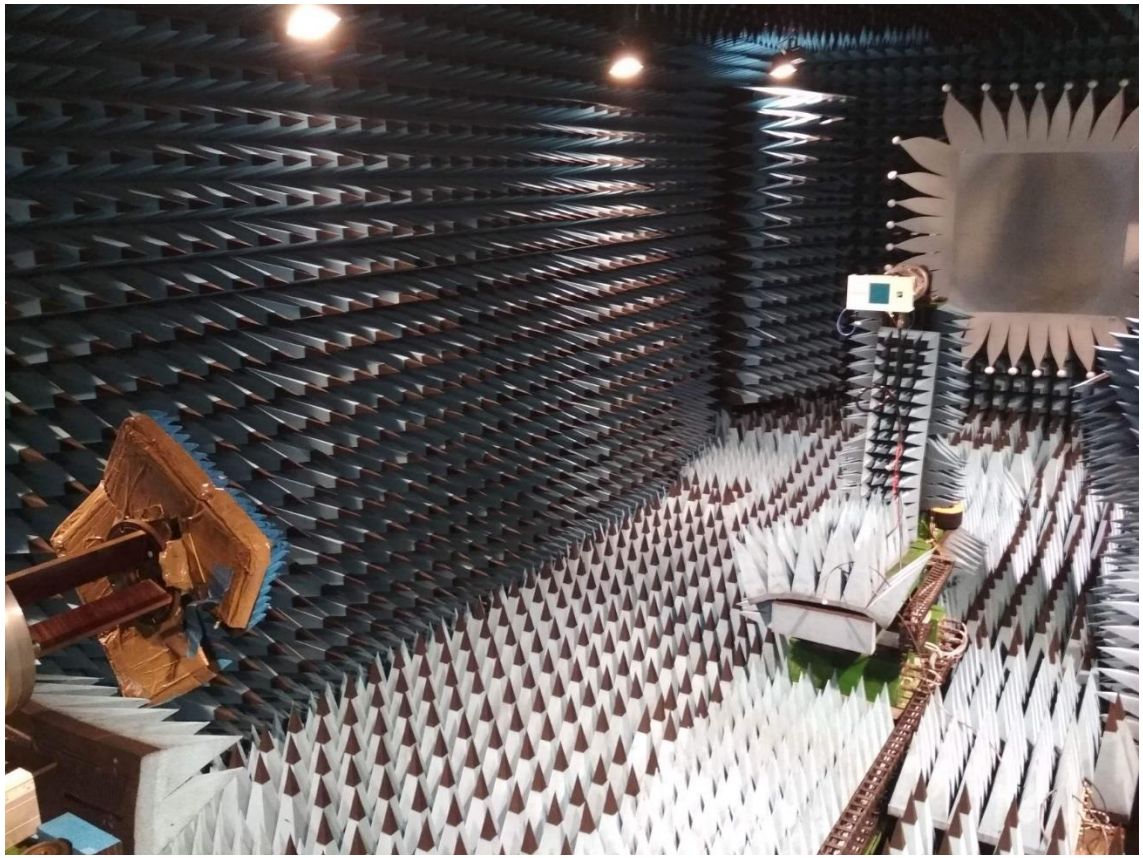
Small cell mmW system

Anechoic chamber – CATR configuration for Rx



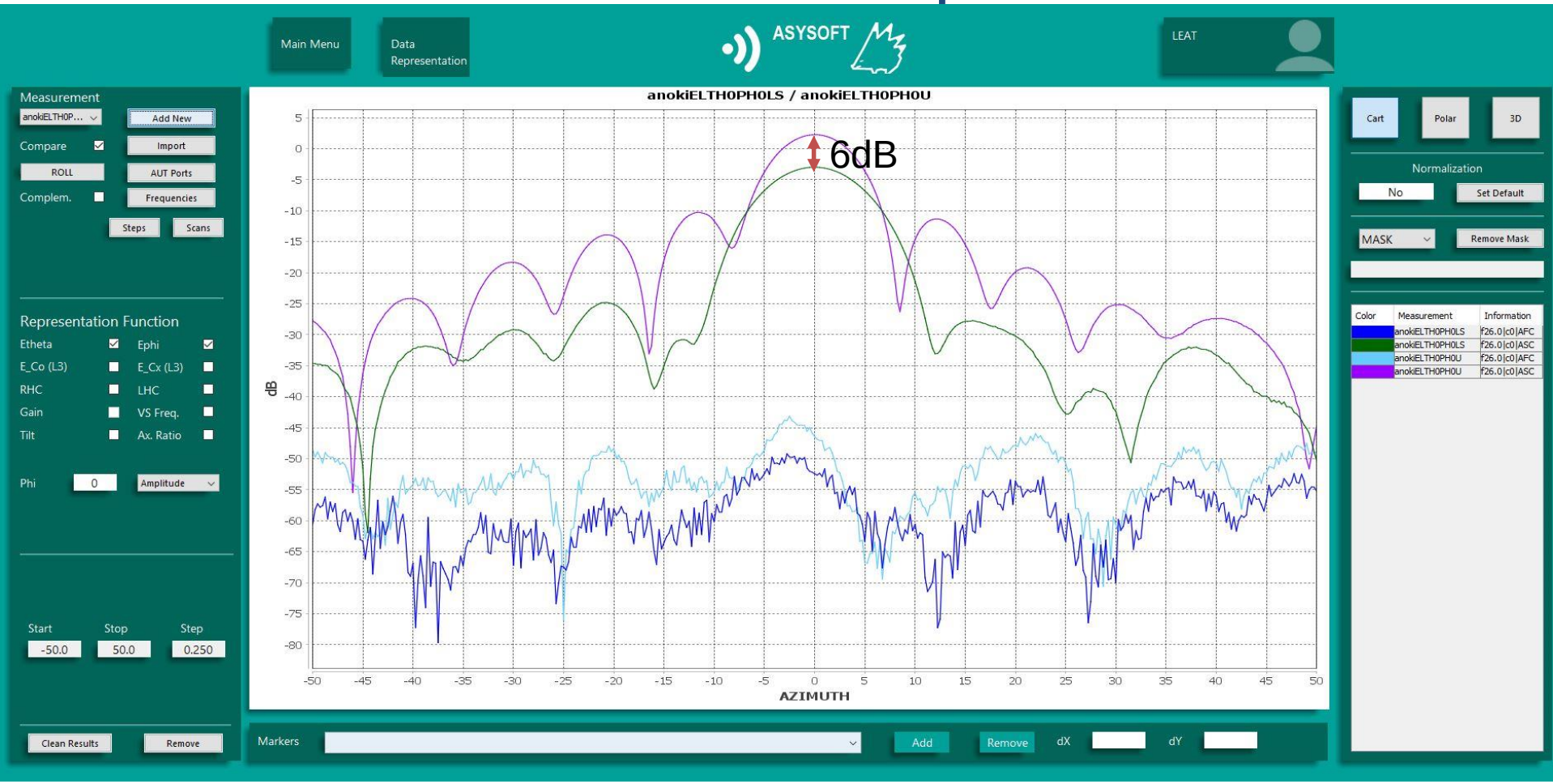
Small cell mmW system

Anechoic chamber – Probe configuration for Tx



Small cell mmW system

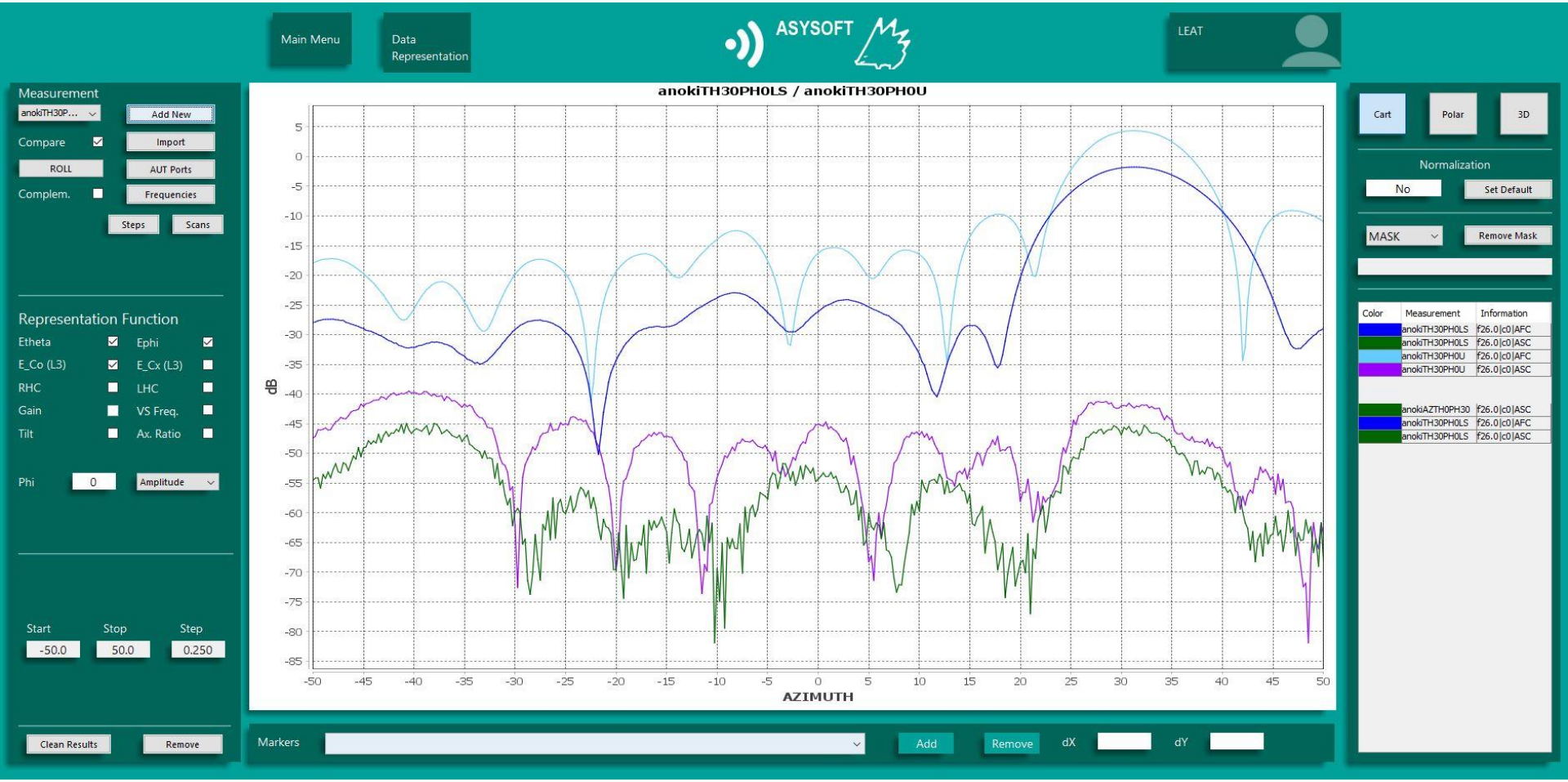
Rx 256E - Phi 0 ° Theta 0° Comp Uni -LSL 26GHz



Low side lobe mode versus equi-amplitude mode

Small cell mmW system

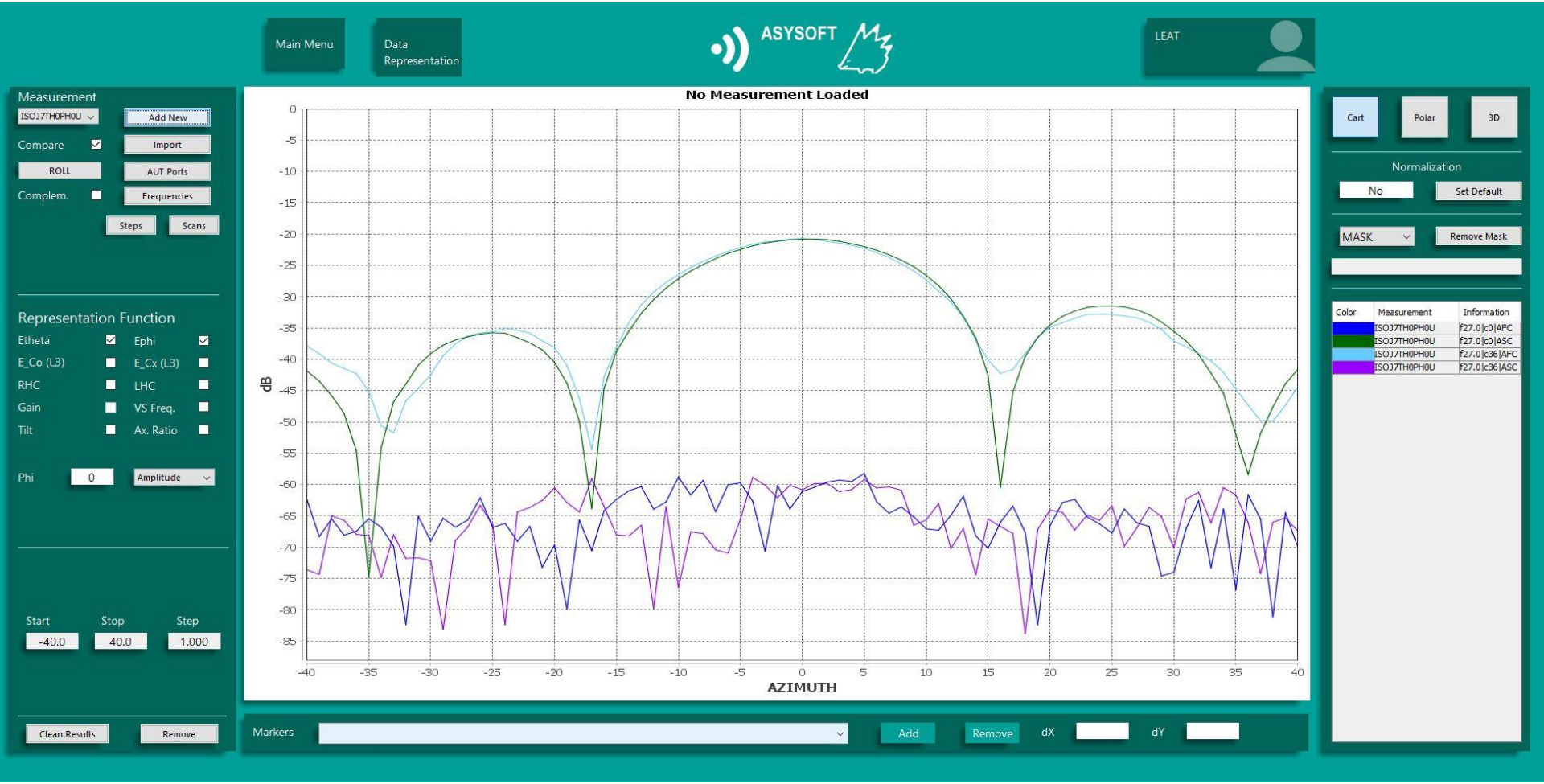
Rx 256E - Phi 0 ° Theta 30° Comp Uni -LSL 26GHz



Low side lobe mode versus equi-amplitude mode

Small cell mmW system

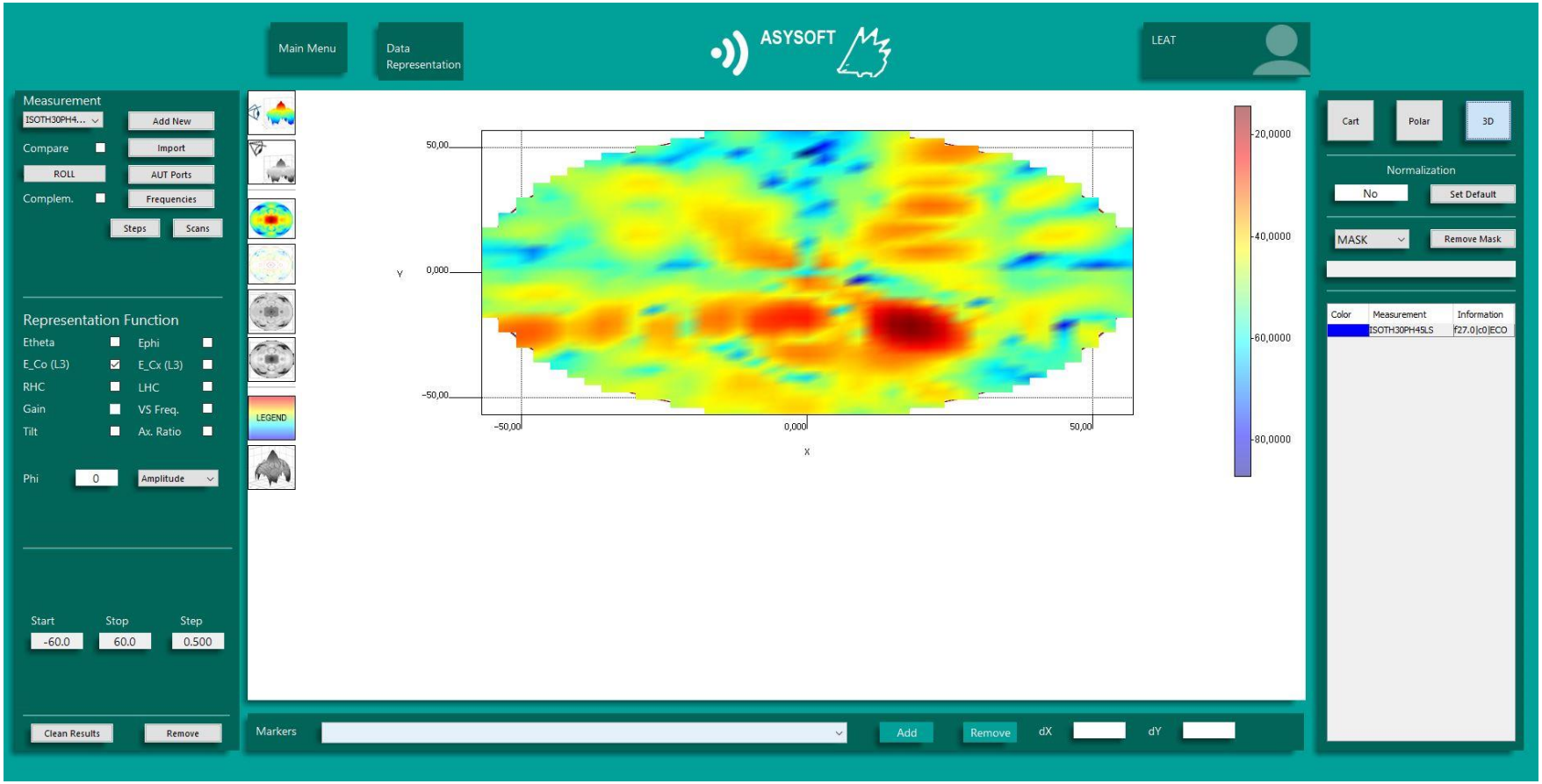
Rx 64E - Phi 0 ° Theta 0° Low Side lobe 27GHz Meas



64 elements only

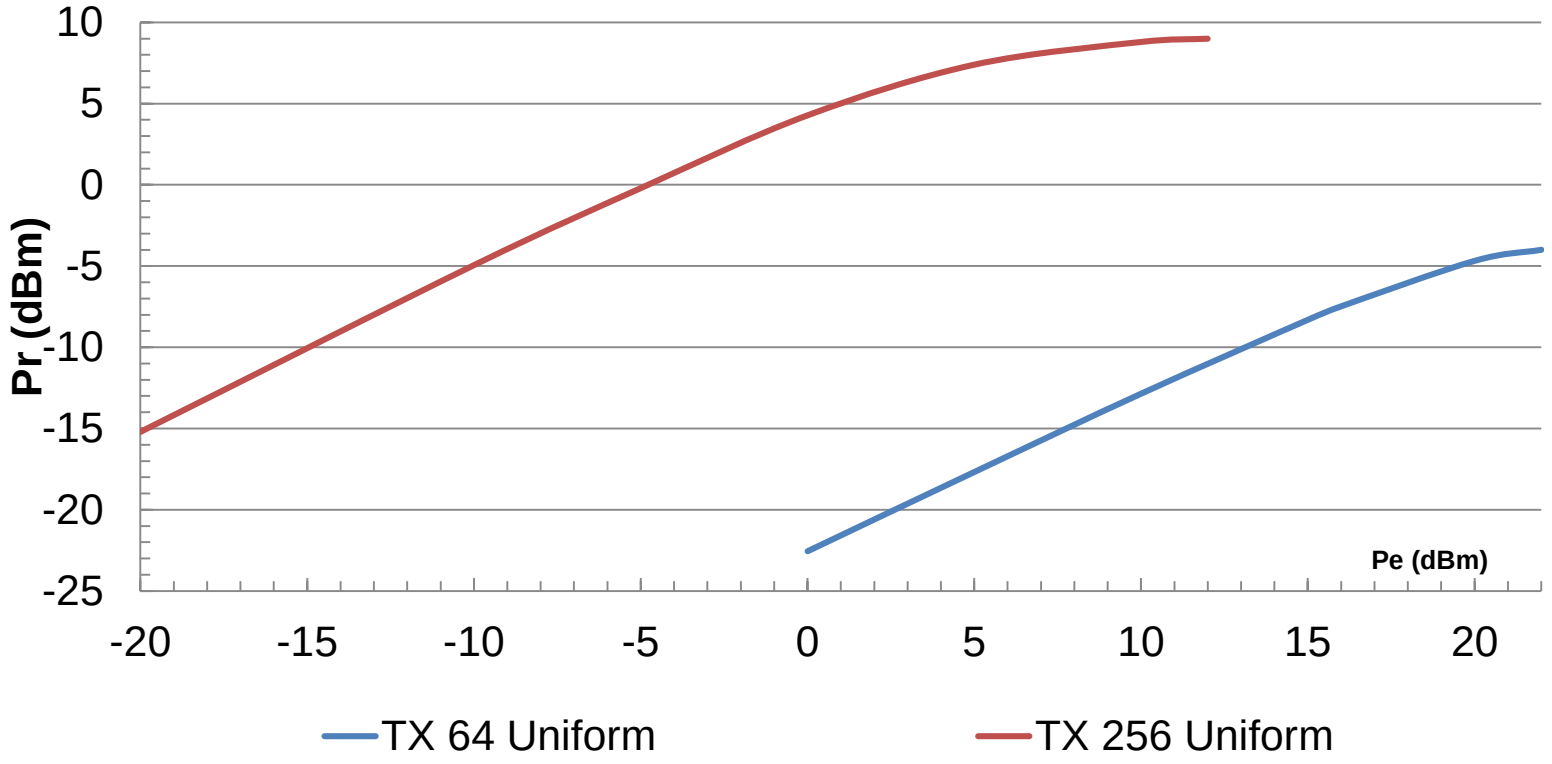
Small cell mmW system

Phi 45 ° Theta 30° Uniform 27GHz 3D Meas



Small cell mmW system

Configuration for Tx Test



64 elements : EIRP = 48.96 dBm

256 elements : EIRP = 61.96 dBm

> 1000 W EIRP

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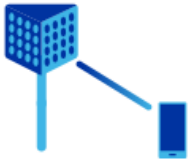
Overcoming numerous wireless challenges to mobilize mmWave



Path Loss

90 dB path loss for 28 GHz signal over 30m

Blockage

From hand, body, walls, foliage, etc.

Device size/power

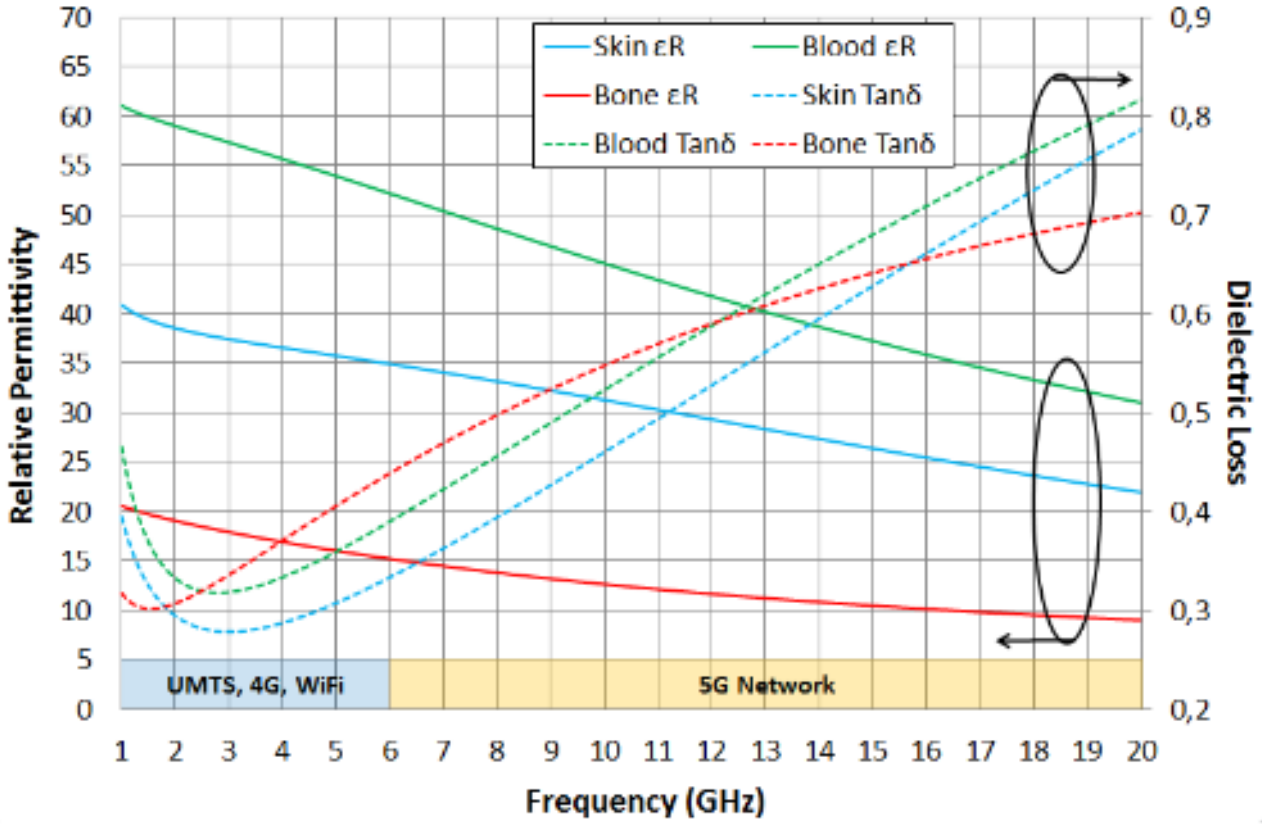
mmWave increases RFFE and modem complexity

Many challenges in mmW 5G are not solved

What about the hand blockage effect ?

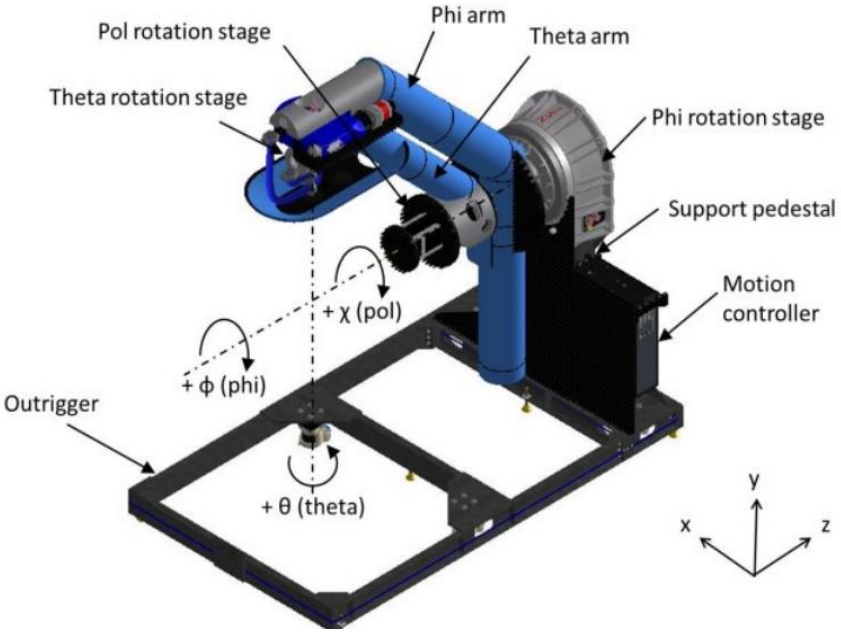
Motivation : Body effect

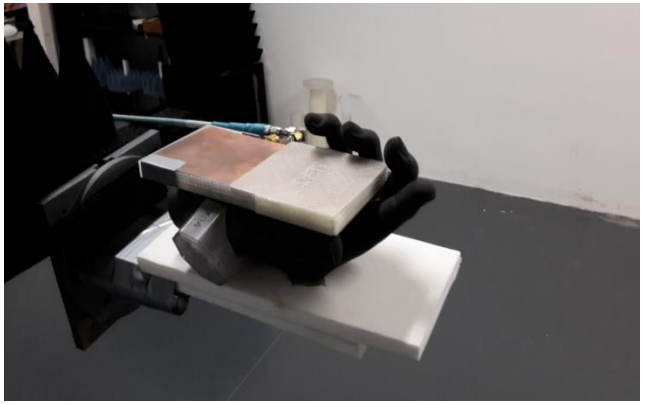
- Body dielectric properties versus frequency are not constant and an important impact of the hand on millimeter Wave terminal can be expected.



Measurement test-bed

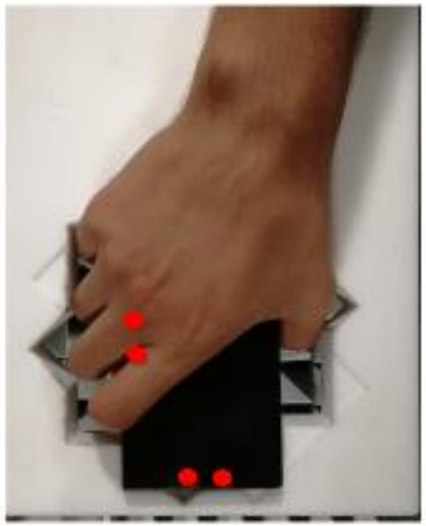
- 3-axis scanner with a fixed Antenna Under Test
- Main advantage of this setup is the fixed AUT which allows to hold the device during the measurement.
- Real hand measurement
- Phantom hand measurement

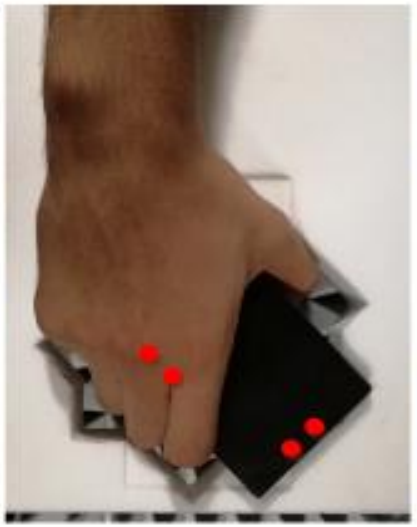


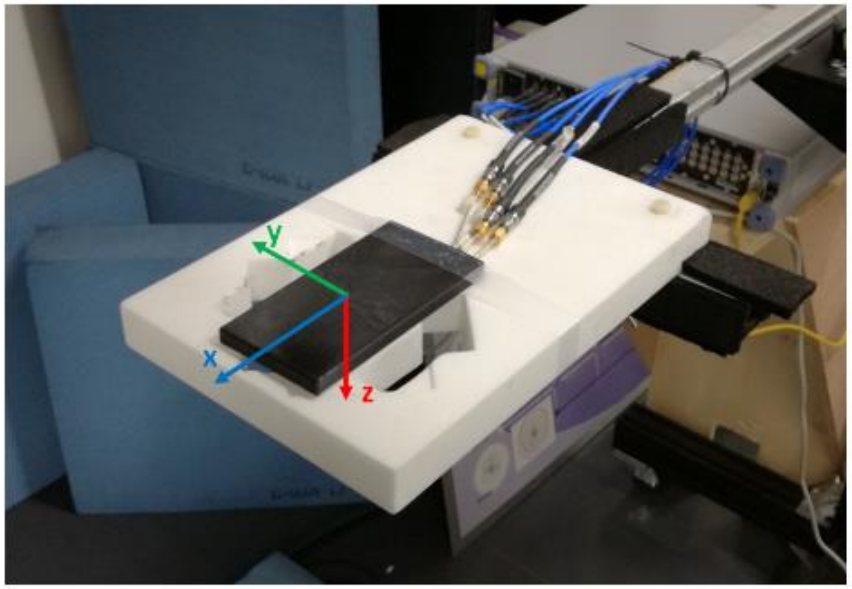


Radiation pattern measurement

- Average radiation pattern of 6 different hands (different size and shape from men and women test subject)

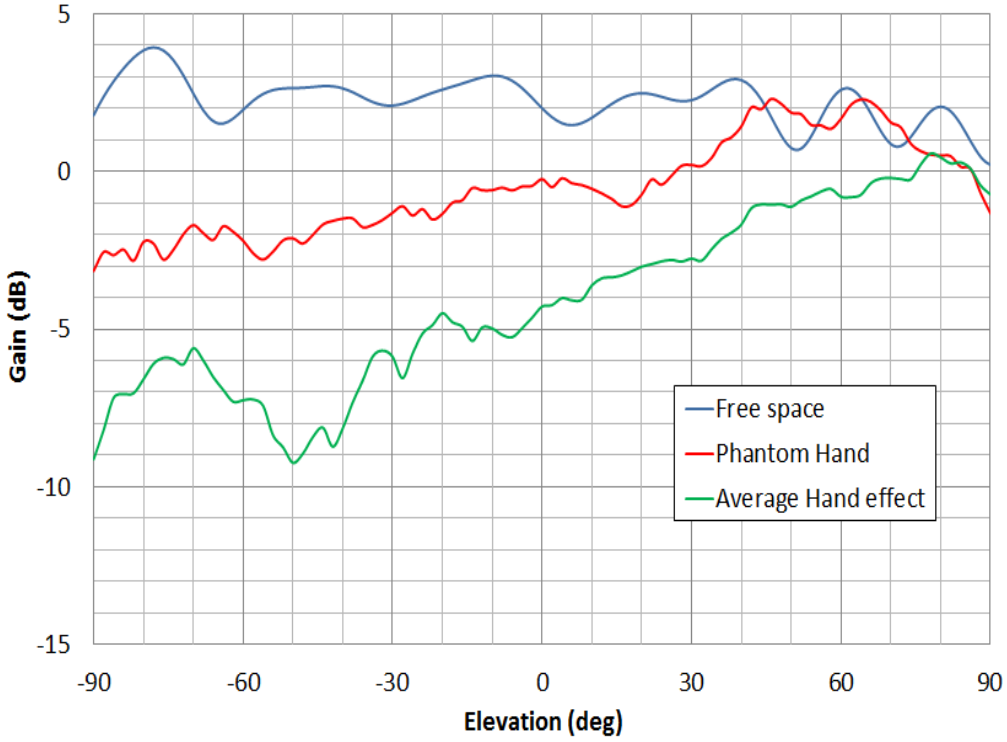






Radiation pattern measurement

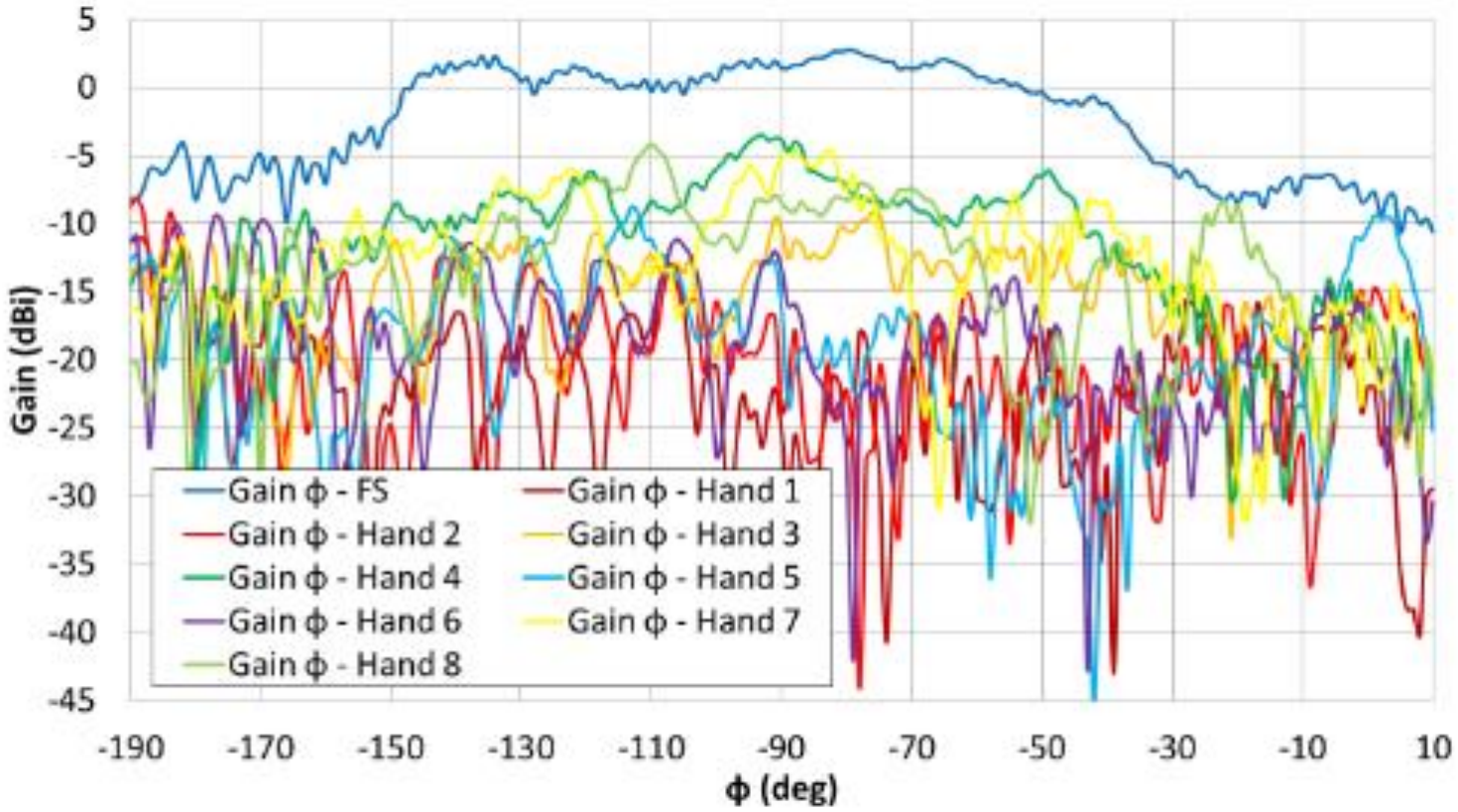
- Average radiation pattern of 6 different hands (different size and shape from men and women test subject)
- Maximum decrease of about 12 dB of the peak total gain for a real hand
- About 6 dB for the hand phantom.



@15GHz

Radiation pattern measurement with hand

- Gain Free space measurement for antenna 1

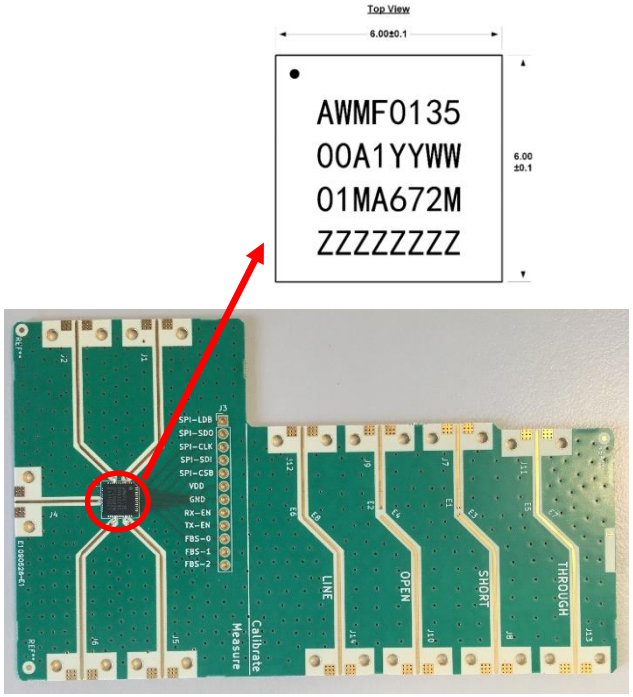


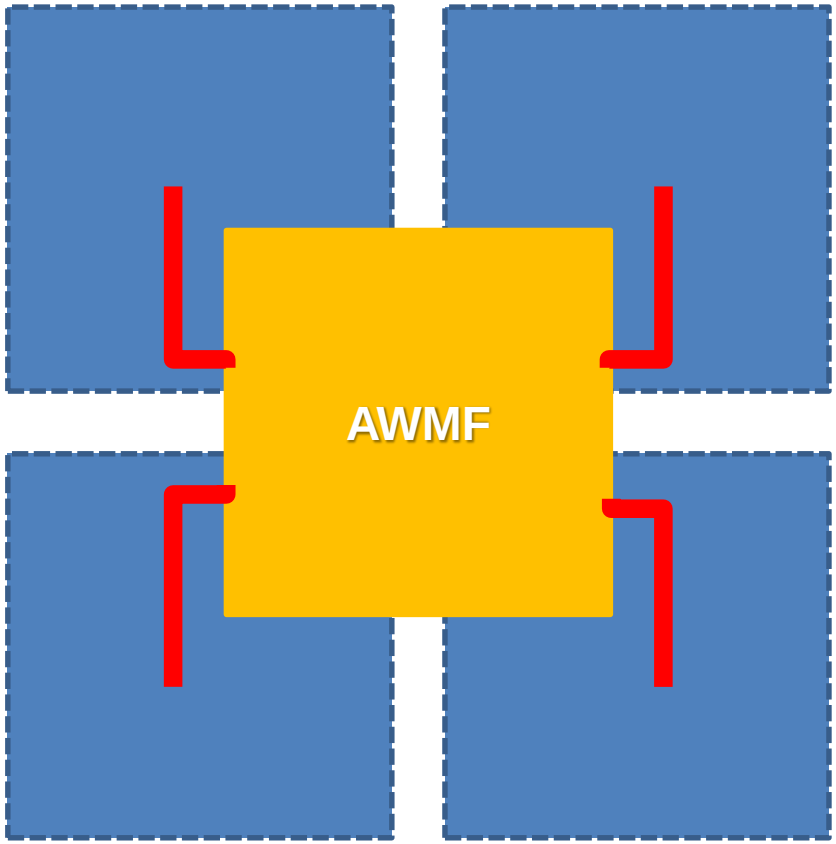
@15GHz

Antenna Design & Simulation results @26GHz

AWMF-0135

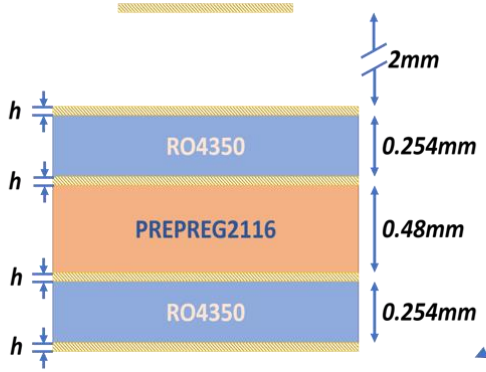
- 24.25 – 27.5 GHz operation
- Tx/Rx half duplex operation
- 5-bit phase control (LSB=11.25°)
- 5-bit gain control (LSB=1.0 dB)

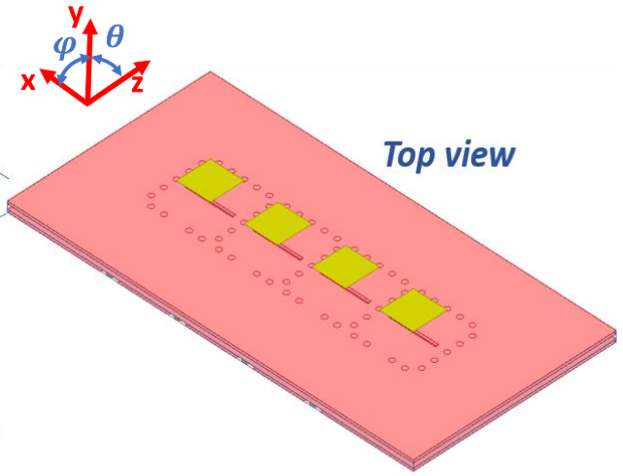


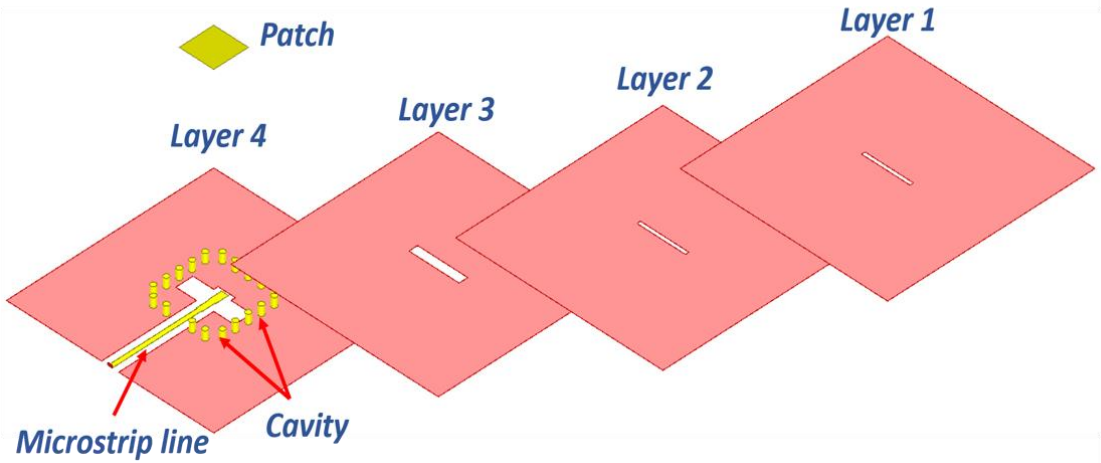


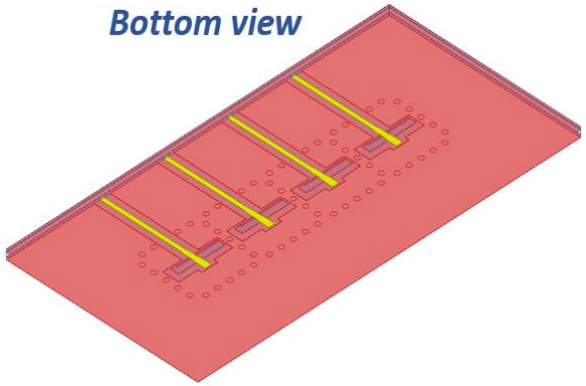
Antenna Design & Simulation results

Antenna Design Solutions



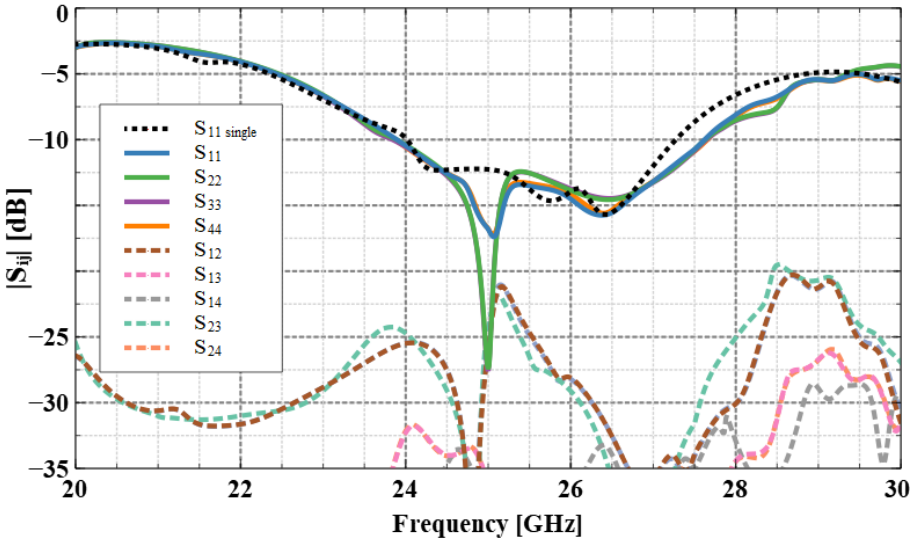






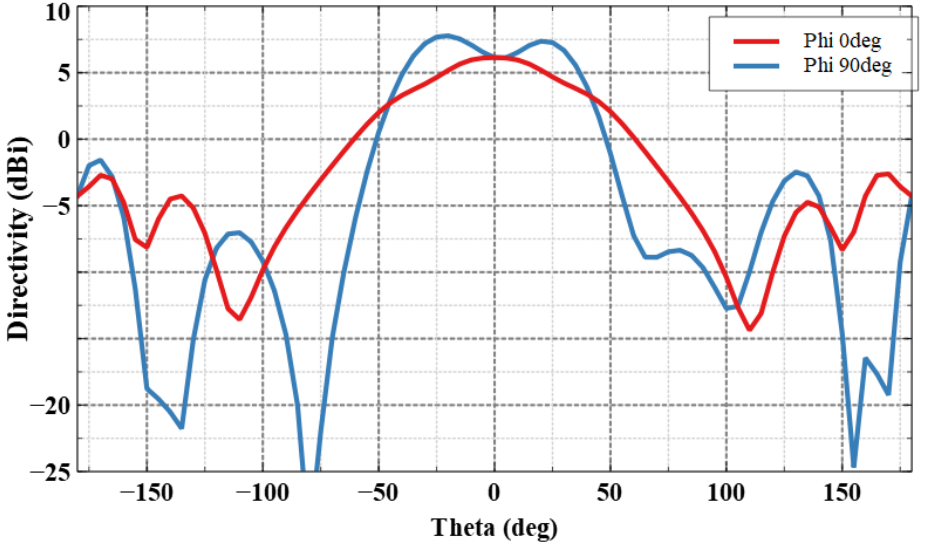
Antenna Design & Simulation results

Impedance Matching



- Band 24.5-27.5 GHz
- Matched all element at $|S_{ii}| <$ -10dB
- Isolation minimum 20dB

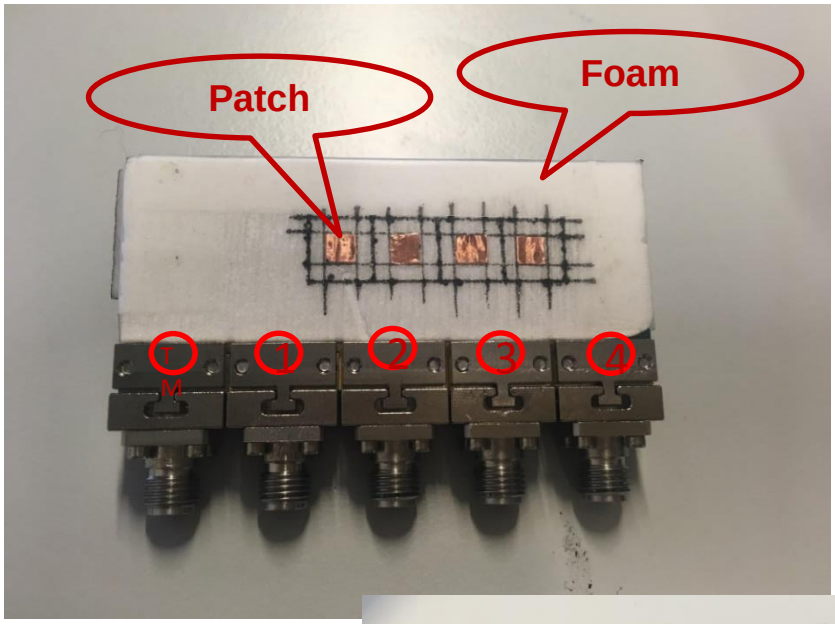
Directivity



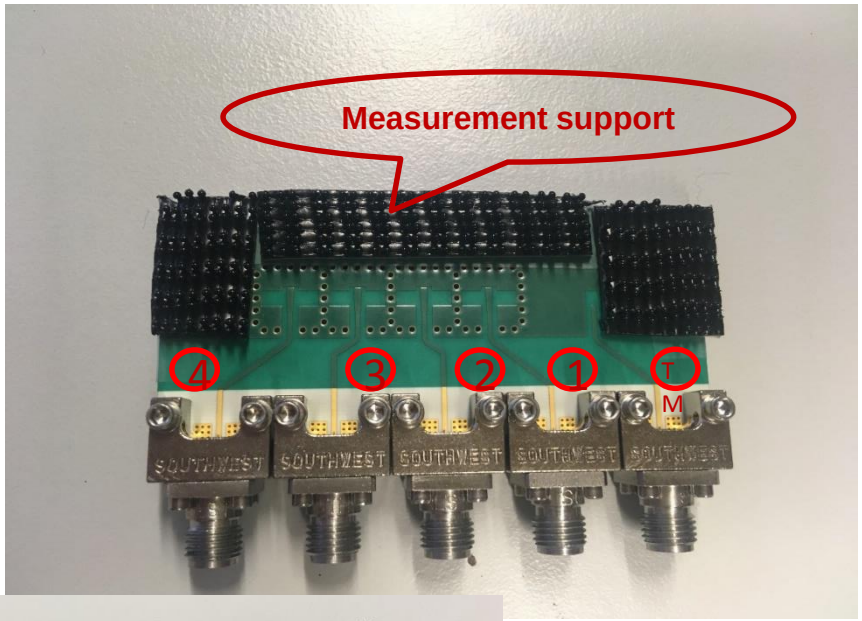
- 3dB-beamwidth 80^o in both $Azimuth\ \&\ Elevation$
- Back lope high due to opening for strip line
- Total efficiency around -1.3dB

Fabrications

Top view



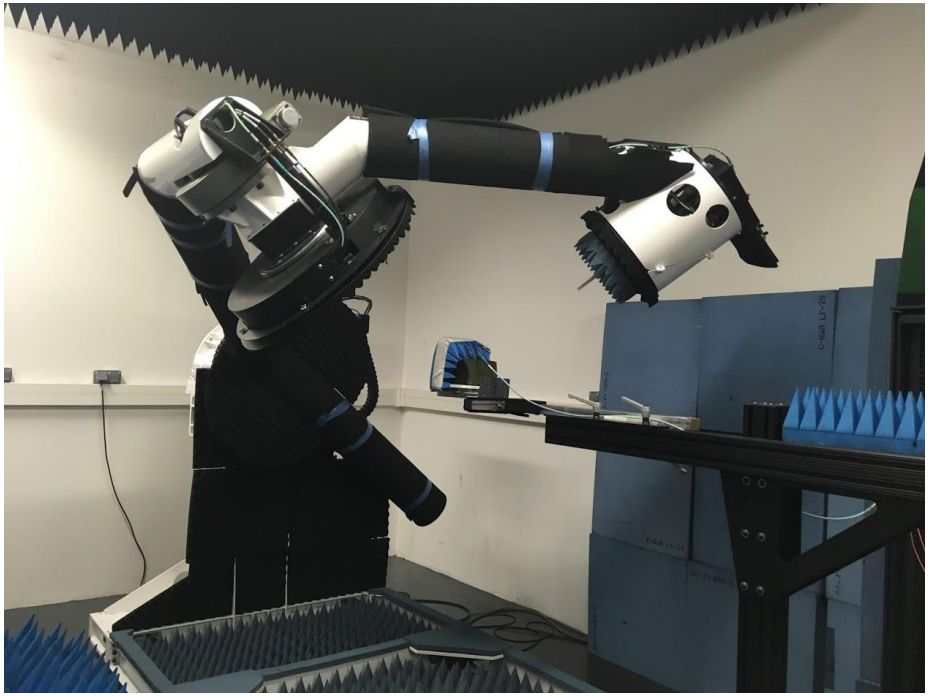
Bottom view



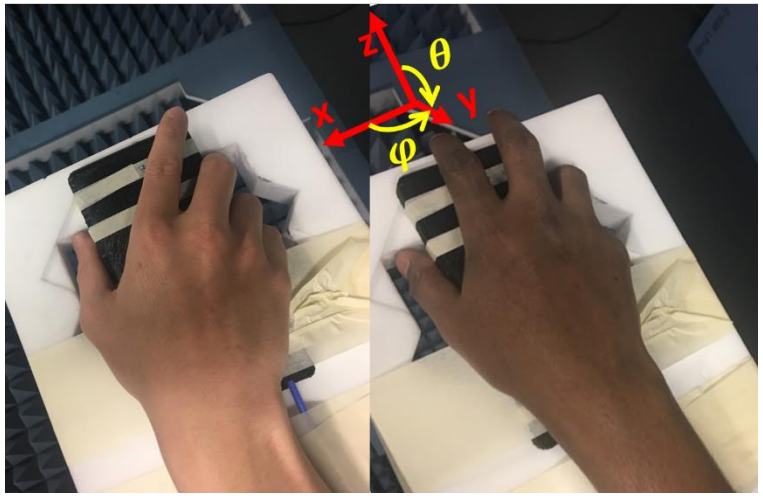
With casing

Measurements

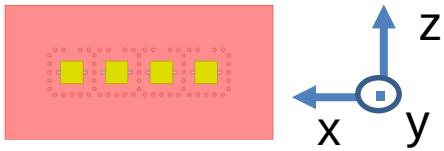
NSI setups



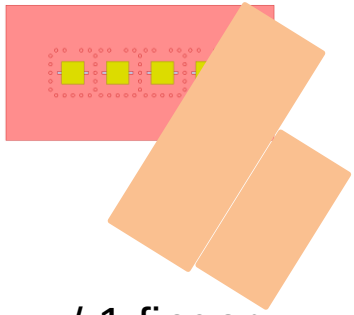
With finger(s)



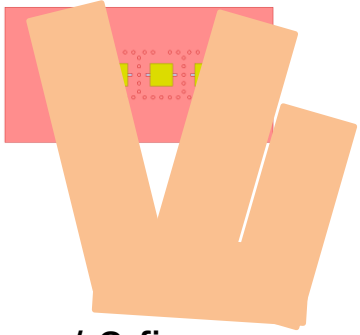
Beamforming Performances



w/o finger

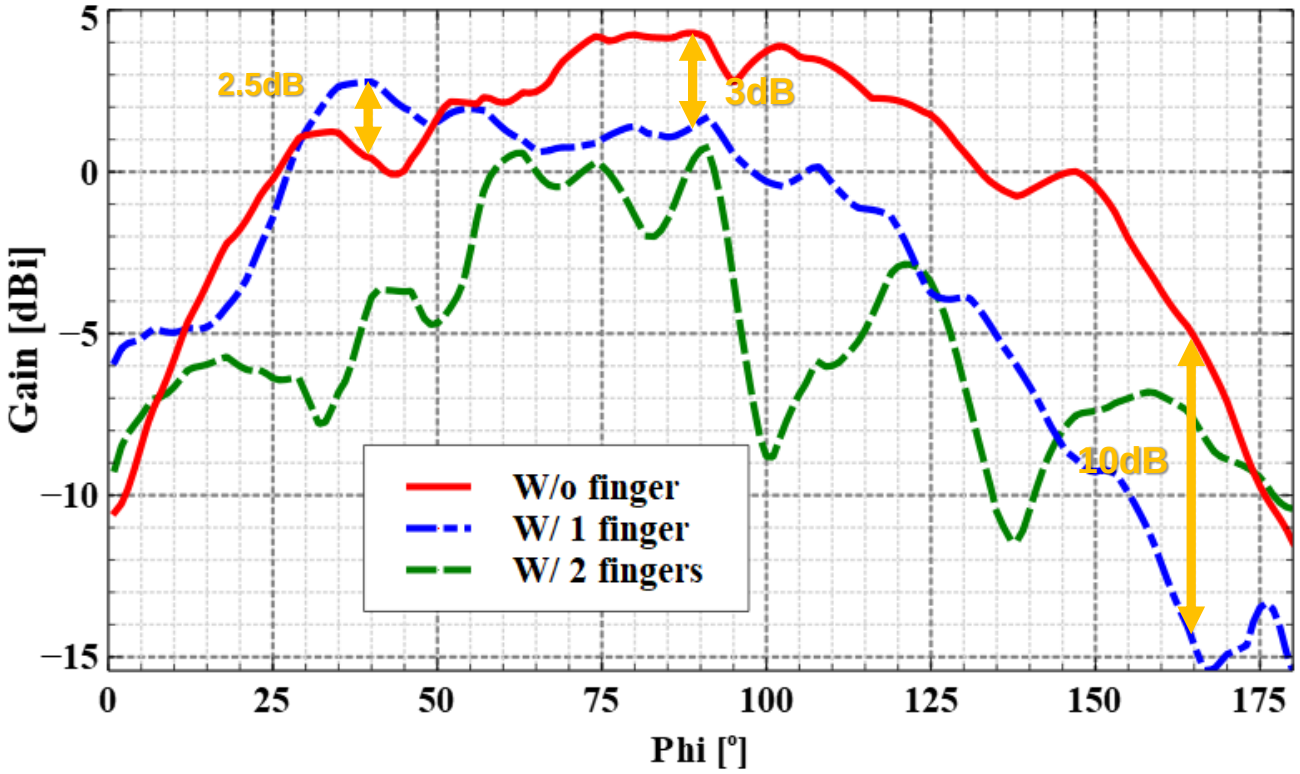


w/ 1 finger



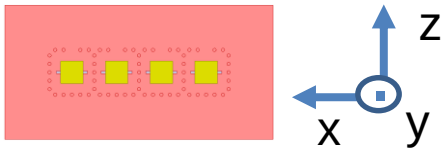
w/ 2 finger

Antenne N°3

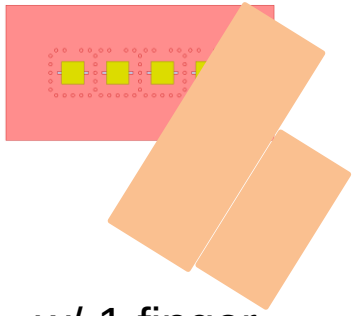


- Up to 10dB loss for 1-finger case
- Cannot form beam in 2-finger case due to blockages of antenna 1-2-4

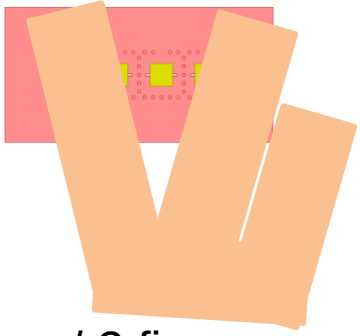
Beamforming Performances



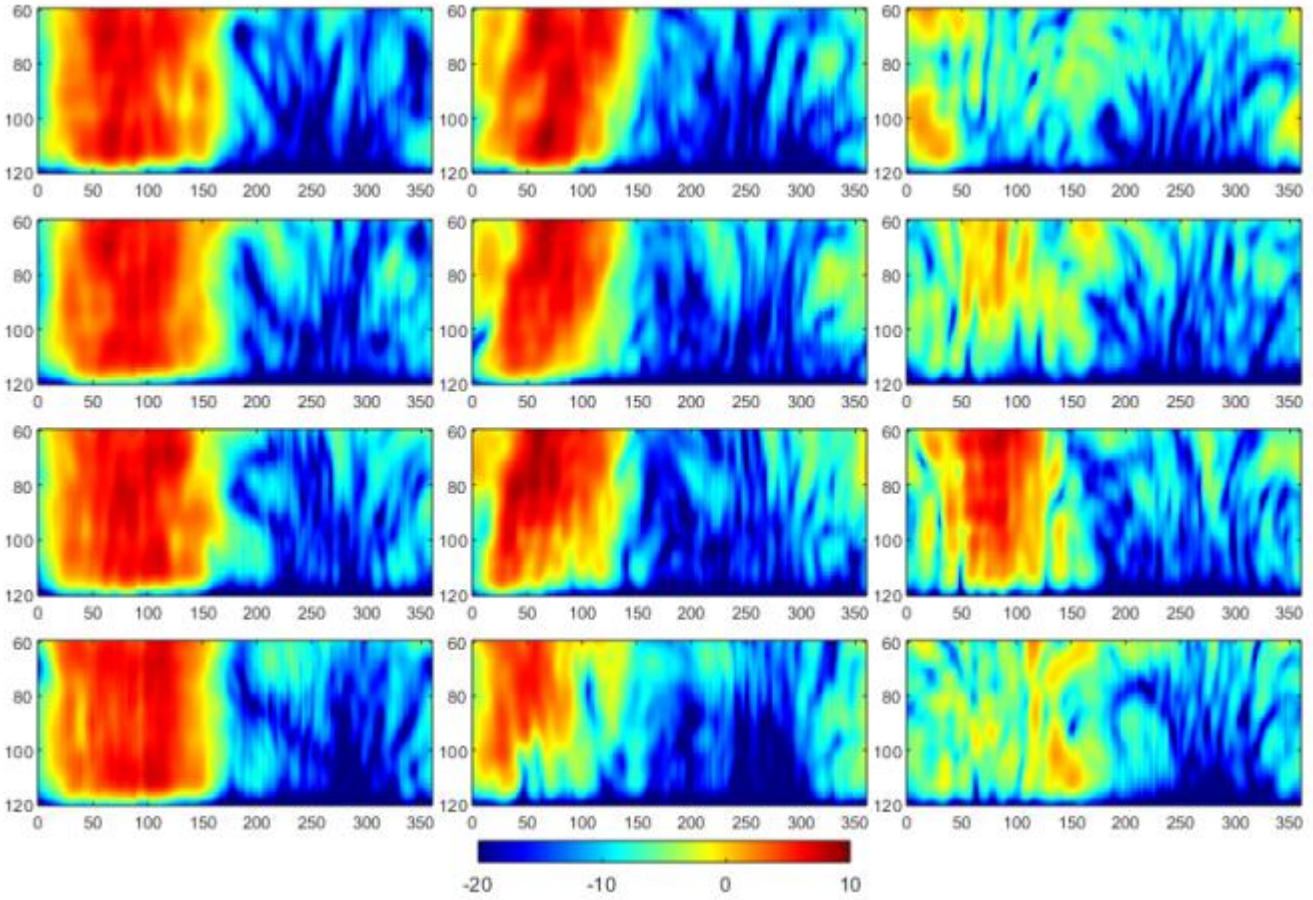
w/o finger



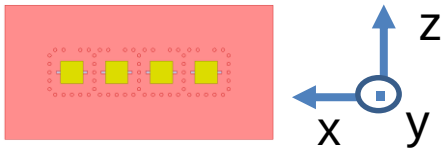
w/ 1 finger



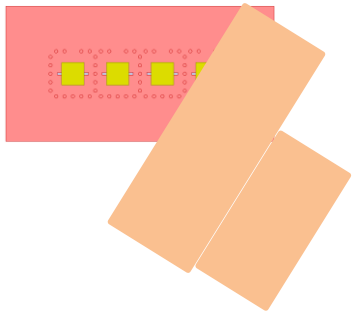
w/ 2 finger

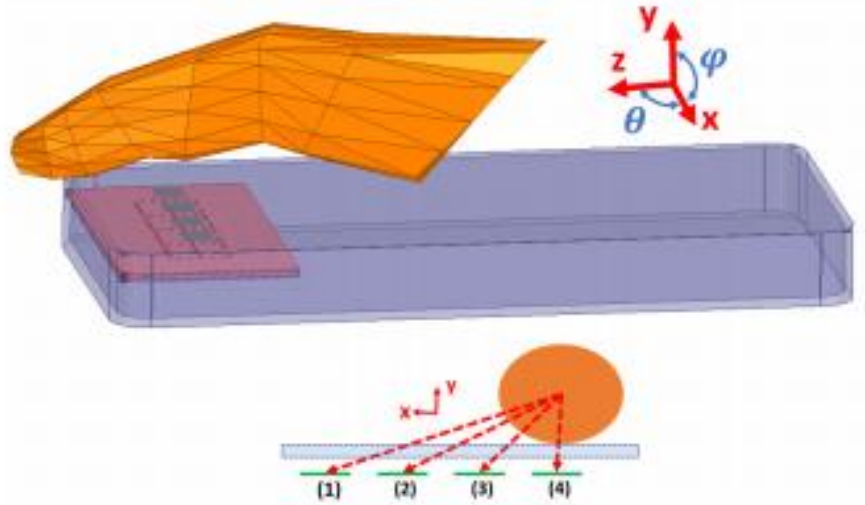


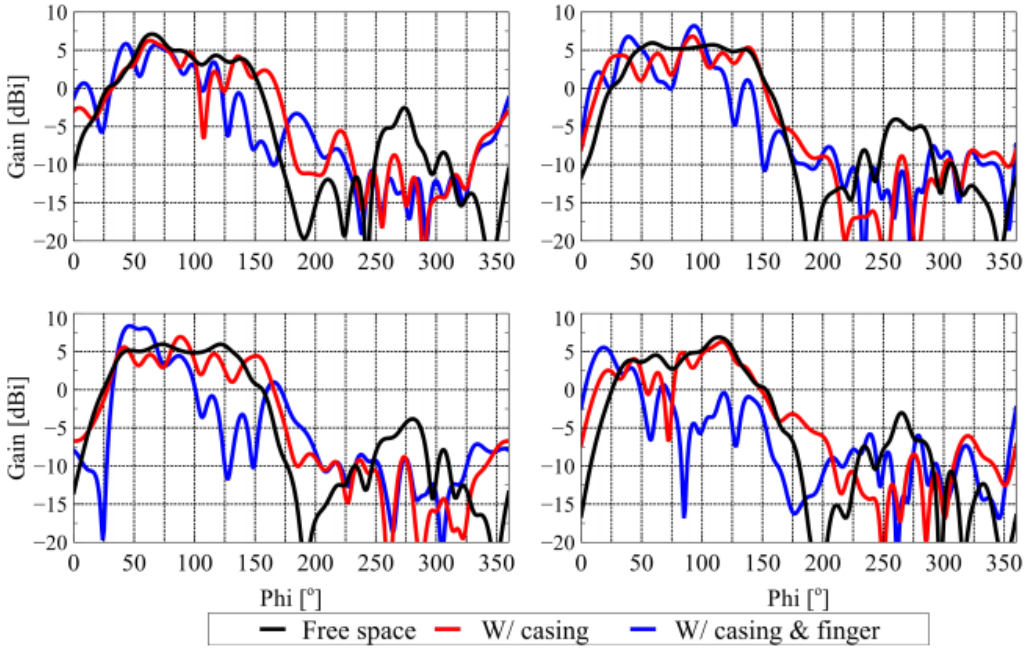
Beamforming Performances



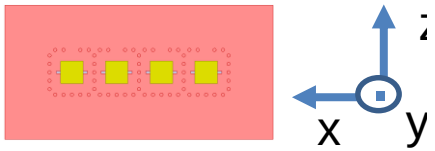
w/o finger



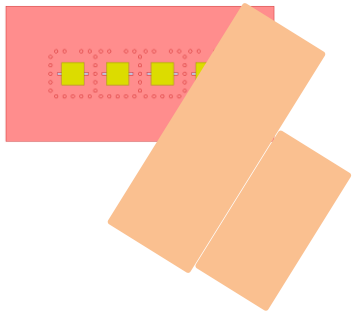


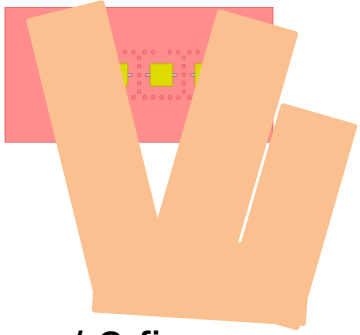


Beamforming Performances

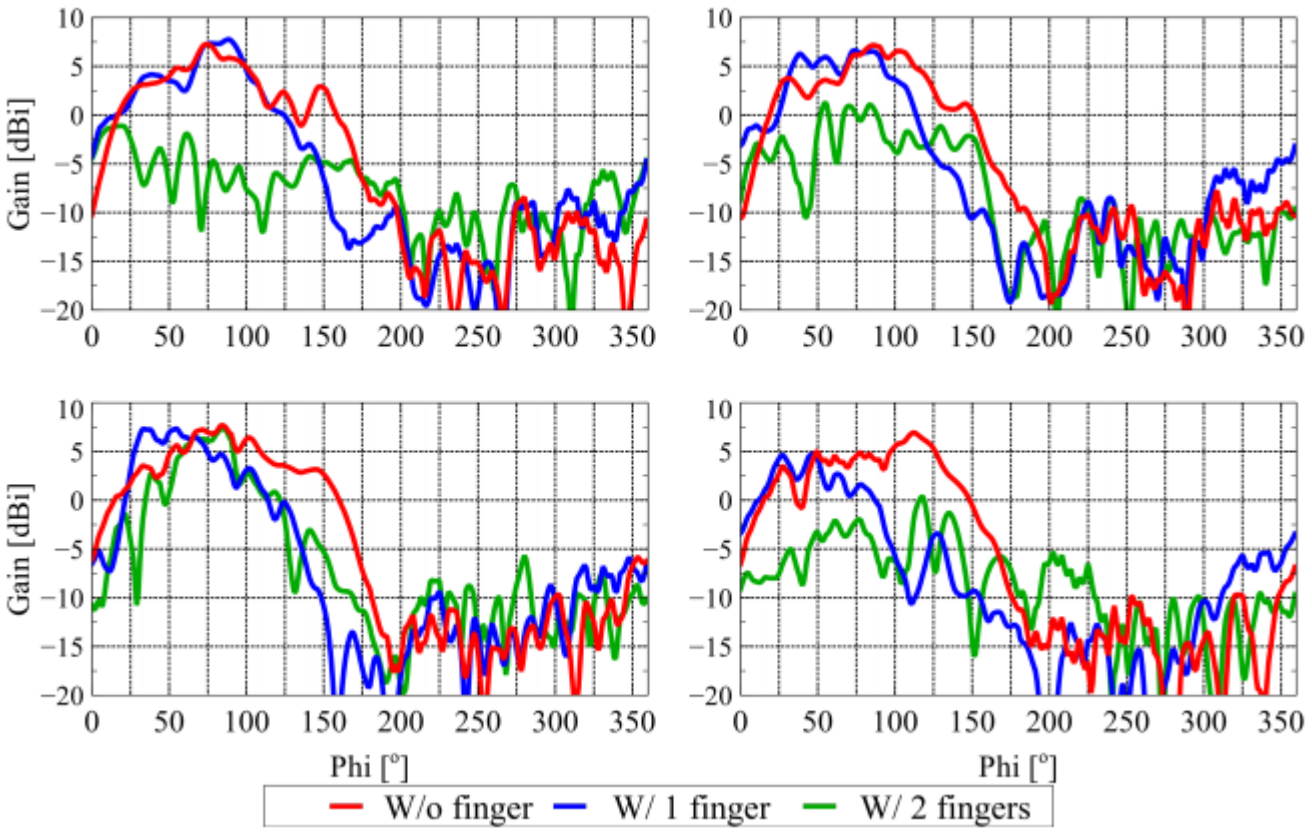


w/o finger

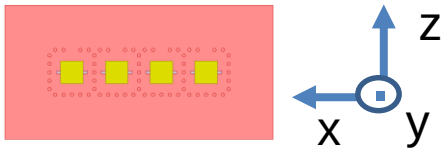




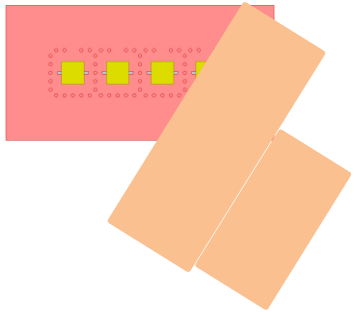
w/ 2 finger

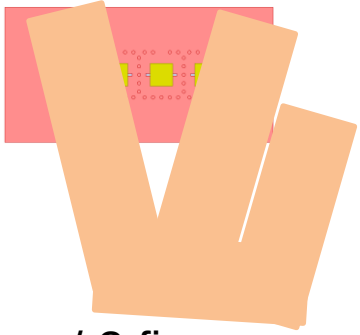


Beamforming Performances

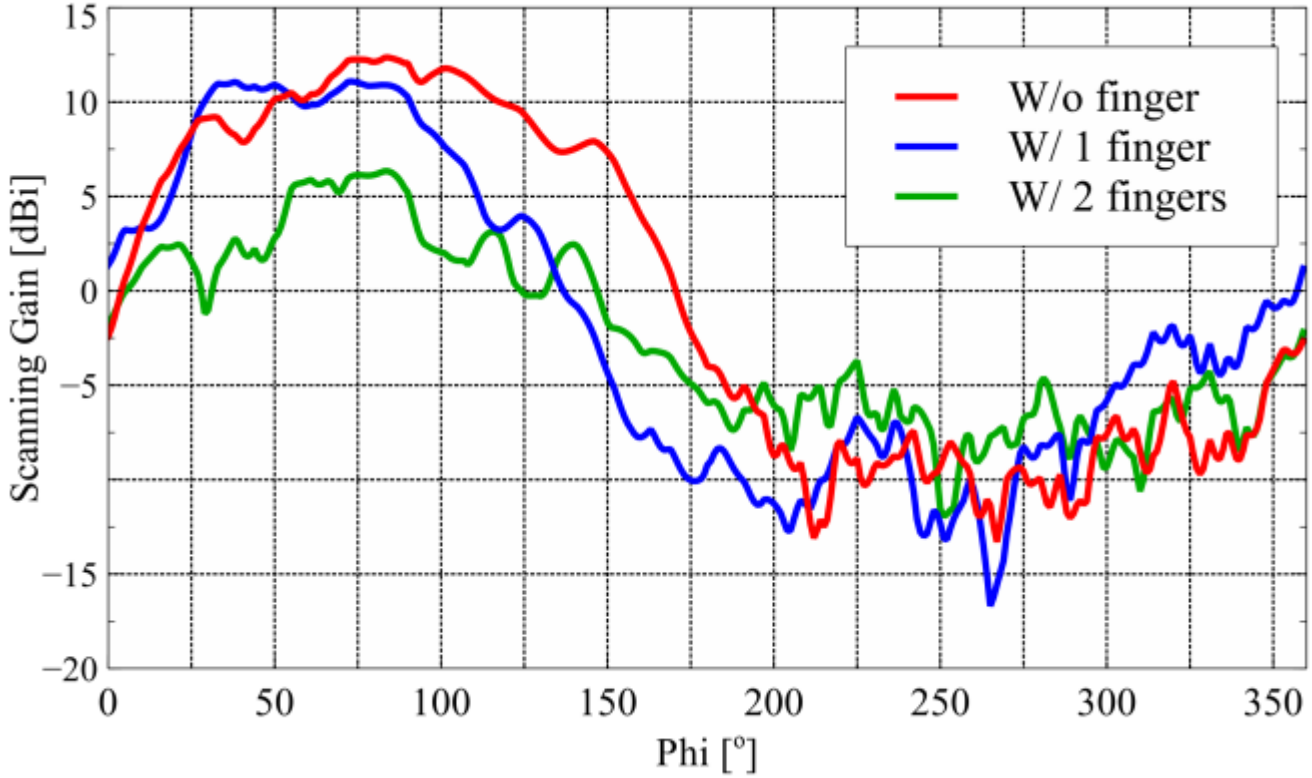


w/o finger

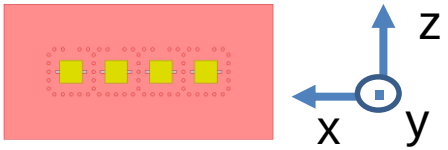




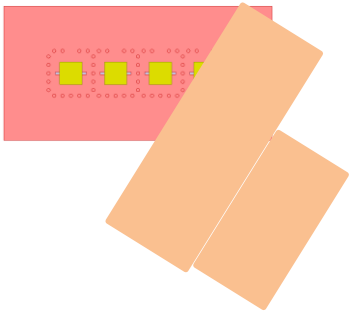
w/ 2 finger

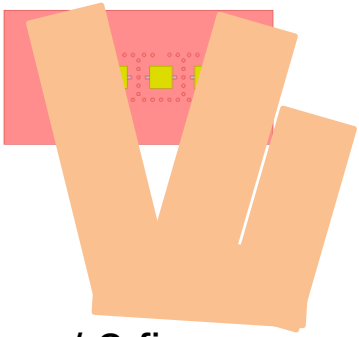


Coverage efficiency

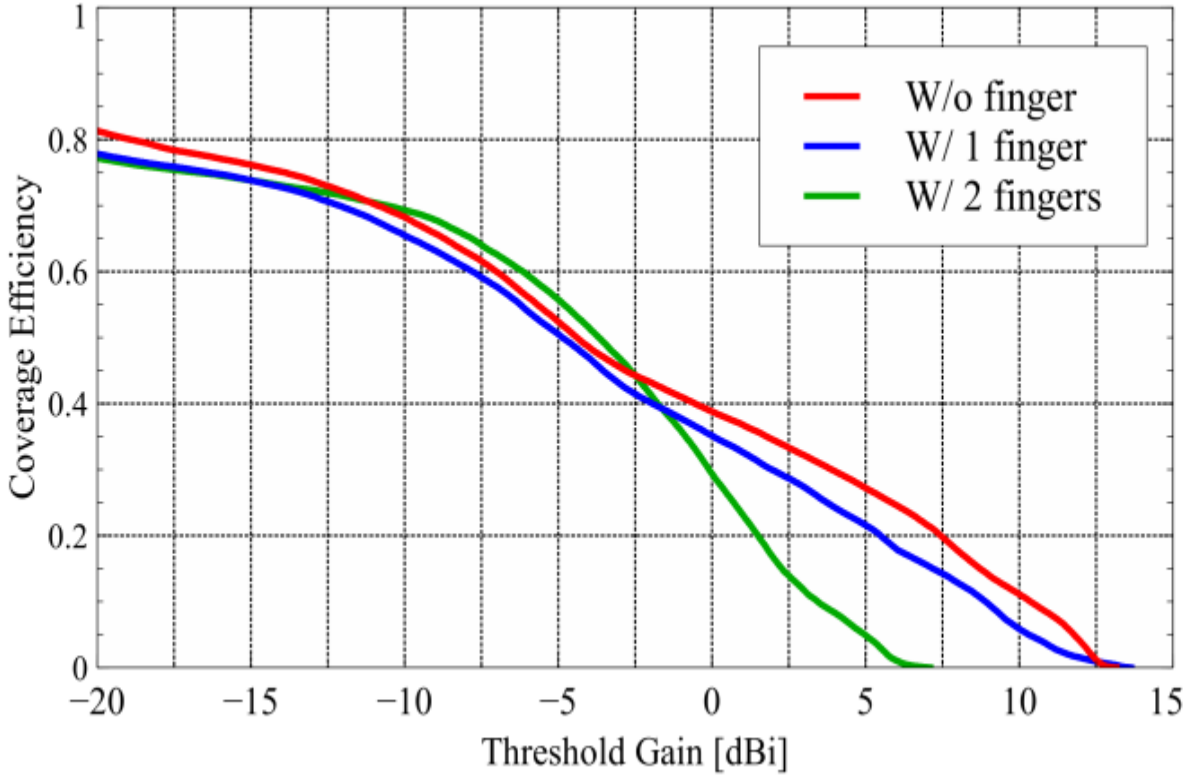


w/o finger





w/ 2 finger



- From -10dBi threshold upward, W/o finger case show higher Coverage efficiency
  - Up to 10% to W/ 1-finger case
  - Up to 30% to W/ 2-finger case

$$CovEff = \frac{Coverage\ Solid\ Angle}{Total\ Solid\ Angle}$$

Motivation : 5G needs

Exemple of integration

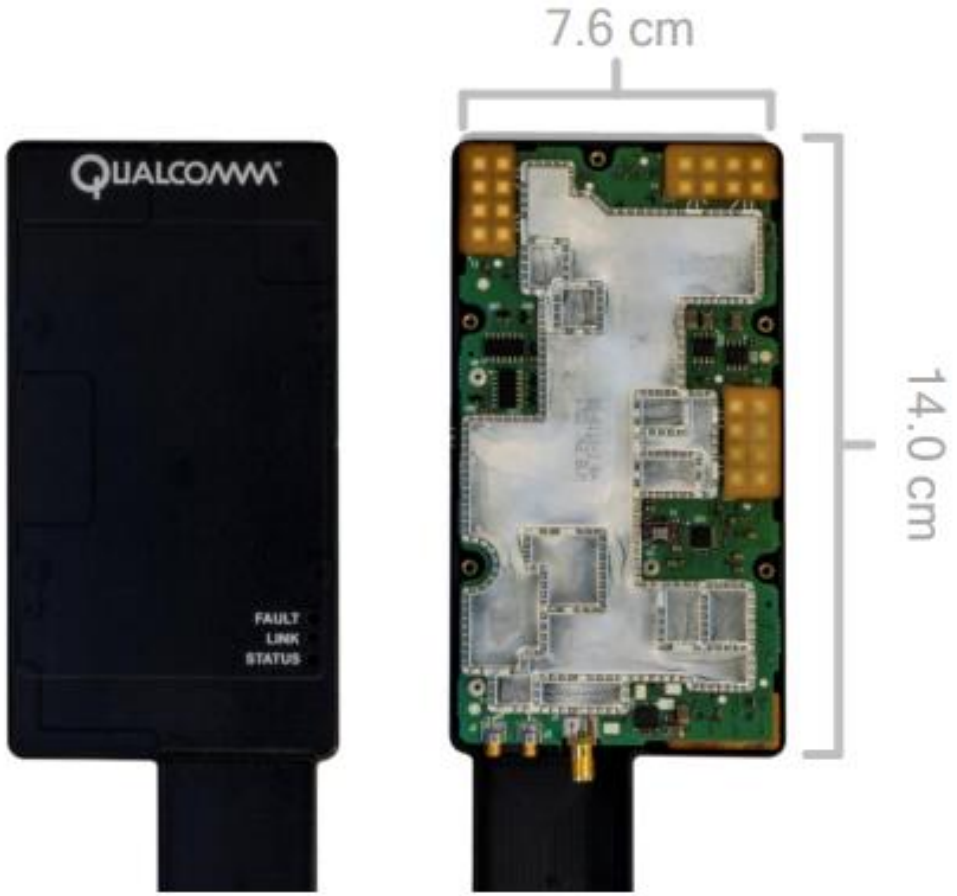
3 arrays with 8 elements

Only one antenna array selected at once

Cable @26GHz are expensive, mixer need to be included in the antenna array

What about the cost ?

Heat issue ?



Qualcomm Research 5G NR mmWave UE Prototype

Conclusions for UE

- No real challenge in the design of antenna array for mobile
- It is again an integration challenge
- Position of antenna array on the mobile is the key
- You have seen 28GHz, just think about 40GHz !
- On a excel spreadsheet, everything is possible
- But 5G mmW UE prototype are already providing good performance

General Conclusion

- Does it make sense ???
- Mmw is a stupid choice for UE from a scientific point of view
- Is 3.5GHz a fake 5G ? Marketing is pushing the mmW
- Who will be the first ? Apple, Samsung or Huawai ?
- USA sent people on the moon ! It was not for economic reason

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