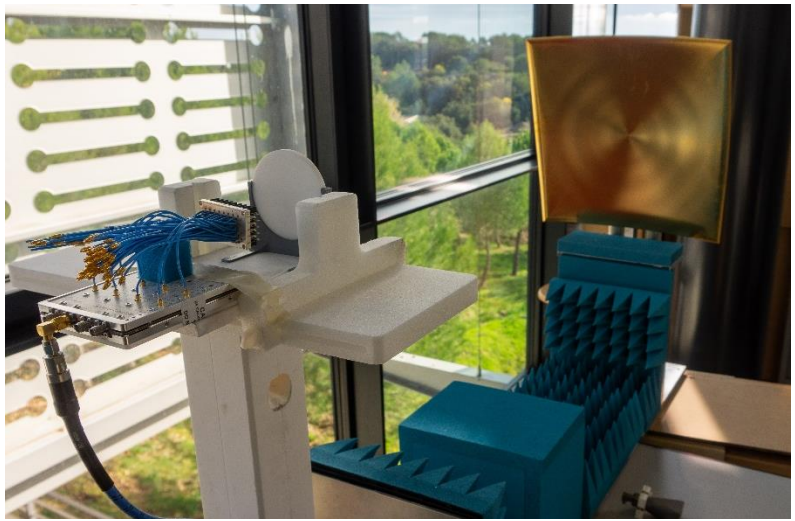
VERSATILE 5G FR2 OVER-THE-AIR ANTENNA CHARACTERIZATION AT YOUR BENCHTOP

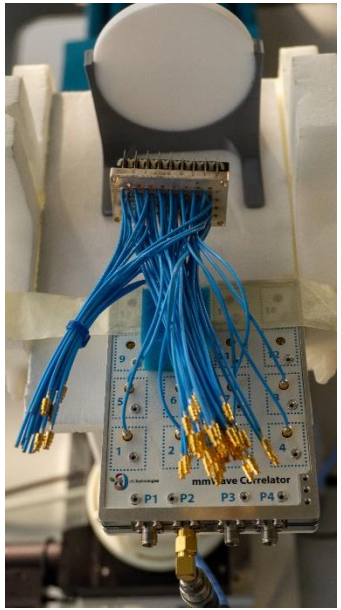
Prof. Fabien Ferrero, University Côte d'Azur, Sophia Antipolis / Nice
Günter Pfeifer, Rohde & Schwarz Product Management Munich

ROHDE&SCHWARZ
Make ideas real

VERSATILE 5G FR2 ANTENNA MEASUREMENTS

- Agenda:
  - Sophisticated antenna design
  - How to measure conveniently
  - Solution offerings from R&S





PRESENTERS

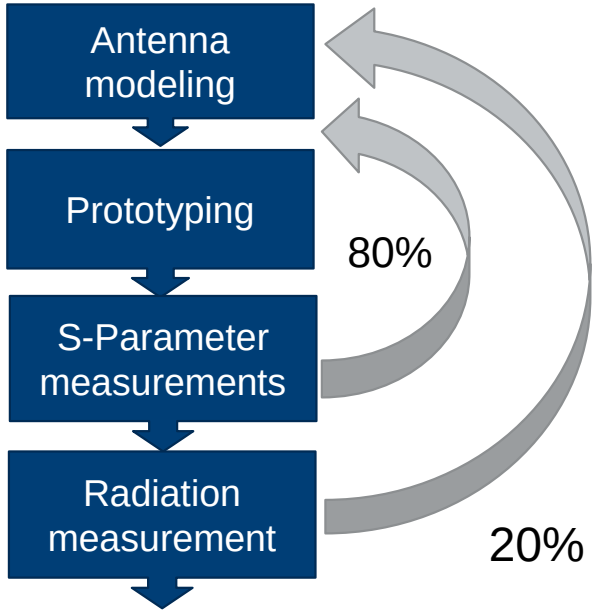
- 25 years of experience in radio com
- 5G FR2 OTA and CATR focused
- Product manager

- Professor for Electronics
- 20 years experience in RF
- Antenna enthusiast
- Researcher

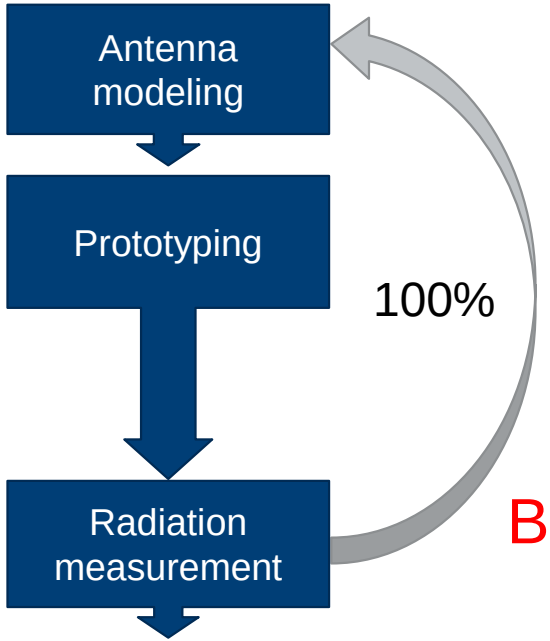
FR2 MEASUREMENT: WHAT IS THE PROBLEM ?

- Measurement at millimeter wave is more challenging
- Integrated mmW Antenna with Front end -> no access to antenna port
- Active Antenna design include development of complex firmware
- FR2 Antenna are more directive and usually include beamsteering
- To fully characterize 5G FR2 system, CW measurement is not sufficient -> EVM

WE NEED A CHANGE IN ANTENNA DESIGN PROCESS



Passive mmW project

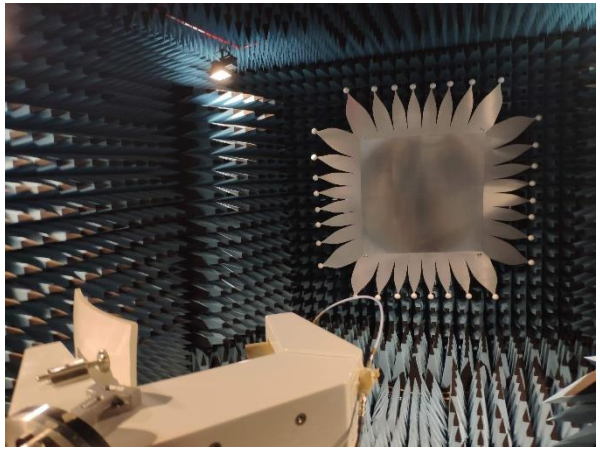


EM debug
Hardware debug
Firmware debug

Bottle neck

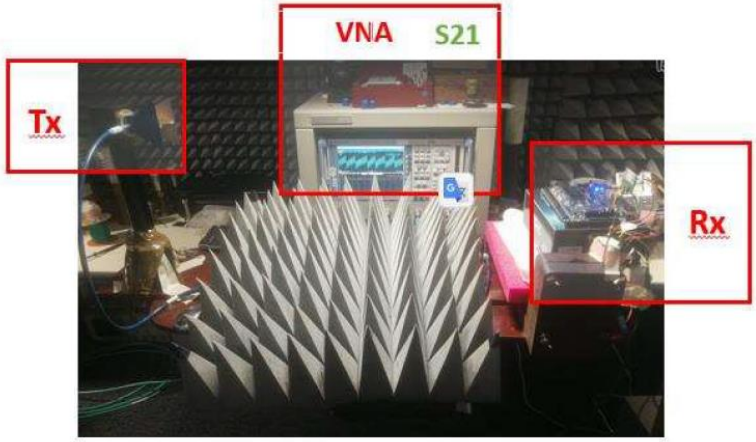
Active mmW project

WE NEED A CHANGE IN ANTENNA DESIGN PROCESS



Antenna optimization in anechoic chamber :

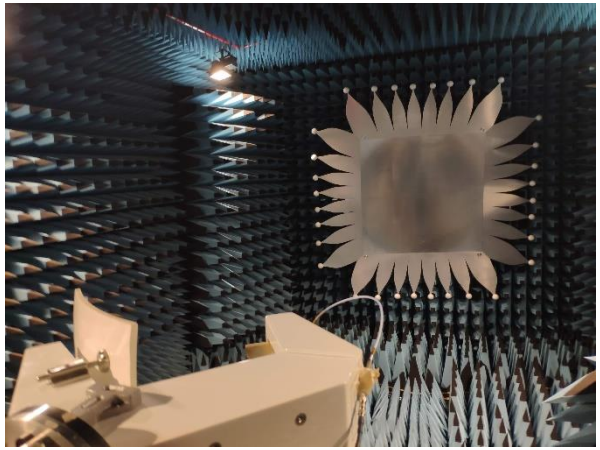
- Costly (very)
- Not practical for prototype
- Full3D spherical scanner
- 1m quiet zone



In-house simple Bench top system:

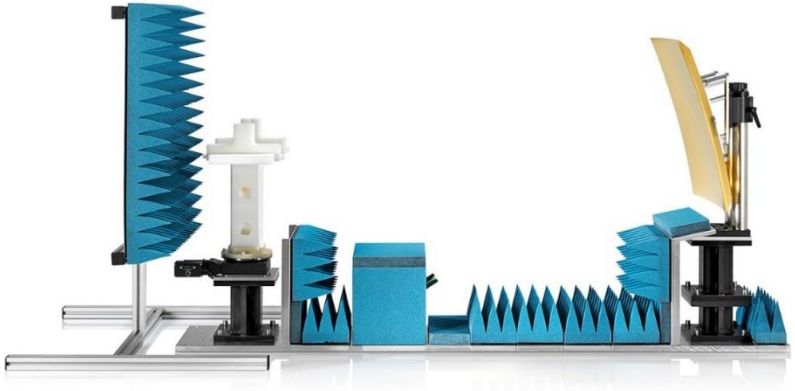
- Very Cheap
- Open environment
- Near-field issue
- No rotational stage

WE NEED A CHANGE IN ANTENNA DESIGN PROCESS



Antenna optimization in anechoic chamber :

- Costly (very)
- Not practical for prototype
- Full3D spherical scanner
- 1m quiet zone



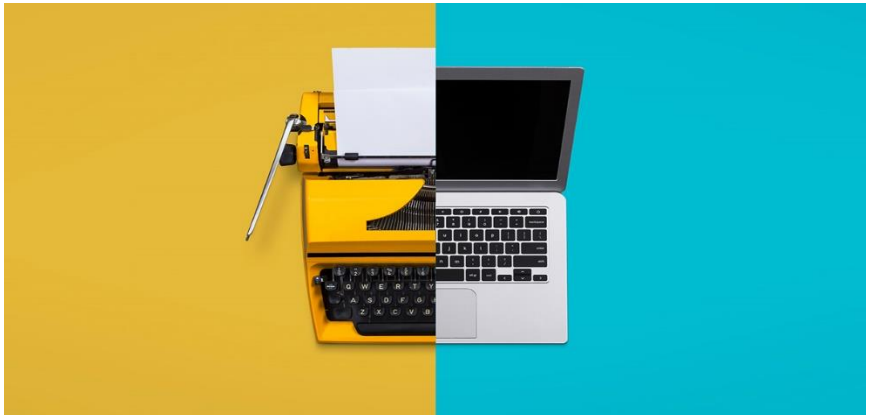
Bench top system:

- Cheaper
- Open environment
- Far-field direct measurement
- Rotational stage

OUTLINE

- EEMW4FIX project : Motivation and Context
- Beam-switched Lens Antenna principle
- Measurement using AT800B
- Conclusion & Perspectives

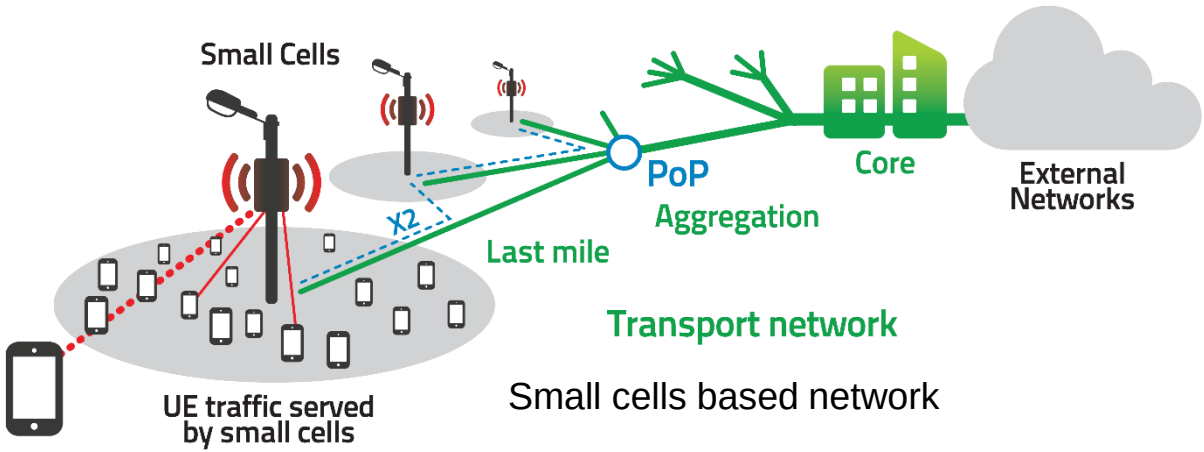
SOLVING THE DIGITAL DIVIDE



- More than one billion homes worldwide still find themselves without a regular broadband connection [1].
- Fixed Wireless Access (FWA) is can provide a broadband service to homes, business and factories, when there is no infrastructure to deliver wired broadband via copper, fiber or hybrid solutions.
- **Next-generation FWA such as beam-switching at millimeter waves (mmW), will deliver robust, reliable and cost-efficient solutions on a massive scale.**

THE 5TH GENERATION OF TELECOMMUNICATIONS

- Operators are utilizing small cells to **fill the gaps** with traditional macro network.
- The backhaul in a small cell environment has significantly **different deployment characteristics** compared to macro backhaul networks.
- Small cell backhaul is constrained by **cost, size and location** to a far greater extent than traditional macro networks.

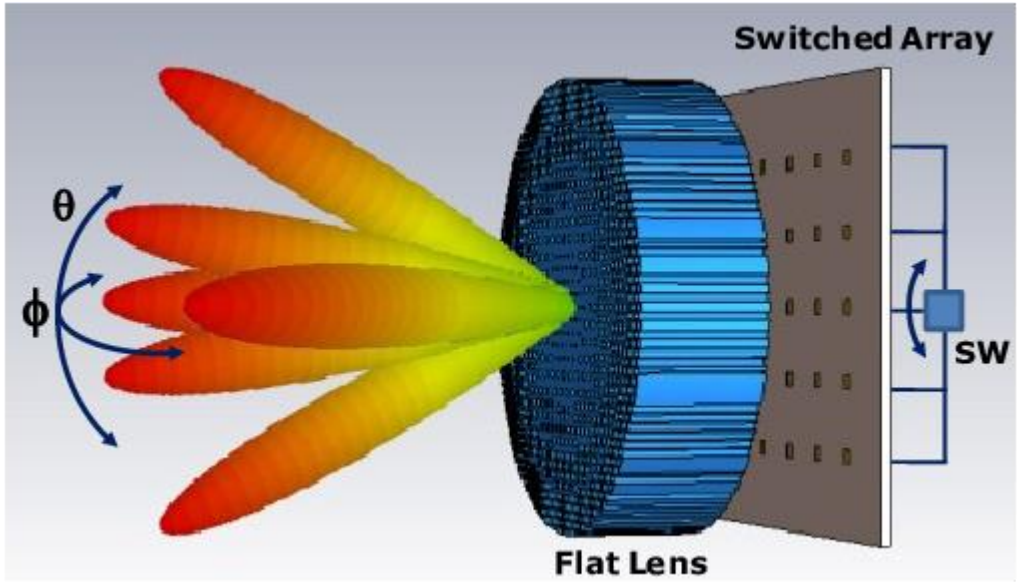


Small cells based network

ENERGY EFFICIENT MMW FOR FIX PROJECT

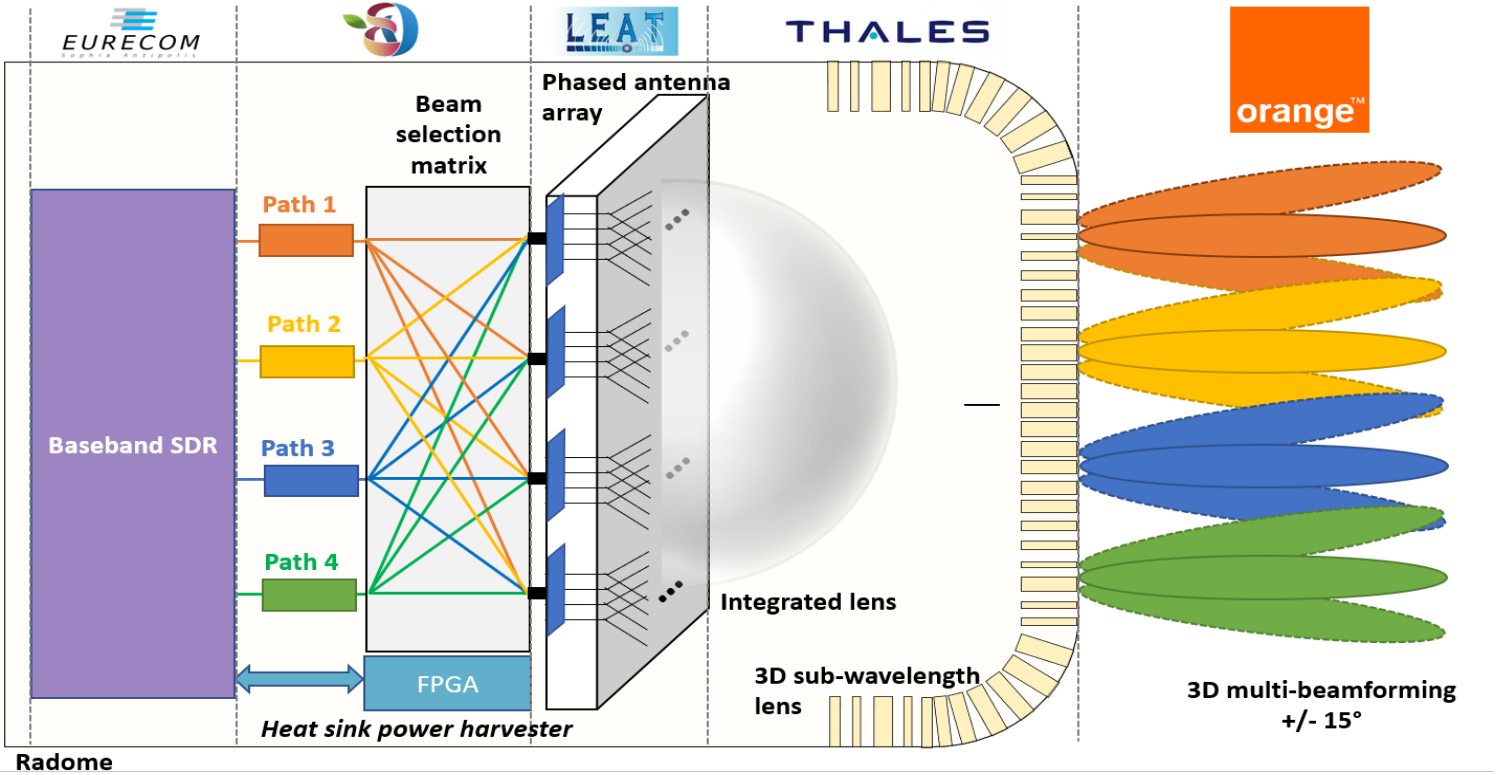
- Started in November 2021
- 5 partners
- Funded by ANR

BEAM-SWITCHED LENS ANTENNA



► [2] Imbert, Marc & Papió, Anna & De Flaviis, Franco & Jofre, Lluis & Romeu, Jordi. (2014). Switched-beam antenna array for 60 GHz WPAN applications. 10.1109/APS.2014.6905162.

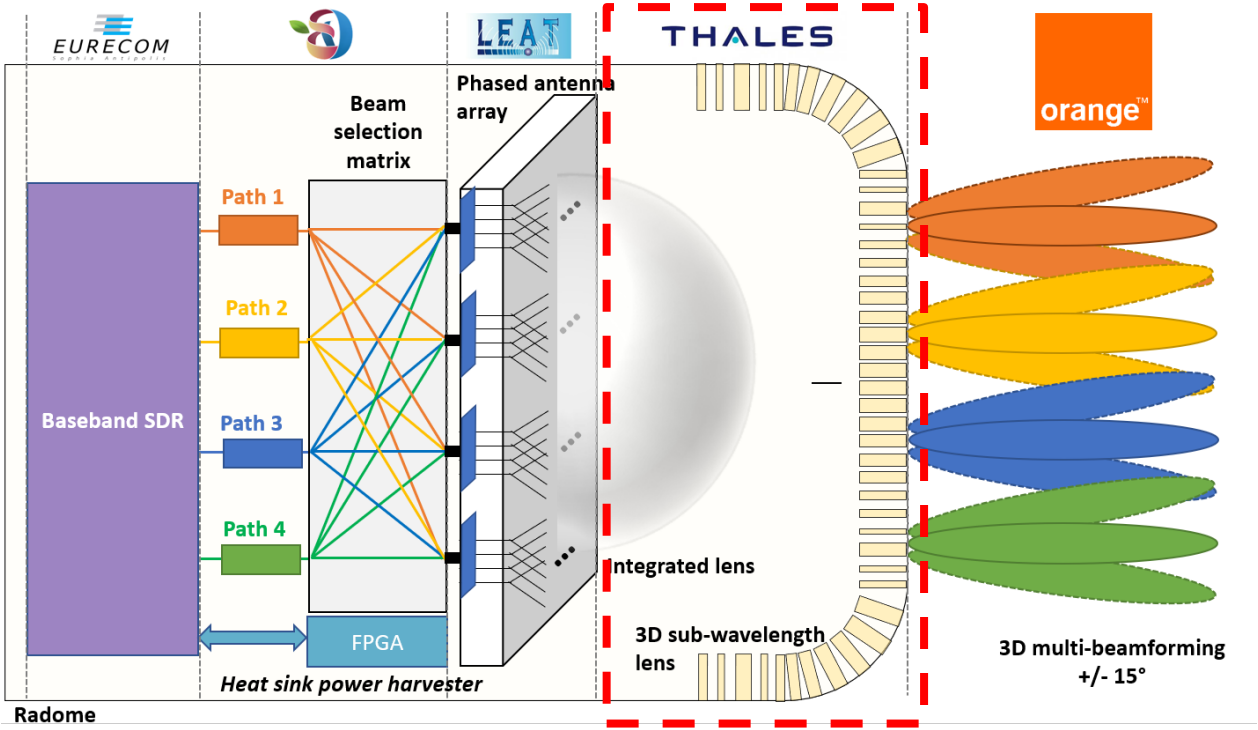
BEAM-SWITCHED LENS ANTENNA



ENERGY EFFICIENCY

	Classical mmW Phased Array	EEMW4FIX solution 1 RF Path	EEMW4FIX solution 4 RF Paths
Dimensions	5*5*5 cm	10*10*~10 cm	10*10*~10 cm
Antenna elements	64	64	64
Tx EIRP	54 dBm	48 dBm	48 dBm per path
Rx gain	23 dB	29 dB	29 dB
Total Tx + Rx	77 dB	77 dB	77 dB
Activated antenna elements	64	4	16
RF Power consumption	10W	0.6W	2.4W
Scanning angle	+/-60°	+/- 15	+/- 15°
Number of beams	1	1	4

BEAM-SWITCH LENS ANTENNA



TOWARDS COMPACT LENS ANTENNA

Height gradient

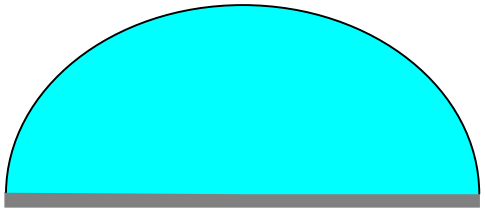
Fresnel lens

Compact but less efficient

Index gradient

Diffractive RF lens by index gradient

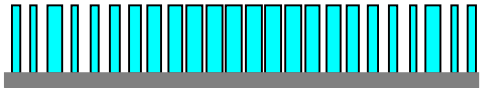
Artificial material approach



Bulk dielectric RF lens

∅180mm – 42GHz Lens antenna

Effective index gradient

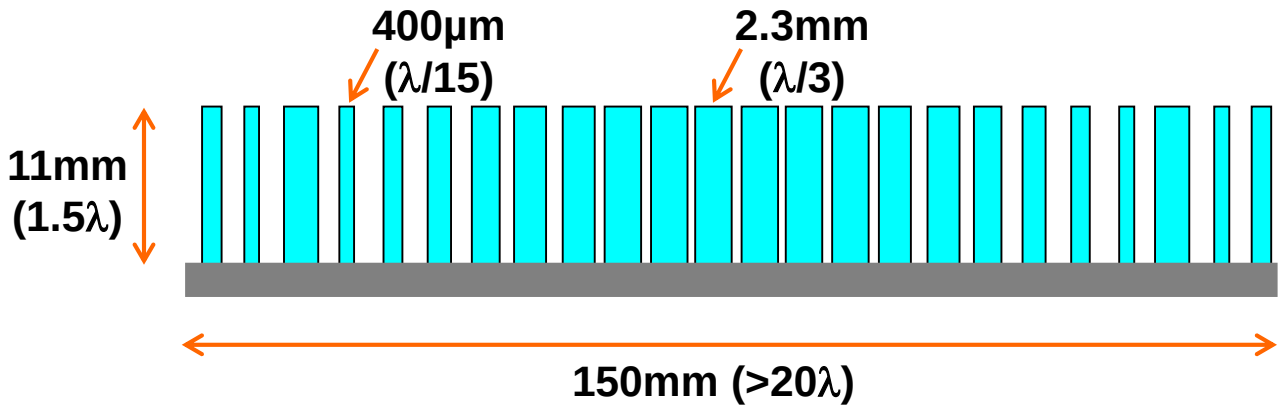


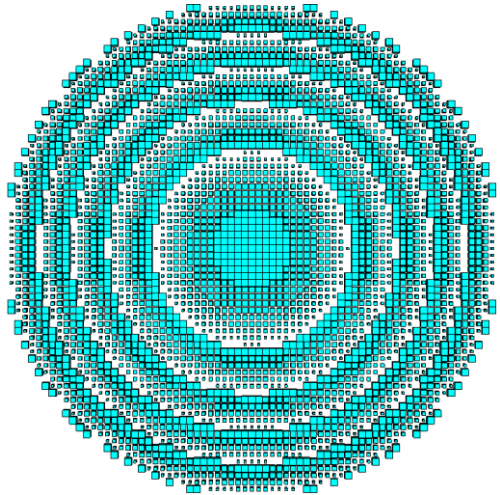
Sub-λ diffractive RF lens

Low profile and efficient

TOWARDS COMPACT LENS ANTENNA

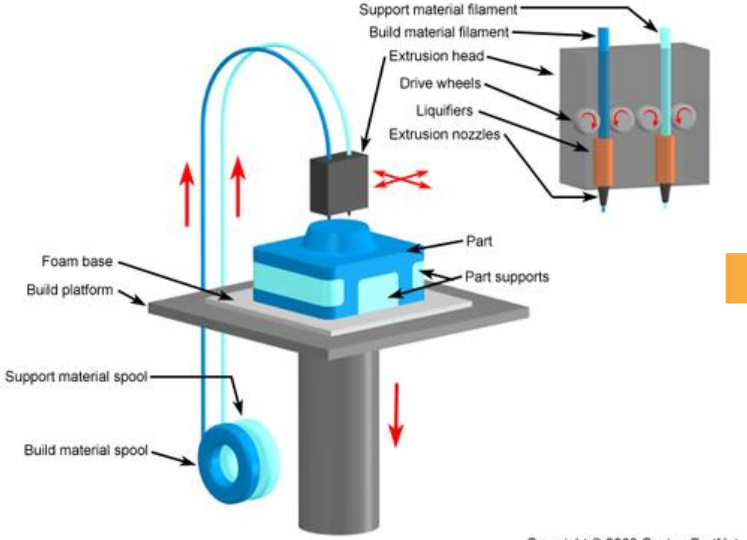
- Example of a sub-wavelength dielectric lens antenna @ 42GHz [3-4]
  - $\varepsilon_R = 2.6$ **and** $\tan\delta = 7.10^{-3}$
  - **Thousands of pillars**

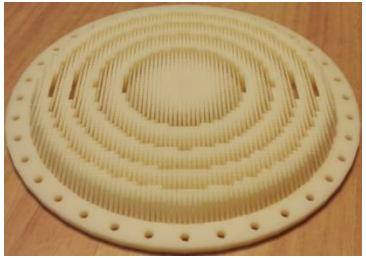




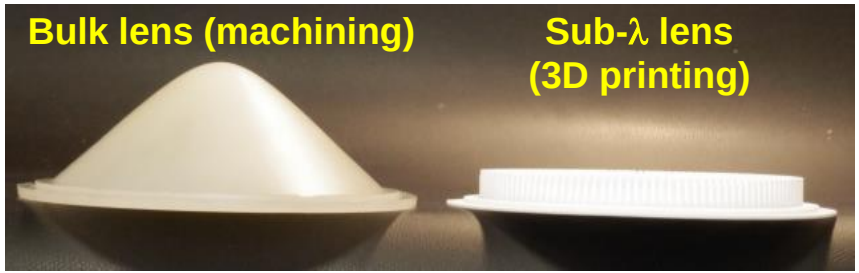
How to fabricate this kind of structure?

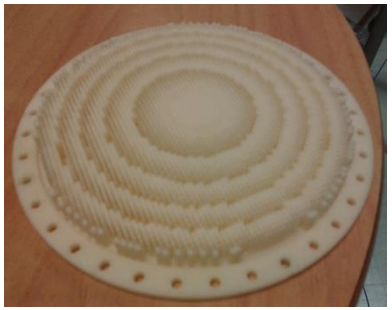
HOW TO MANUFACTURE ?





TOWARDS COMPACT LENS ANTENNA



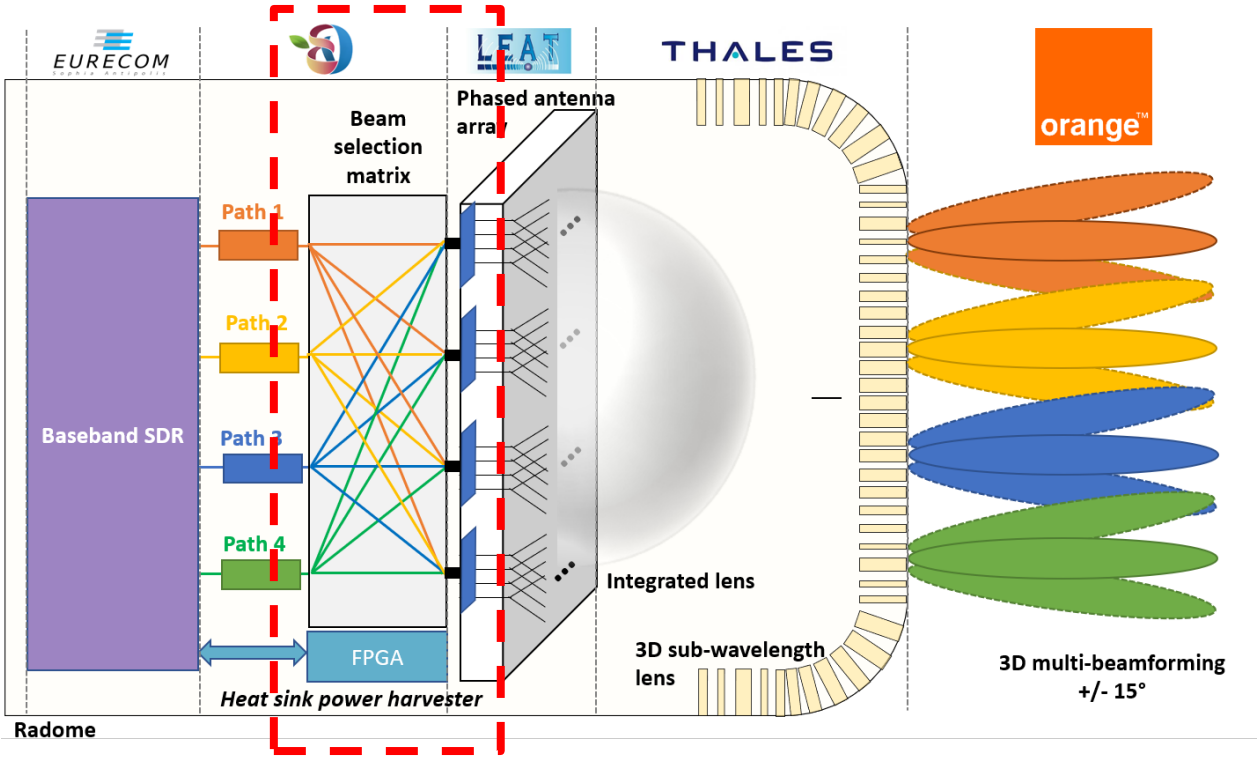


** Q-band*

Artificial material + 3D printing
= <u>Functional</u> RF parts with better performance

- **Gain improvement up to 1.5 dB**
- **Thickness reduction by 4 (13mm vs. 53mm)**
- **Weight reduction by 3 (160g vs. 445g)**
- **Cost reduction by 10 (100€ vs. 1000€)**

BEAM-SWITCH LENS ANTENNA

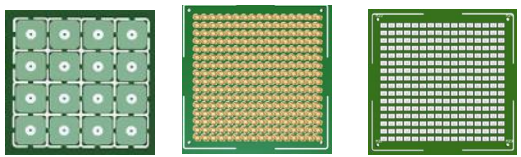


PRELIMINARY EXPERIMENTAL RESULT

eV Technologies

Think Energy!

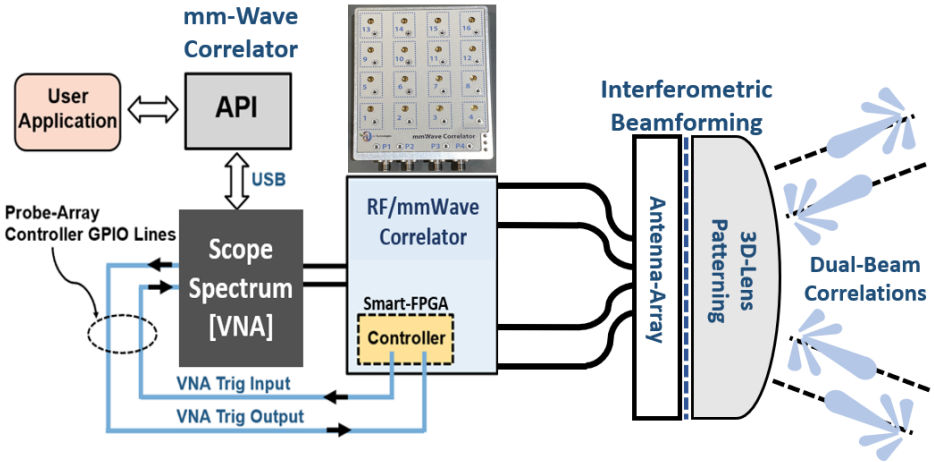
- 100dB Channel Isolation
- Integrated Signal- Processing & Control Module
- StableTemperature Regulation
- Wireless Signal Control

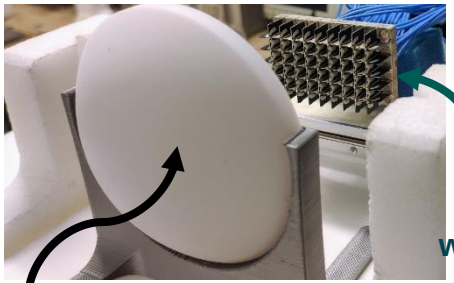


BEAM SELECTION MATRIX

eV Technologies

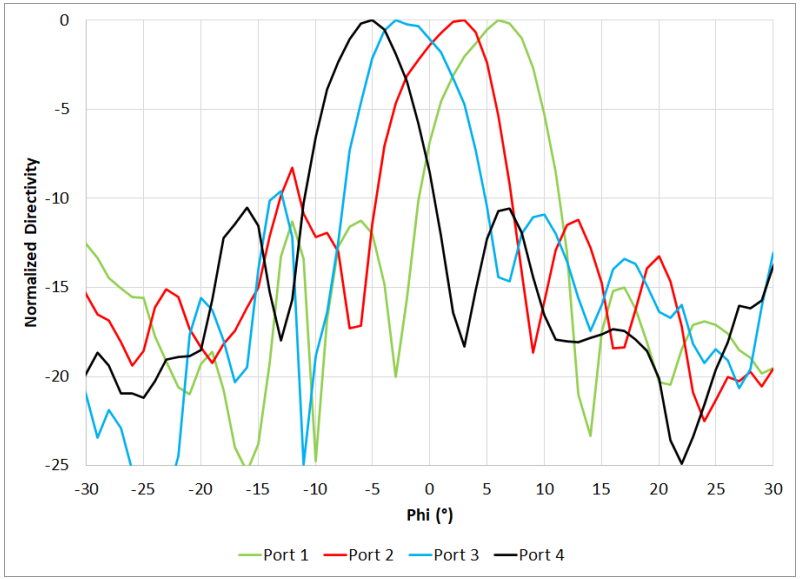
Think Energy!





64-Channel
Antenna-Array
with mmWave Correlator

Lens System

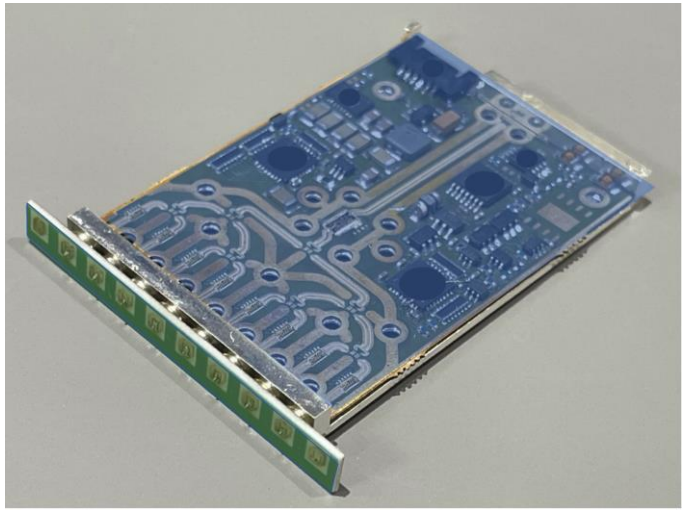


BEAM FORMER FRONT-END

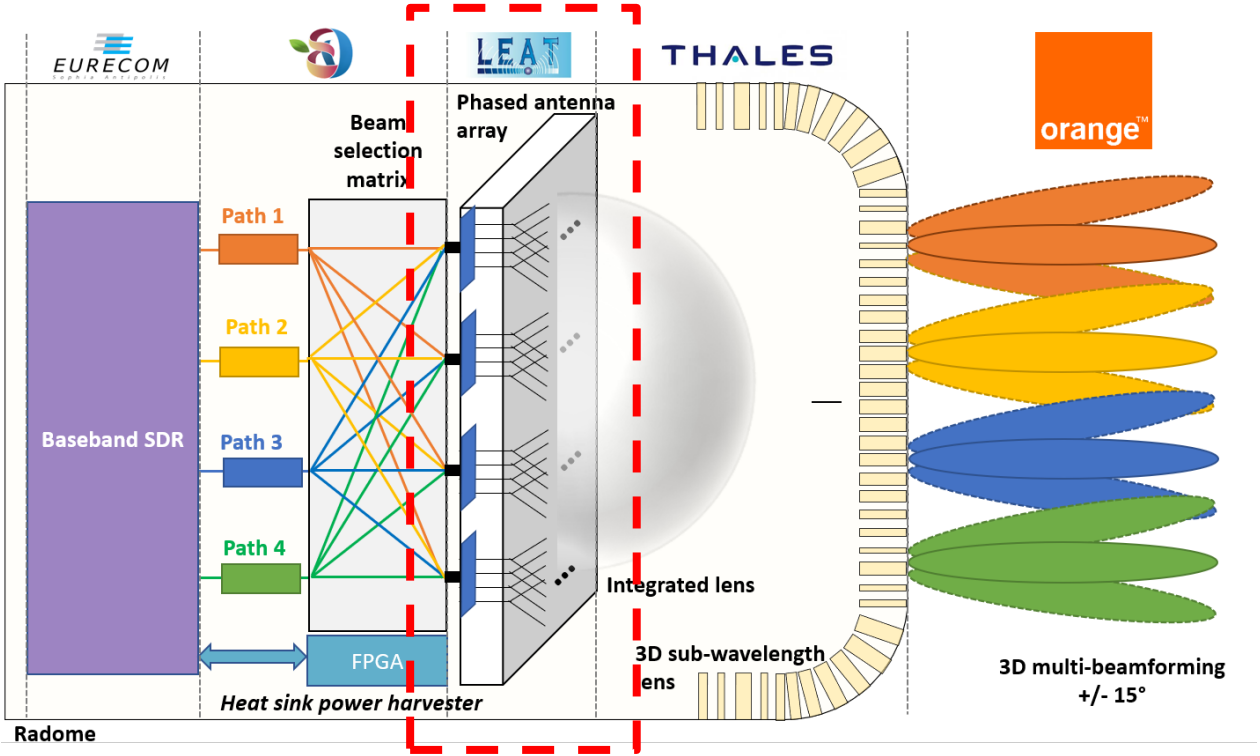
eV Technologies

Think Energy!

- 26 – 30 GHz operational frequency band
- Supports 4 dual-pol radiating elements
- Tx/Rx half duplex operation
- Tx output power: o +12 dBm @ 3% EVM o +20 dBm @ P1dB
- 20 dB Tx gain
- 25 dB Rx coherent gain for 8 channels
- 3.4 dB Rx coherent NF
- -25 dBm Rx coherent IIP3 (adjustable)
- 6-bit phase control (LSB=5.6 deg)
- 5-bit gain control (LSB=0.5 dB)
- Fast beam steering • Telemetry reporting
- 5mm x 4.5 mm WLCSP • Single 1.8V supply operation
- 22nm FDSOI process

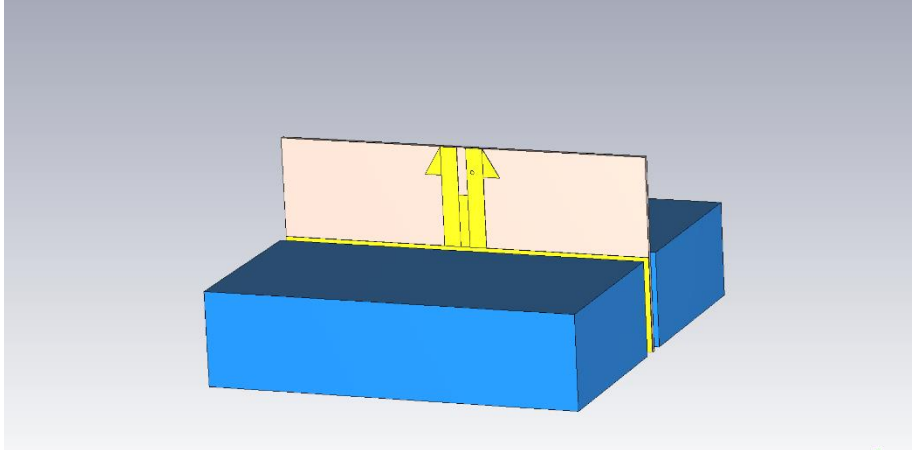


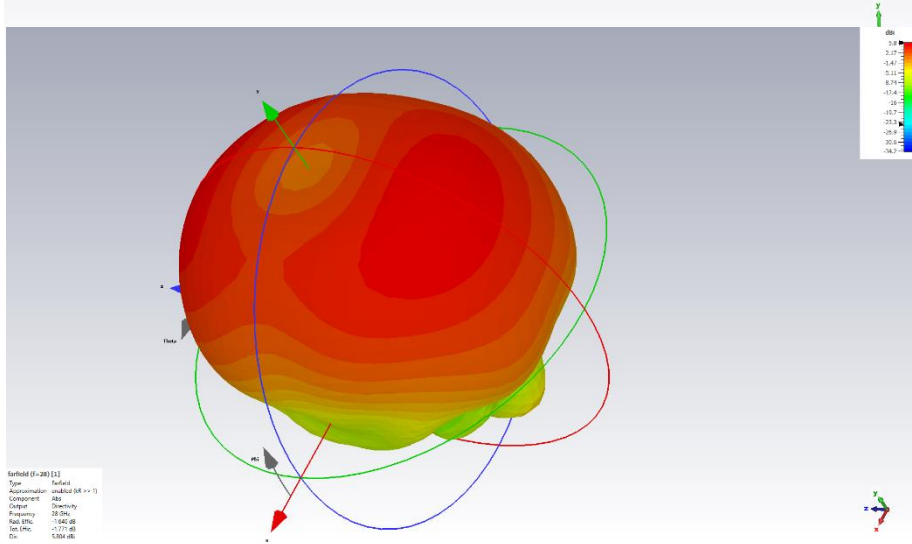
BEAM-SWITCH LENS ANTENNA



PHASED ARRAY DESIGN

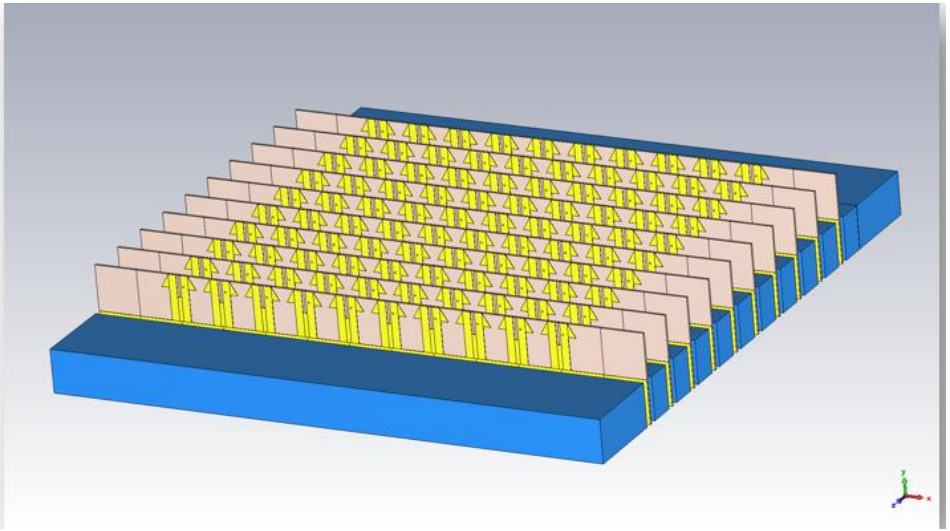
- Dipole printed antenna fed by microstrip line
- 28GHz with more than 3GHz bandwidth with -10dB S_{11} criteria
- 0.25mm thick Rogers 4350B substrate
- Wide aperture radiation pattern
- Compatible with dual-polarized assembly

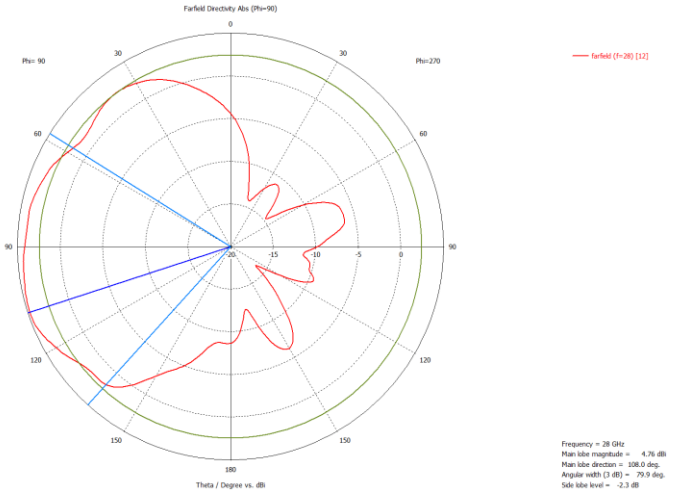




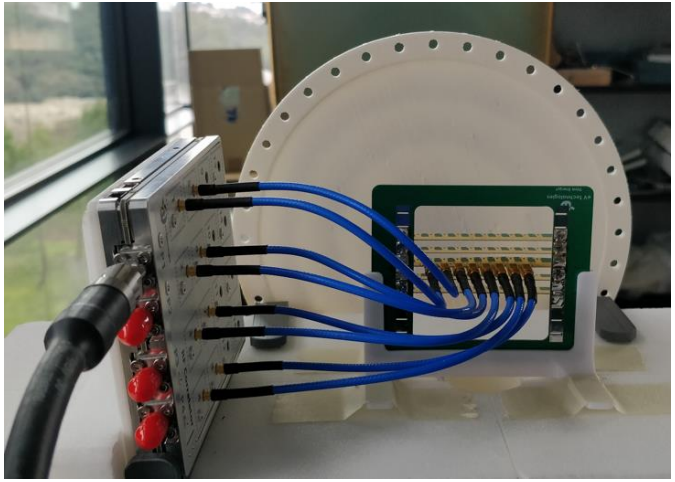
PHASED ARRAY DESIGN

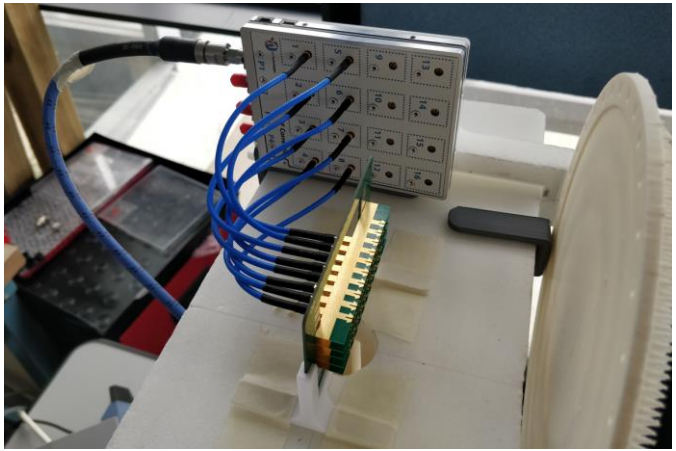
- Up to 8*8 array for 3D beamsteering
- Array assembly with dummy elements
- Only single polarization as a start
- 0.5 lambda element distance between element for fine beam steering





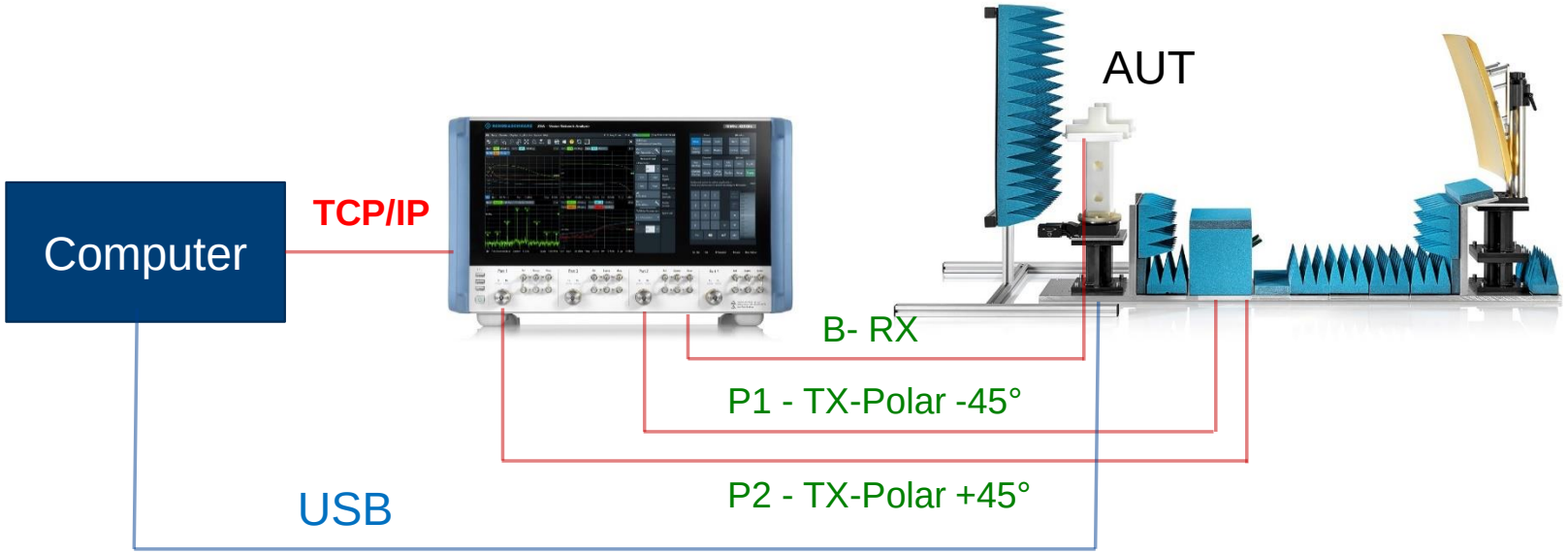
MEASUREMENTS





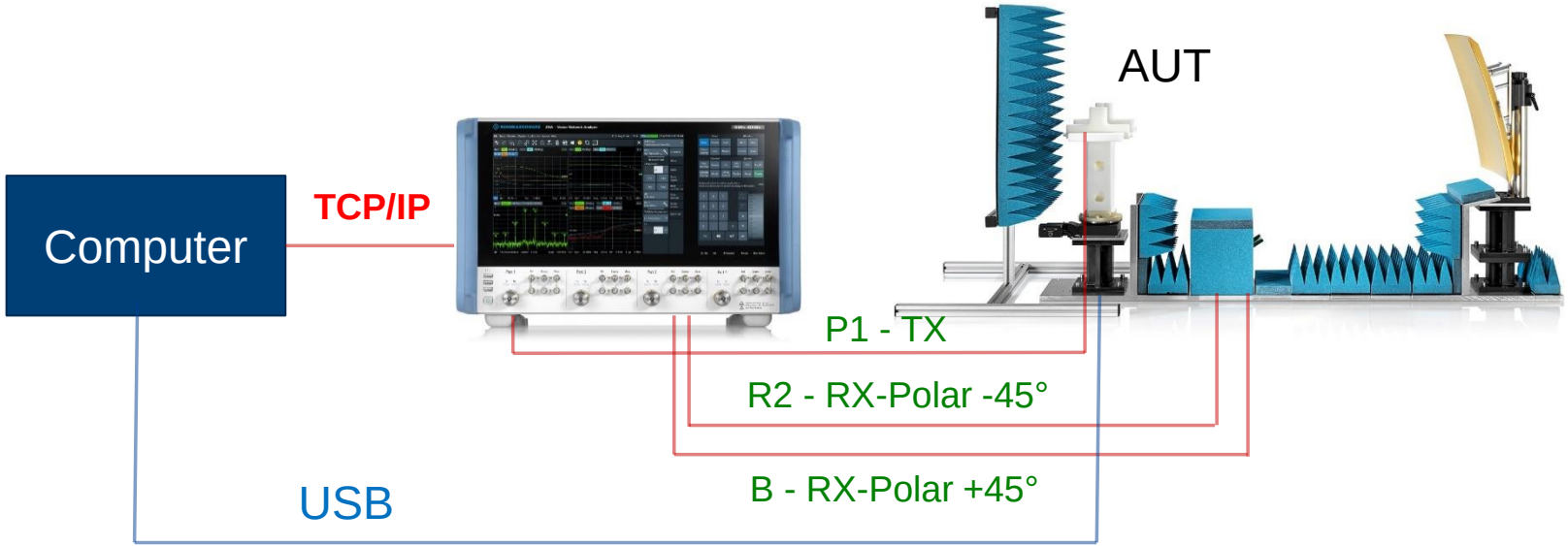
RX MODE

- The two ports of the reflector source are connected to VNA port 1 et 2
- The AUT cable is connected to receiver B

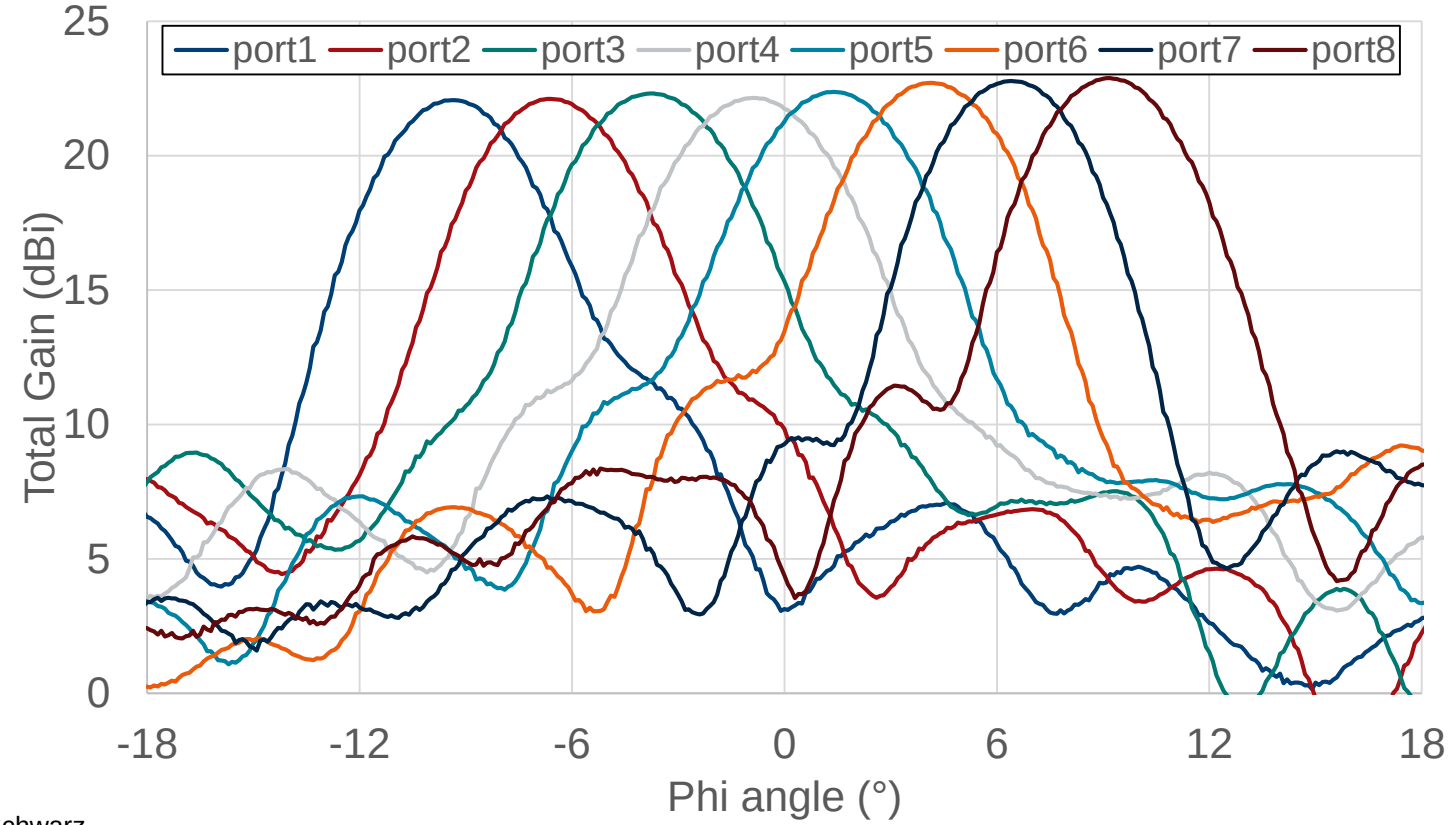


TX MODE

- The two ports of the reflector source are connected to receiver R2 and B
- The AUT cable is connected to Port 1



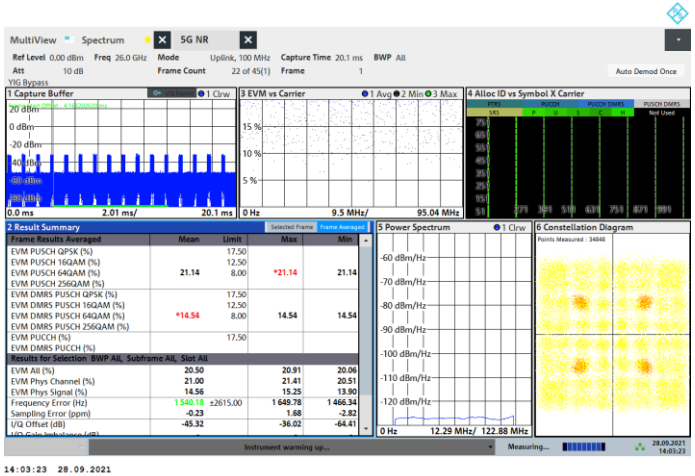
MEASUREMENT RESULT

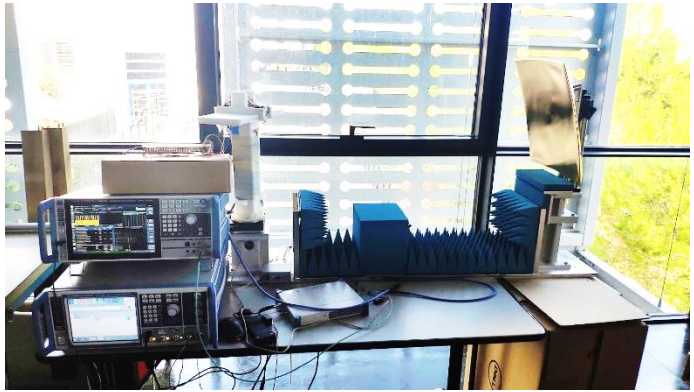


CONCLUSION & PERSPECTIVE

- Versatile solution to conduct prototype measurement and optimization
- Integration of various instruments and equipment is facilitated

- In the next steps, measurement of Active parameters : EVM, TRP, TIS





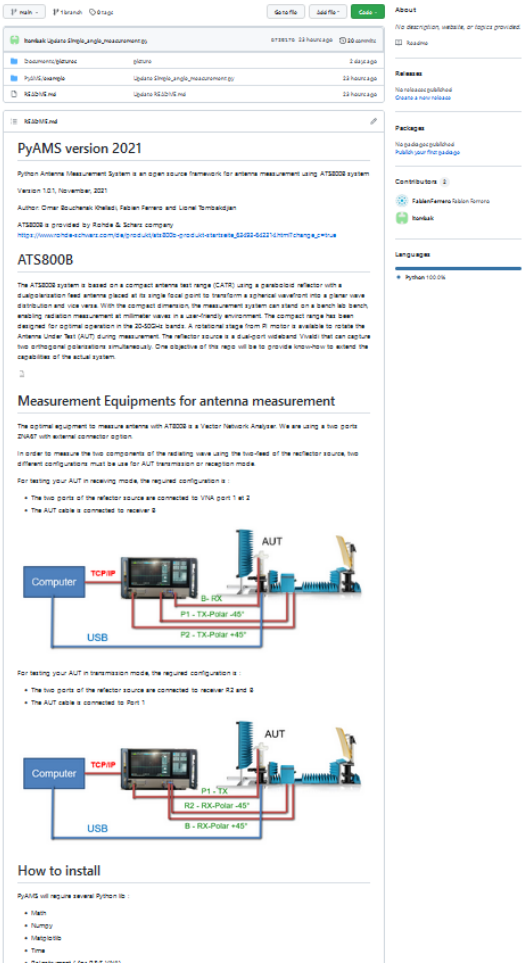
REFERENCES

- [1] "5G For FWA (Fixed Wireless Access): 2017-2030 – Opportunities, Challenges, Strategies & Forecasts," Market Insight report, SNS TELECOM, 2017.
- [2] Imbert, Marc & Papió, Anna & De Flaviis, Franco & Jofre, Lluis & Romeu, Jordi. (2014). Switched-beam antenna array for 60 GHz WPAN applications. 10.1109/APS.2014.6905162.
- [3] A. O. Diallo, B. Loiseaux et al., "Comparison Between a Thin Lens Antenna Made of Structured Dielectric Material and Conventional Lens Antennas, in Q-Band in a Compact Volume," IEEE Antennas and Wireless Propagation Letters, vol.17, no.2, pp. 307-310, Feb. 2018.
- [4] R. Czarny and al, "Q-Band High Gain radome integrated lens antenna for compact backhaul terminal," European Conference on Antennas and Propagation, Mar. 2017.

PYTHON LIBRARY

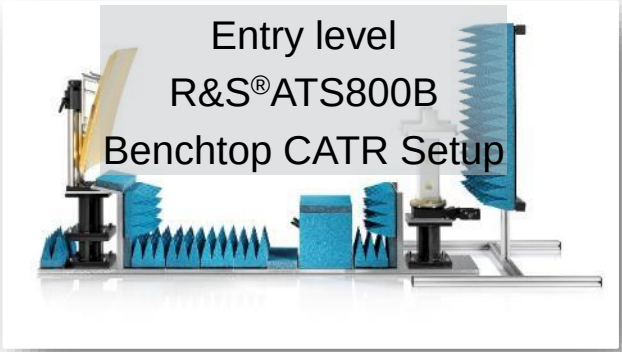
- https://github.com/FabienFerrero/PyAMS
- https://github.com/rohde-schwarz/OTA-Toolbox

- Comprehensive control of rotational stage, instruments and DUT on a single platform
- Generic and open source framework



WHICH CATR PRODUCTS DO WE OFFER (SO FAR)?

- R&S®ATS800B
- R&S®ATS800R
- R&S®ATS1800C

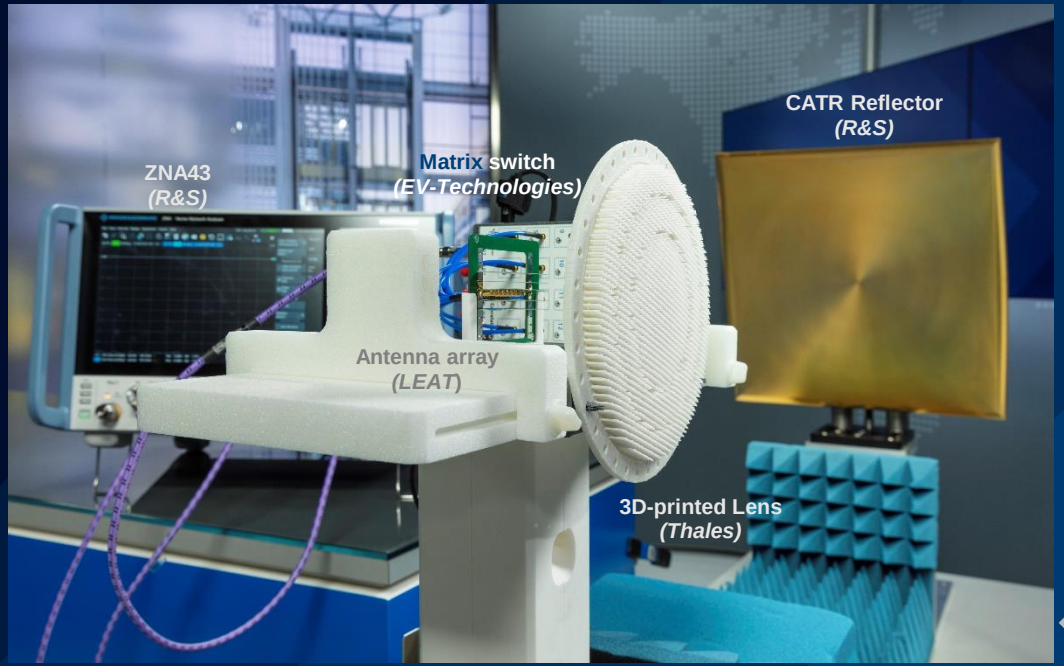


R&S FR2 OTA IFF CATR SOLUTIONS OVERVIEW

	ATS800B	ATS800R	ATS1800C	ATS1800M
				
Dim. (WxHxD)	1.2 x 0.8 x 0.6	0.6 x 2.0 x 1.2	0.9 x 2.0 x 1.5	~3.5 x 2.0 x 1.5
Application	Benchtop R&D, academia, research institutes	R&D, pre-conformance (RF, LBS, Netop, PCT, PQA)	R&D, conformance & pre-conformance (RF, LBS, Netop, PCT, PQA)	R&D, conformance & pre-conformance RRM multiple AoA
Type	Black box CATR	Black box CATR	Black box CATR	Black box CATR
Freq. Range	20 - 50 GHz	20 - 50 GHz	(6) 23 - 90 GHz	(6) 23 - 90 GHz
Supported freq. Range	Full range	Full range	Full range (feed switcher)	Full range (multiple feeds)
Quiet zone	Ø 20 cm	Ø 20 cm	Ø 30 cm	4x Ø 30cm
Positioner	2D positioner (opt.)	3D Az over El (opt.)	3D Az over El	3D Az over El
Shielding Eff.	N/A	>60dB	>90 dB	>70dB
Extreme Temp.	N/A	1D	3D	3D

Find out more

www.rohde-schwarz.com/products/OTA



ROHDE&SCHWARZ

Make ideas real