

# Experimenting with Next Generation Wireless

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Politecnico di Milano

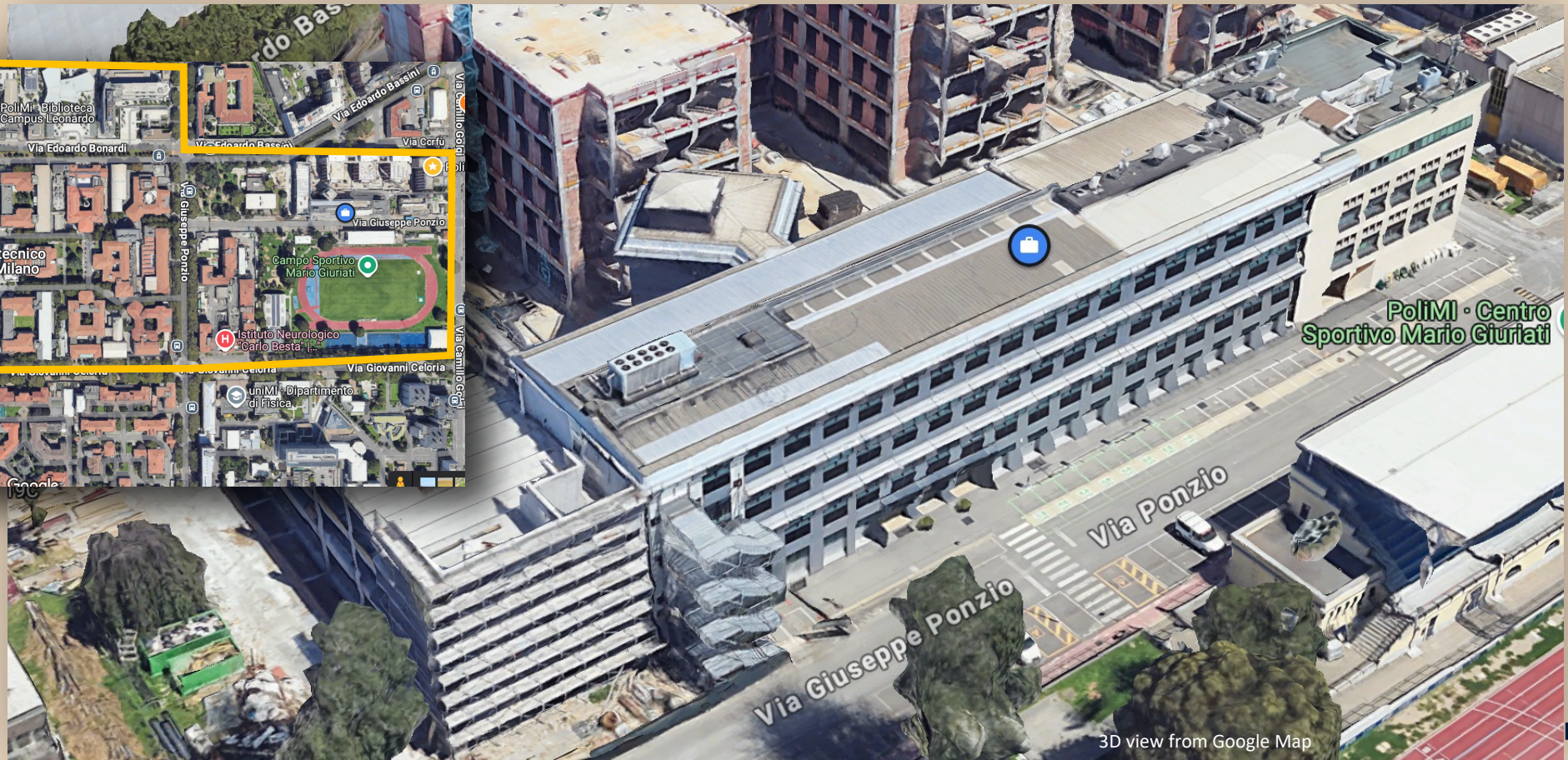
PI 6G Wireless Network

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# Main Campus and DEIB



LITECNICO  
MILANO 1863

# 6G Wireless Networks (RESTART structural project on 6G)



Consiglio Nazionale  
delle **Ricerche**



ALMA MATER STUDIORUM  
UNIVERSITÀ DI BOLOGNA



UNIVERSITÀ DI PISA



siae microelettronica





# Index



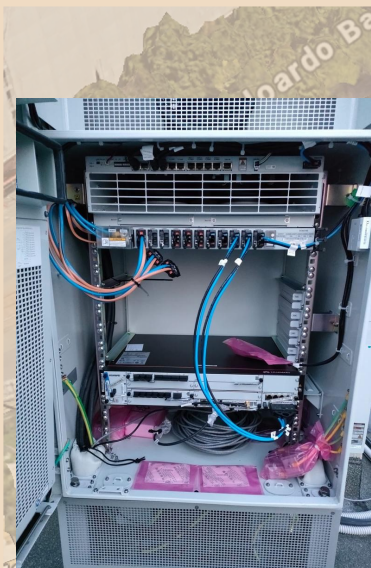
1. Open-Air Experimental facility
2. Prototyping
3. ISAC Experiments



# Open-Air Experiments

(FR1, 7-24 GHz, 28-30 GHz, 60-75 GHz, 148-251 GHz)

# FR2 Basestation 5G NR mmW with 2 cells



 **Hewlett Packard  
Enterprise**





**ANTLAB**  
ADVANCED  
NETWORK  
TECHNOLOGIES  
LAB



O2I test location

6GHz TUE

6GHz AAU

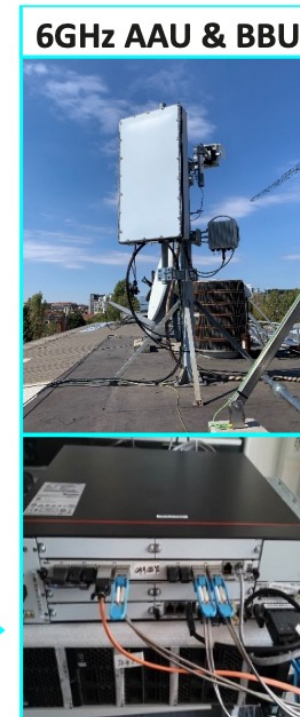
E (90°)

N (0°)

Google Earth

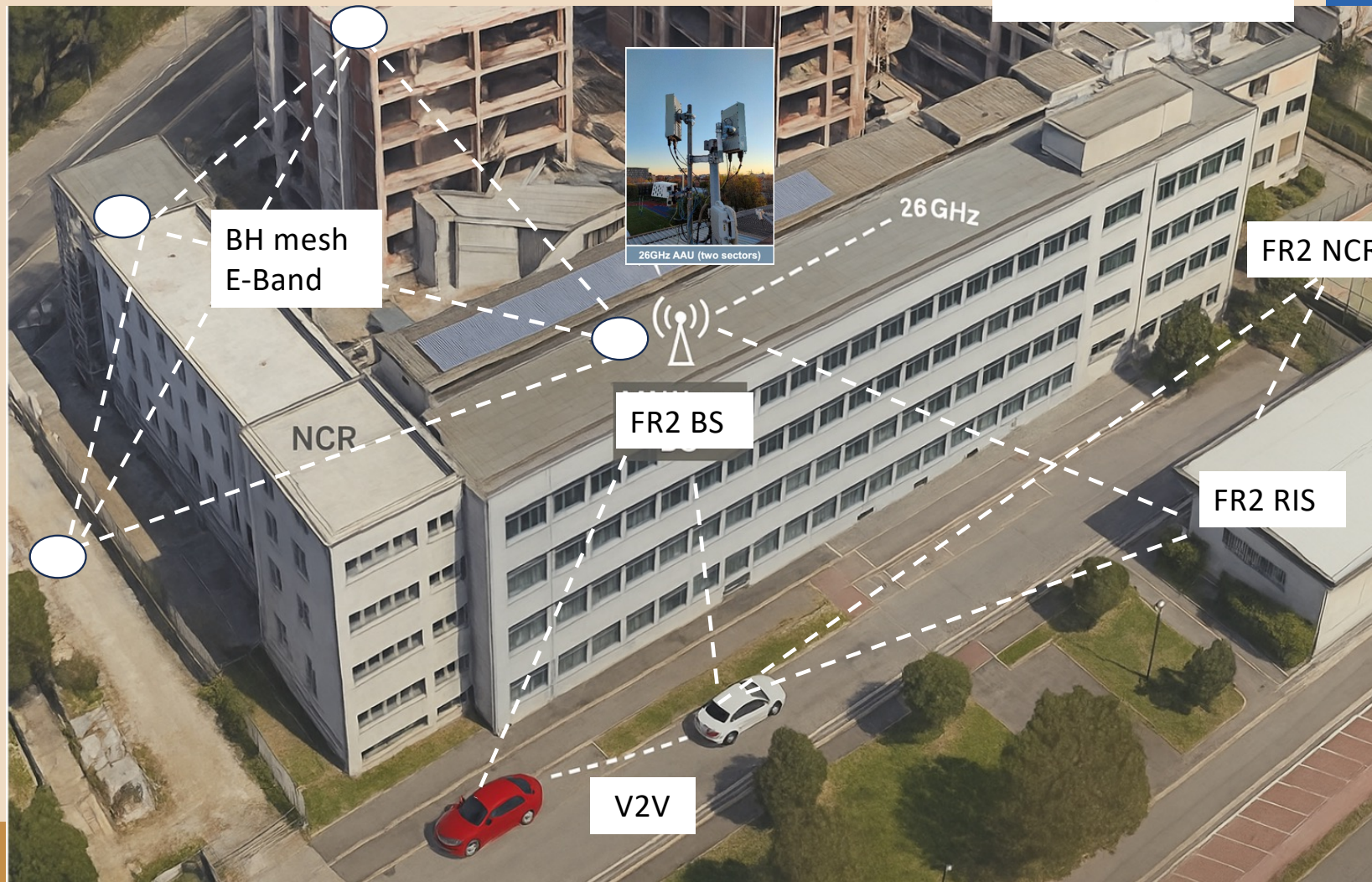
Image Landsat / Copernicus

50 m





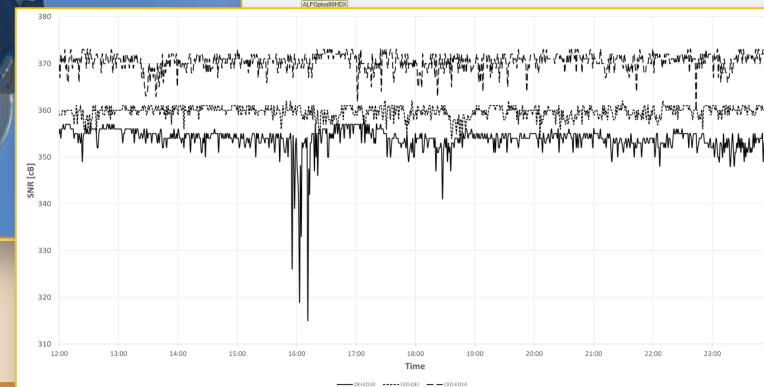
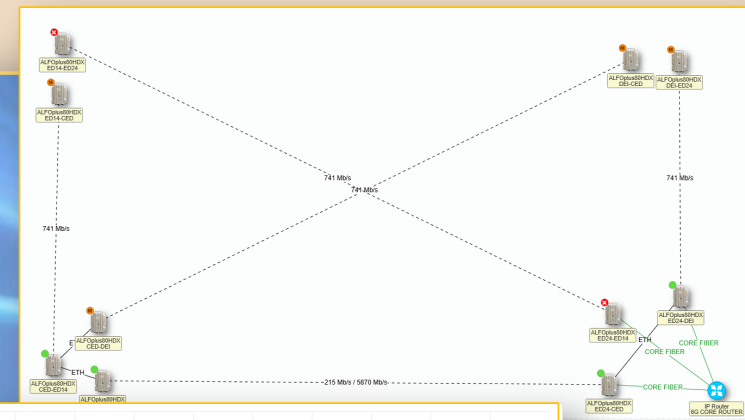
# Open-Air ongoing experiments



# HFC – Microwave backbone at E band



Single Frequency Network at 74.5GHz and 84.5 GHz with 1 GHz FDD radio channel with an **aggregate capacity > 10 Gbit/s**



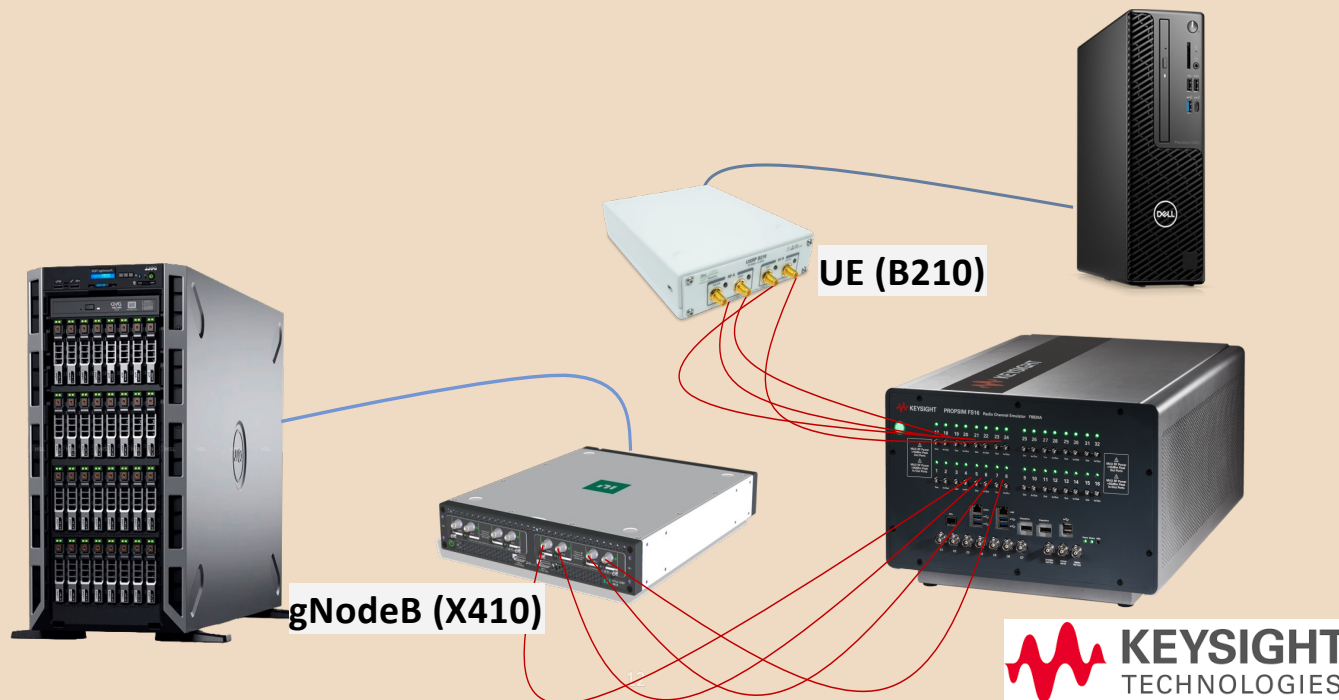




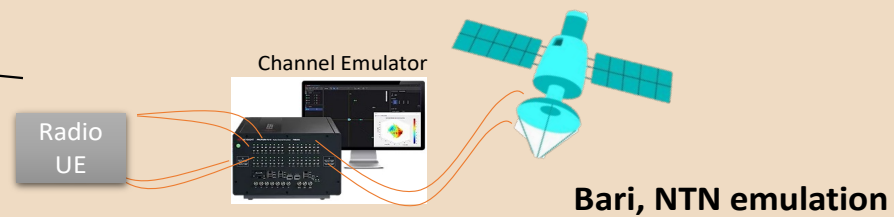
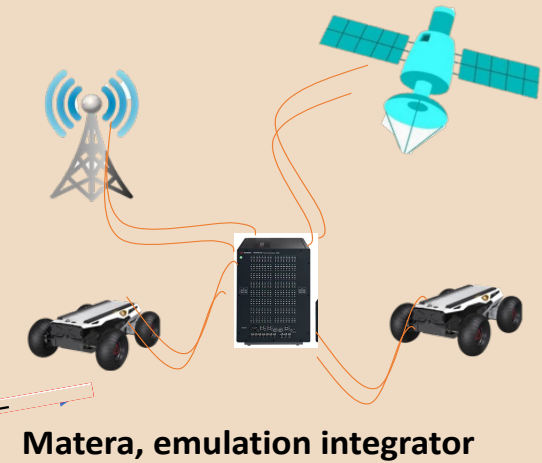
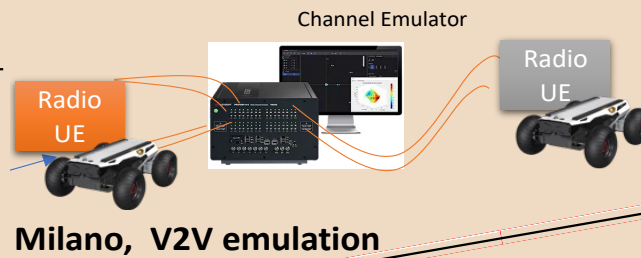
6GWINET  
RESTART PROJECT



- ## Federated Lab

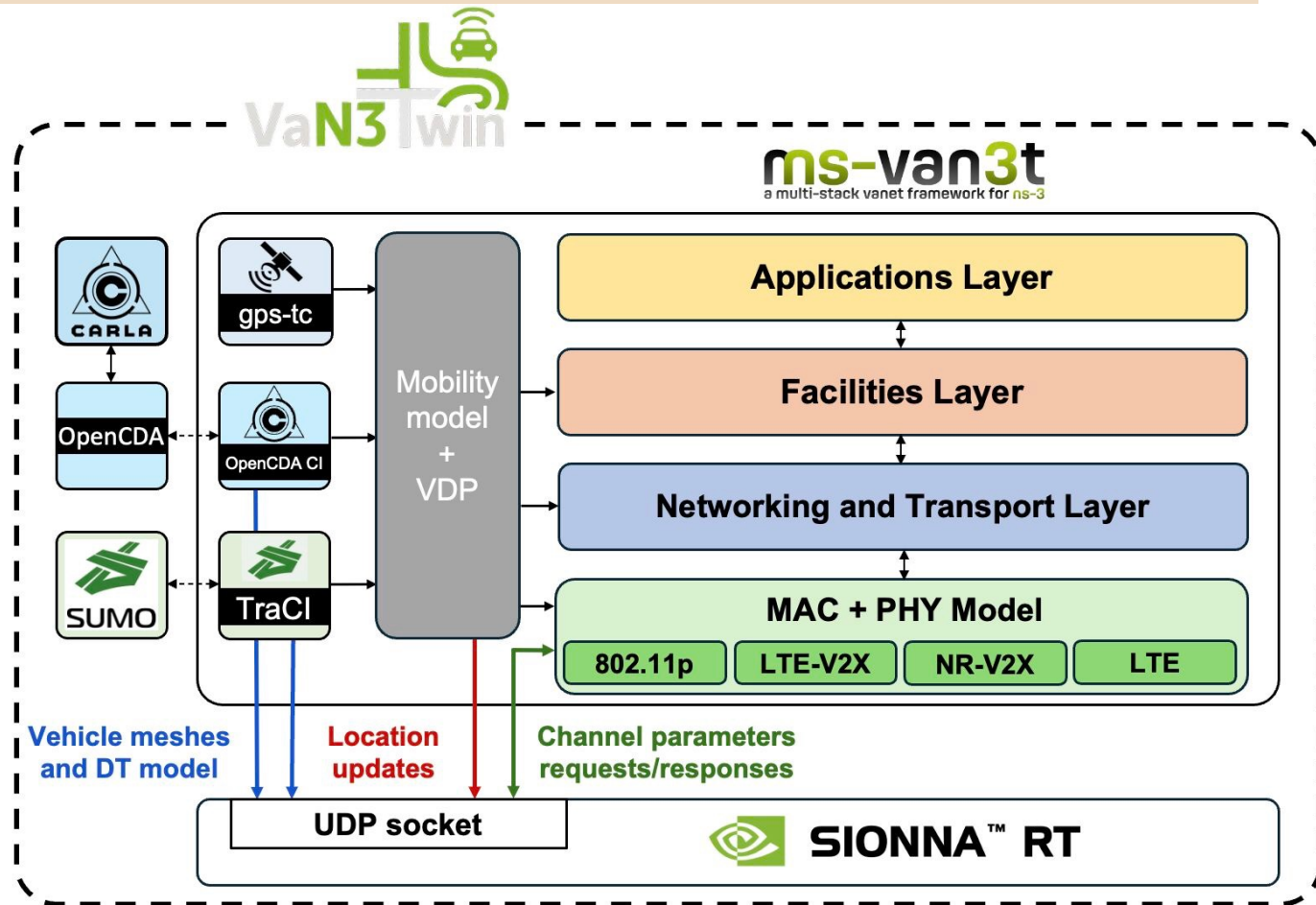


# Channel Emulation and Federated Lab





# Van3Twin: Digital Twin for V2X



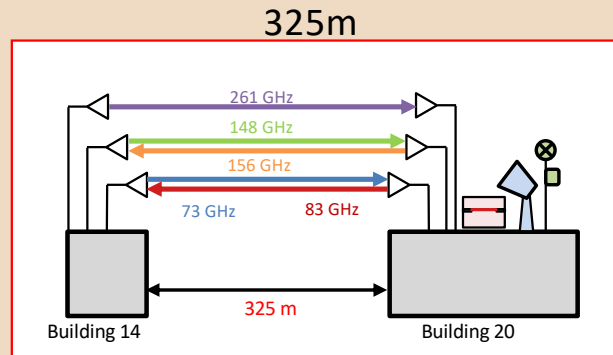
Cooperation with



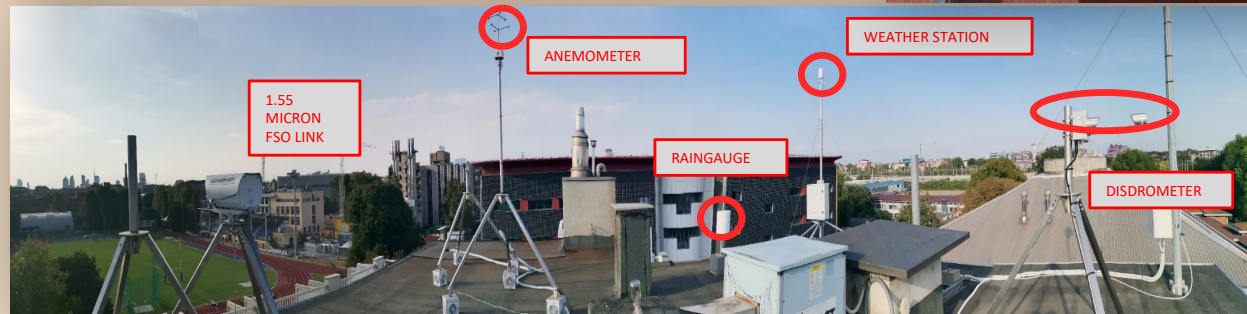
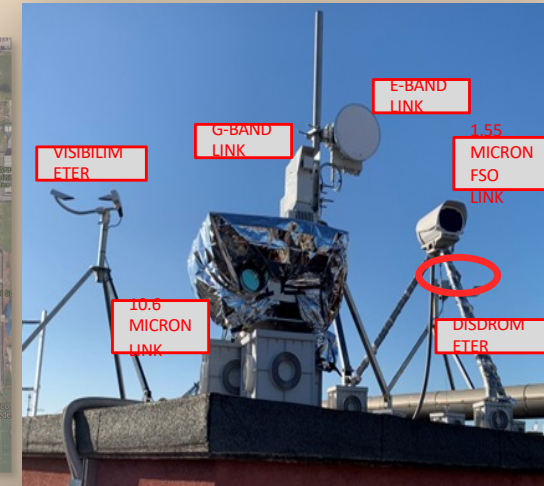
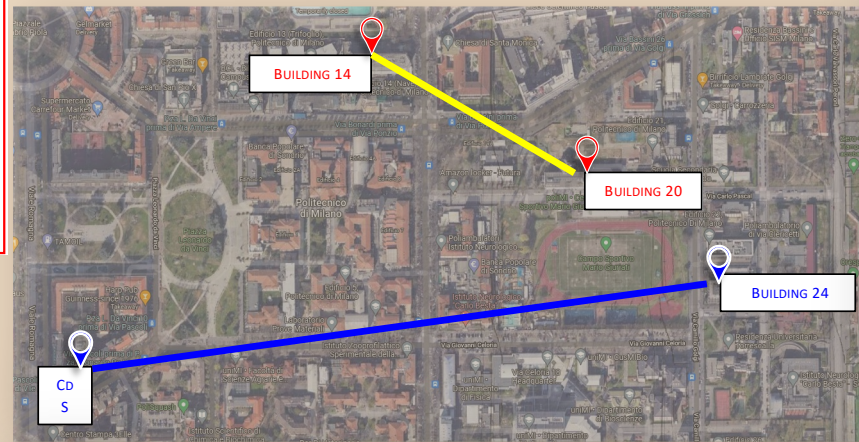
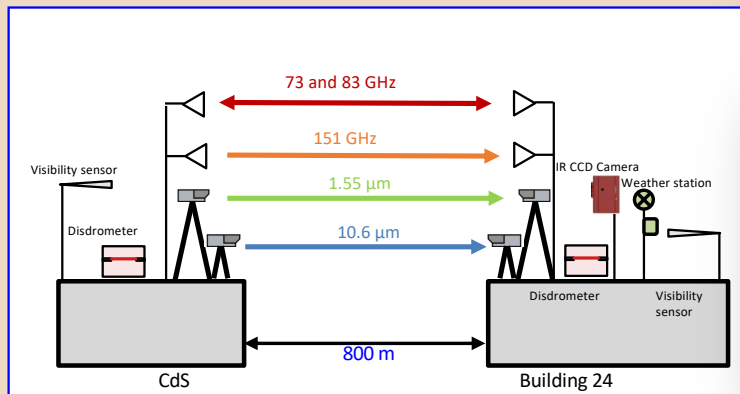
[1] R. Pegurri, et al., "Van3Twin: the Multi-Technology V2X Digital Twin with Ray-Tracing in the Loop", 2025 (<https://arxiv.org/abs/2505.14184v1>).

[2] R. Pegurri, F. Linsalata, E. Moro, J. Hoydis, U. Spagnolini, "Toward Digital Network Twins: Integrating Sionna RT in ns-3 for 6G Multi-RAT Networks Simulations", IEEE INFOCOM 2025

# Propagation at E, D, G and optical (1.55/10.6 $\mu$ m) bands



800m

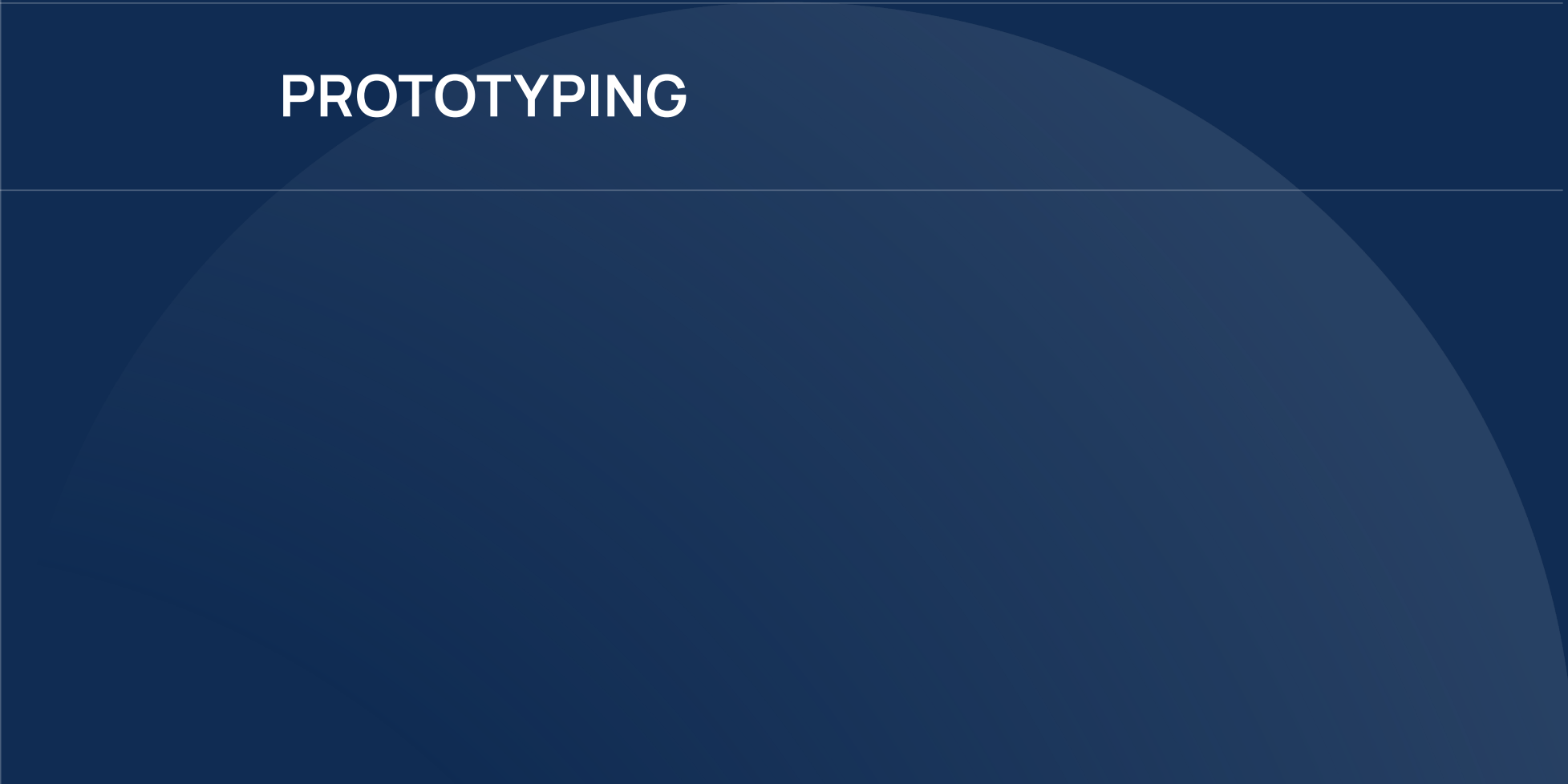


Activity in cooperation with Huawei Technologies, Milan



- [1] E Verdugo et al., "mmWave vs FSO Propagation: First Results from an Experimental Testbed in Italy", Int. Conf. on Infrared, Millimeter, and Terahertz Waves, 2023.
- [2] E. Verdugo et al., "Near-IR and Mid-IR wave propagation through patchy fog", Free-Space Laser Communications, 2024.



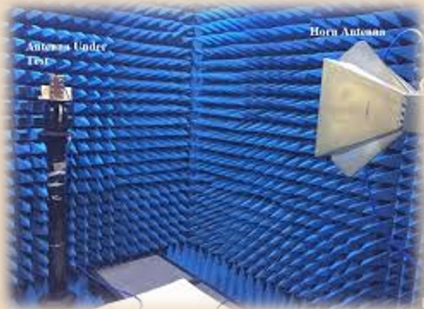


# PROTOTYPING

# WiSyNet Lab (130mq)

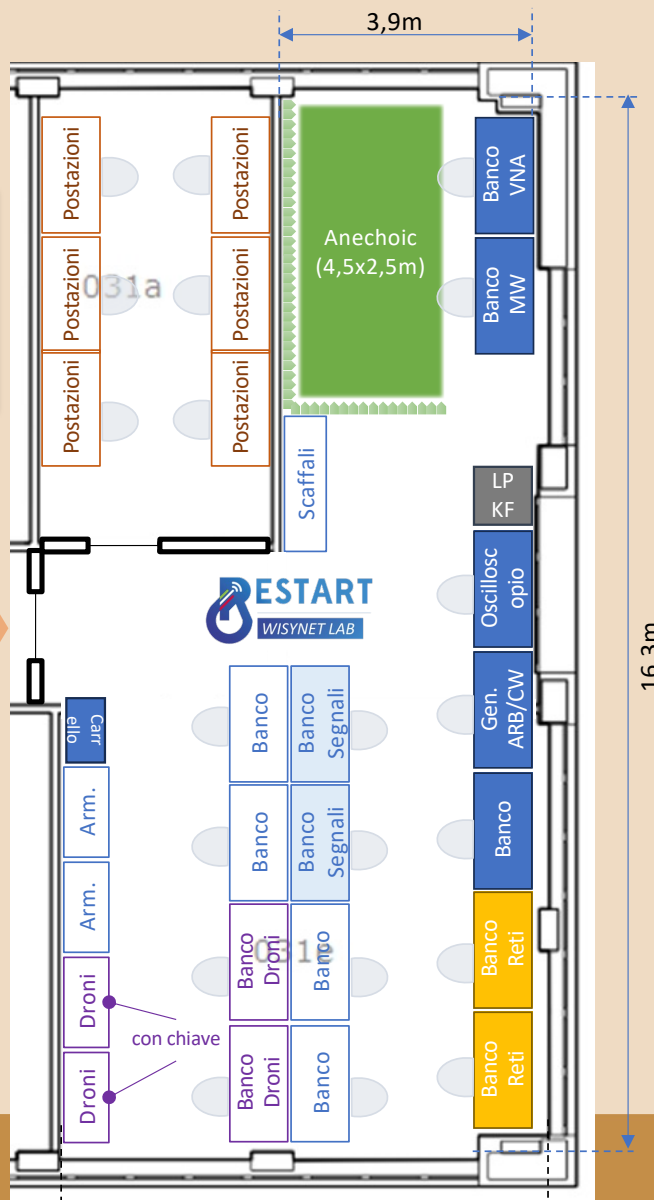
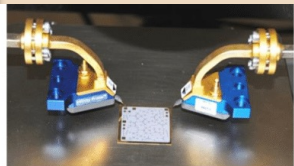
## ANECHOIC AREA 3 GHz – 110 GHz

- CHARACTERIZATION OF ANTENNA AND ARRAY 3GHz-110GHz
- REFLECTIVITY PERFORMANCE BETTER THAN -45dB @3GHz-110GHz
- PRECISE POSITIONERS WITH NEAR FIELD MEASURES CAPABILITIES
- NCR, RIS, SMART SKINS @ 3.5GHz AND 26GHz



## DRONE AND SENSING AREA

- ITALDRONE H8SE UAV
- ANT-X MARK-1 UAV
- 10GHz RADAR PAYLOAD
- SAR
- 3D IMAGING
- JCAS



## INSTRUMENTS

### Vector Network Analyzer

4 ports 0.01-70GHz  
Full SW Options  
Extenders in WR15&WR10 (up to 110GHz)  
Possibly to 3THz



### Probe Station

8" manual - For stereozoom microscope  
RF & Microwave micropositioner



### WAVEMASTER 8330HD (Lecroy)

High Definition 4 Ch. Oscilloscope  
33 GHz, 12 bits, 160 GS/s, 200 Mpts/Ch



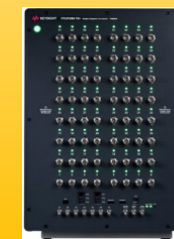
### SMA100B (Rohde & Schwarz)

Signal Generator up to 40GHz  
High output power  
Ultra Low phase noise



### AWG70002B (Tektronic)

2 ch. 25GS/s 10 bit Arbitrary Wave Generator  
BW 13.5 GHz, IBW 10 GHz  
Ultra low SFDR



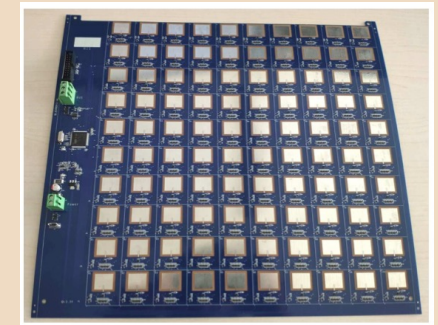
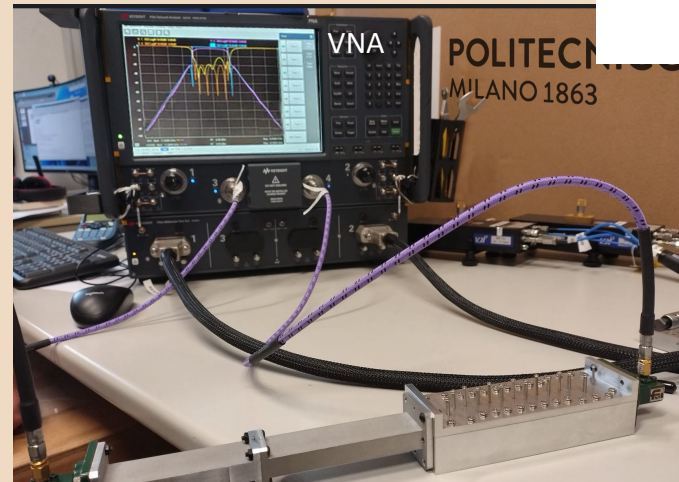
### F8800A PROPSIM F64 (Keysight)

8 Ch. 0.45-6GHz TRX  
100dB Dyn. Range  
Dynamic 3D Modelling Scenario Generation

### Radio Nodes 5G Private

5G OAI Radio nodes on (TBA) x86 Server  
4x4MIMO 100MHz gNB  
SDR up to 6GHz  
NUC & Snapdragon based UE

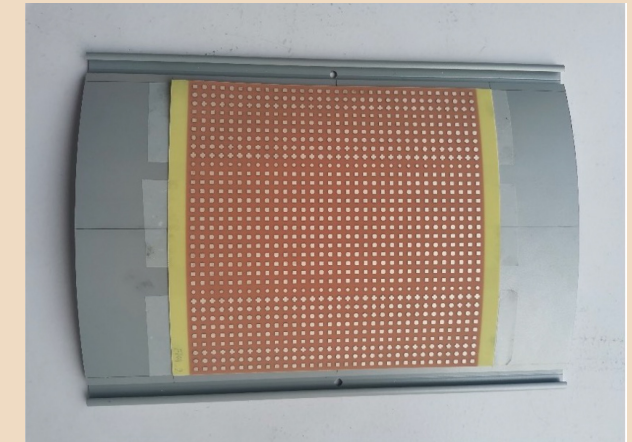
# Array Calibration, RIS, and HF Filters



Active RIS 3.5 GHz



Anechoic Environment 3-150GHz

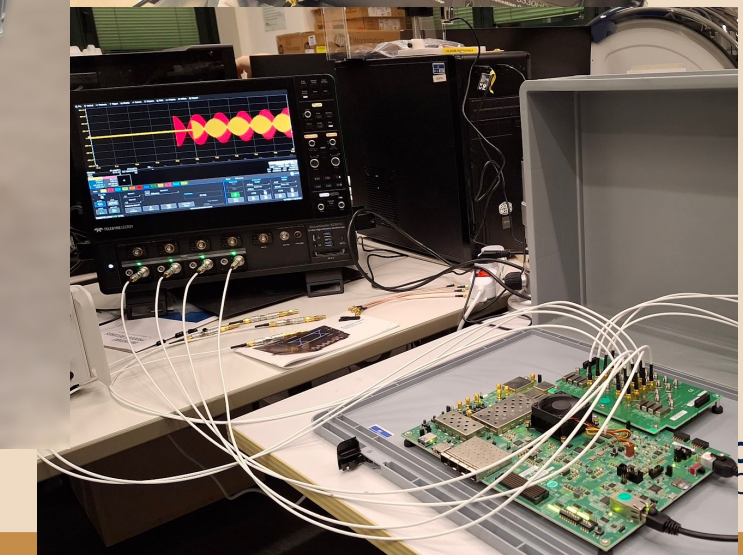
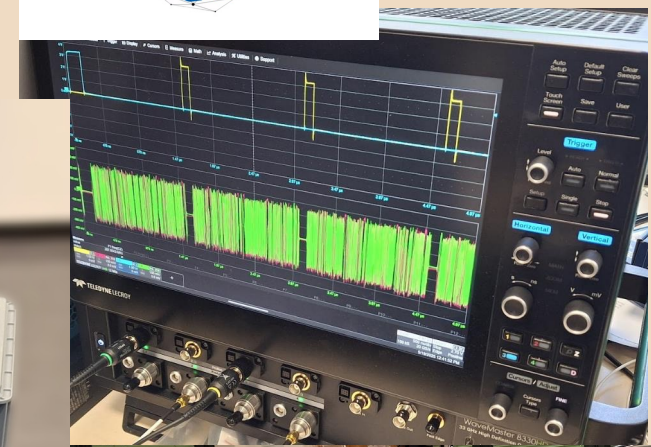
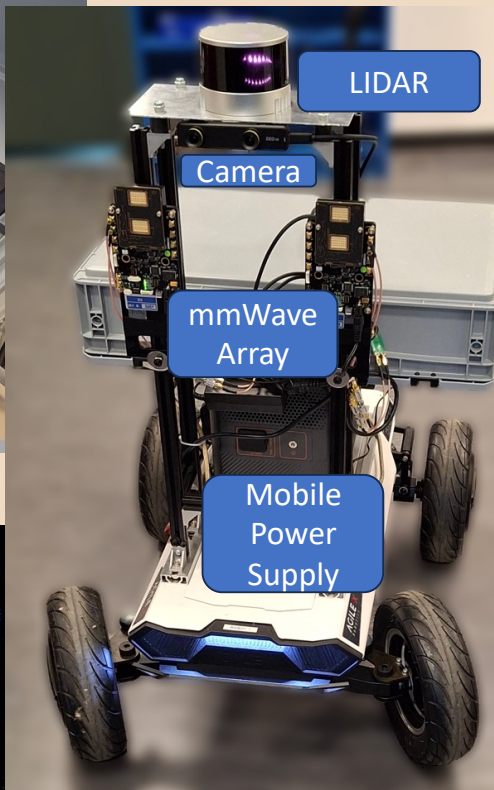
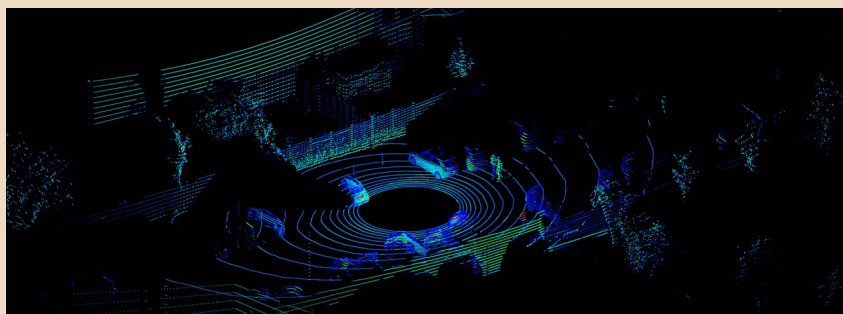
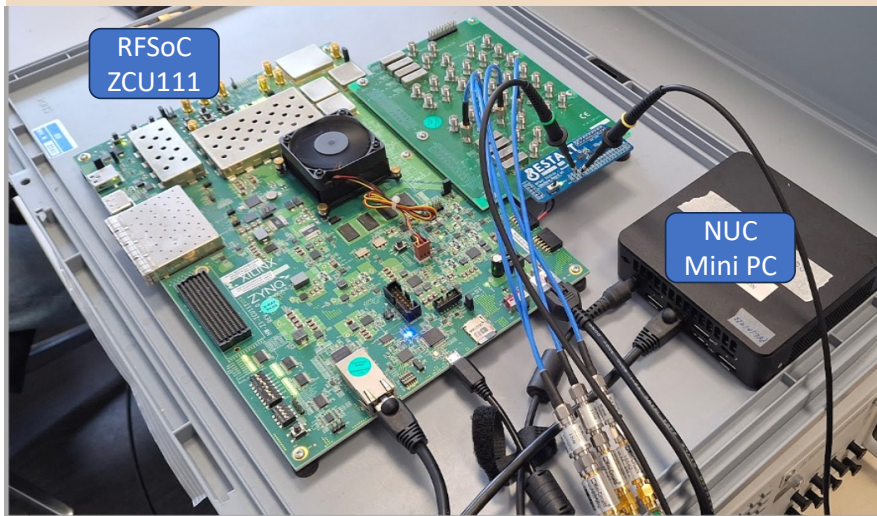


[1] M. Mizmizi, et al. "Conformal metasurfaces: a novel solution for vehicular communications." *IEEE Transactions on Wireless Communications* 2022.

[2] M. Mizmizi, et al. "Wireless communications with space-time modulated metasurfaces." *IEEE Journal on Selected Areas in Communications*, 2024.



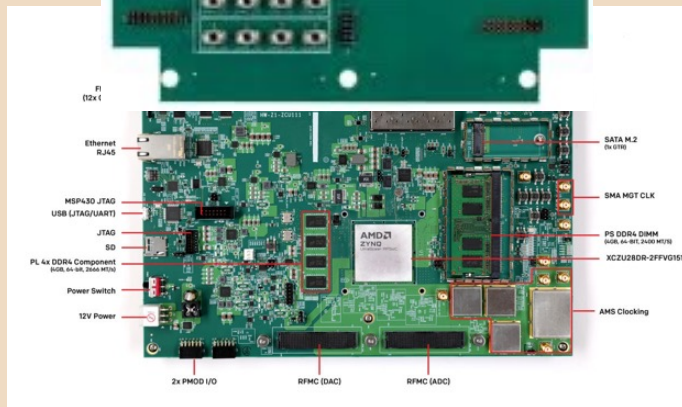
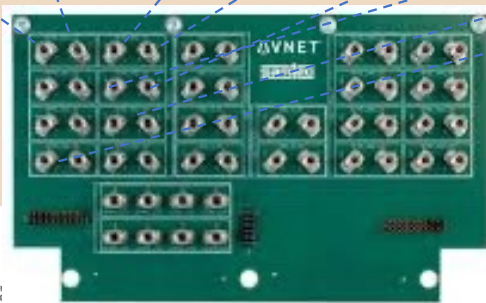
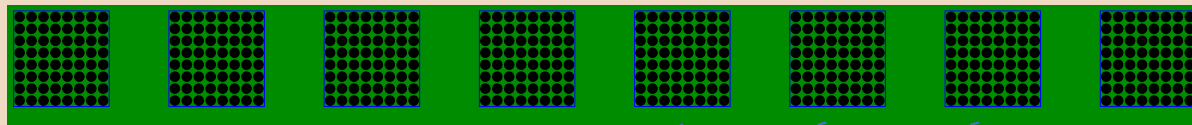
# V2X at mmw 5G NR FR2



# Near Field V2V mMIMO connectivity and beam tracking

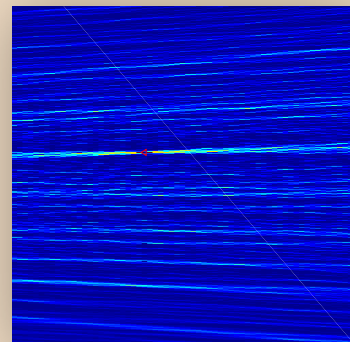
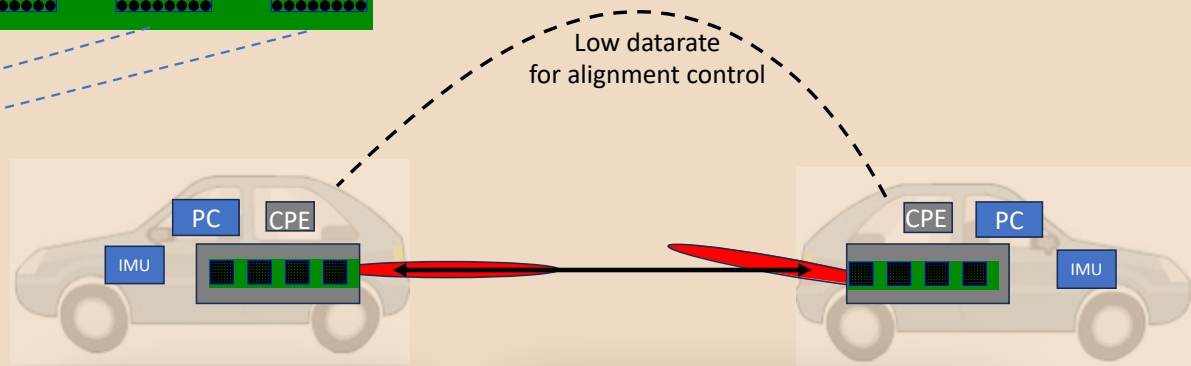


Layout massive MIMO 64x8 with 1.5° beamwidth



Xilinx ZCU111

**Challenge:** guarantee a NF beam tracking mMIMO in a dynamic context





# 6-24 GHz FR3 Prototyping Platform (2x2)



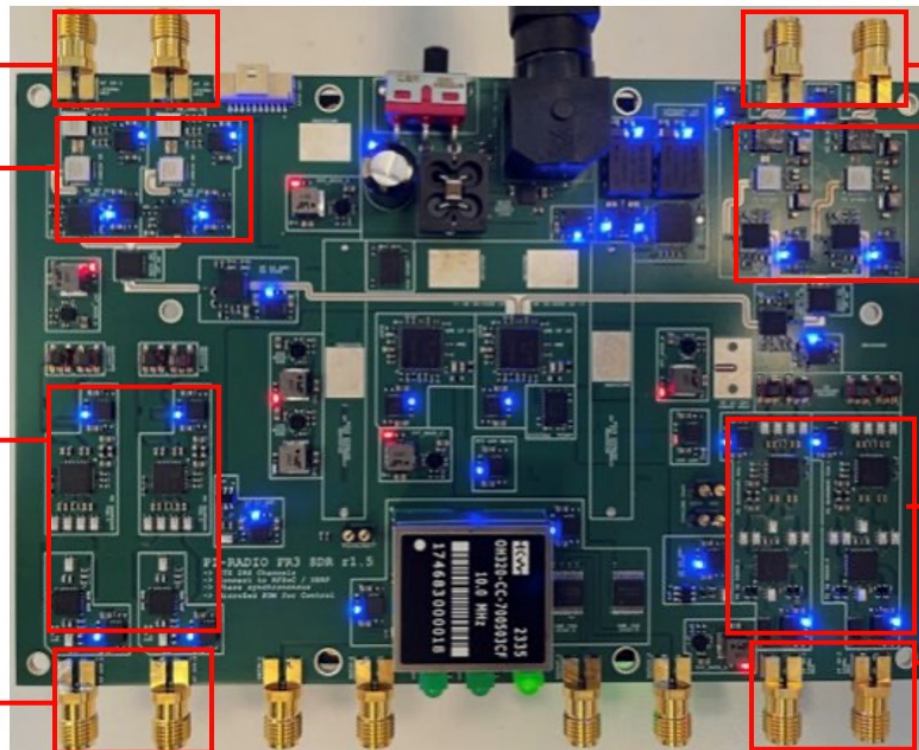
Front-face of the Pi-Radio FR3 Transceiver Board

RX Side: 2-channel FR3 RF  
Input (from antenna board)

RX Side: 2-channel low-noise  
amplification (LNA) +  
down-conversion to baseband

RX Side: 2-channel  
programmable baseband  
amplification +  
filtering + up-conversion to IF

RX Side: 2-channel IF  
Output (to USRP/RFSoc)



TX Side: 2-channel FR3 RF  
Output (to antenna board)

TX Side: 2-channel baseband  
to FR3 RF up-conversion +  
power amplification (PA)

TX Side: 2-channel IF to  
baseband down-conversion +  
filtering + programmable  
amplification

TX Side: 2-channel IF  
Input (from USRP/RFSoc)

**Two-stage up- and down-conversion is used to meet the out-of-band (OOB) and adjacent channel rejection ratio (ACLR) requirements.**



pi-radio





# OAI at FR3 (DEMO at IEEE WCNC 2025)



## New features in the pipeline:

- ☐ MU-MIMO
- ☐ Multi-band pilot design for CF-MIMO / NF-MIMO
- ☐ Inter-band carrier aggregation
- ☐ New signaling tailored for co-existence

pi-radio

# Multi-Band FR3 Sensing

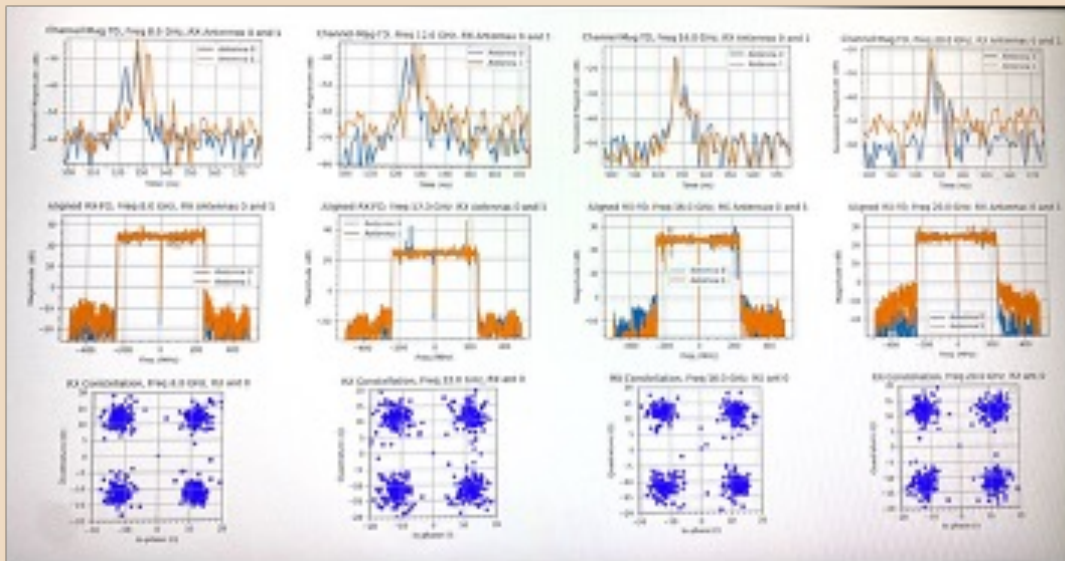
Enhance localization and imaging accuracy by aggregating measurements from various FR3 sub-bands

8 GHz

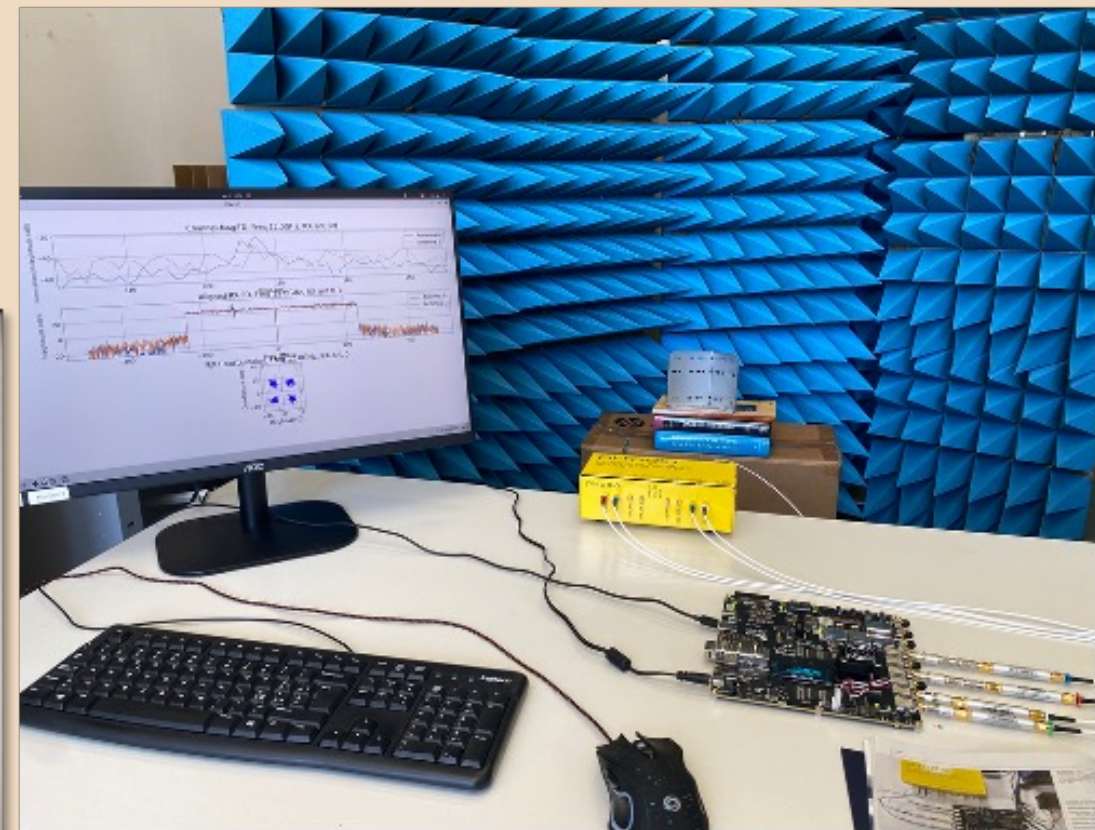
12 GHz

16 GHz

20 GHz



pi-radio



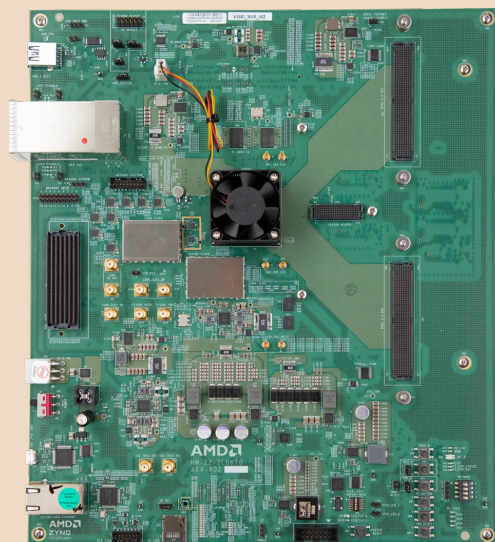


# 2x8 MIMO at FR3 6-18GHz (in progress)

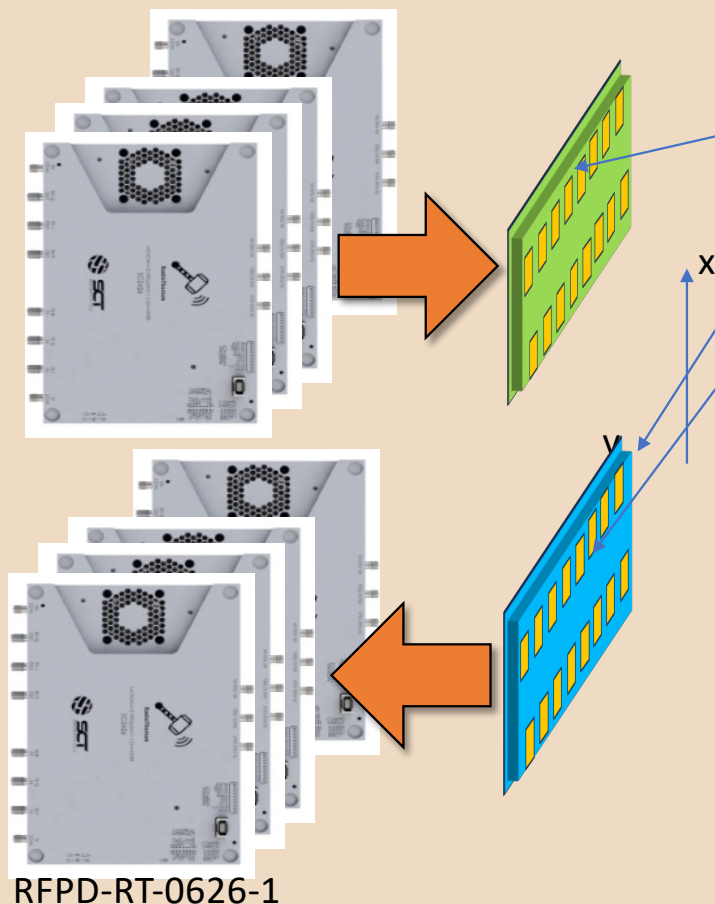


2x8 RX Array BW=6-18 GHz , scanning= $\pm 20^\circ$  x -  $\pm 60^\circ$  y

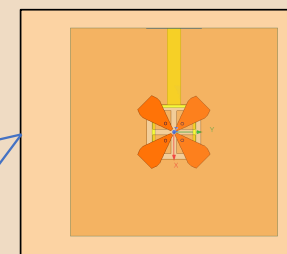
TX & RX IQ ports  
IF up to 4GHz



ZCU 670

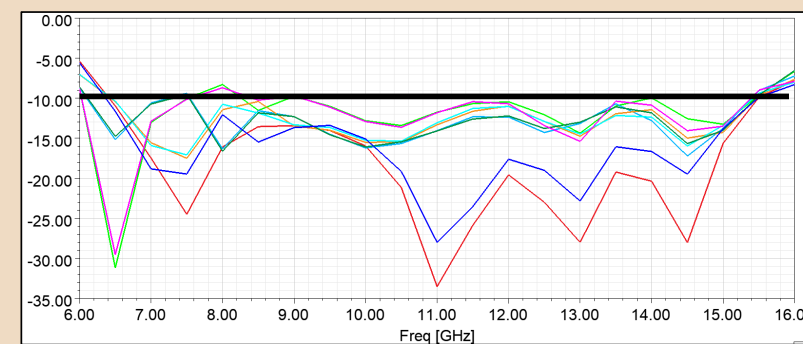


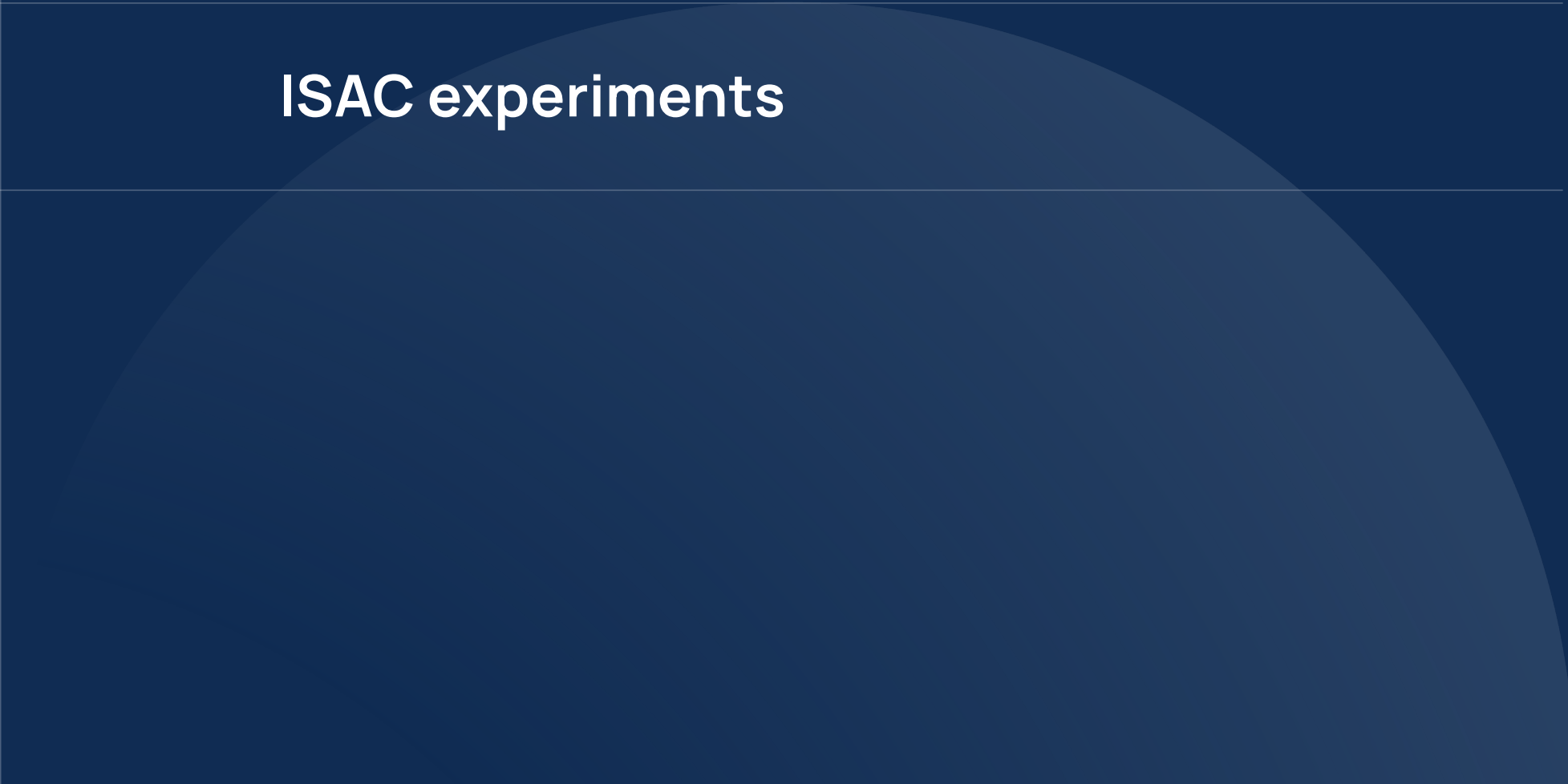
RFPD-RT-0626-1



Magneto-Electric  
Dipole Elements

Active return loss of a 1X8 array



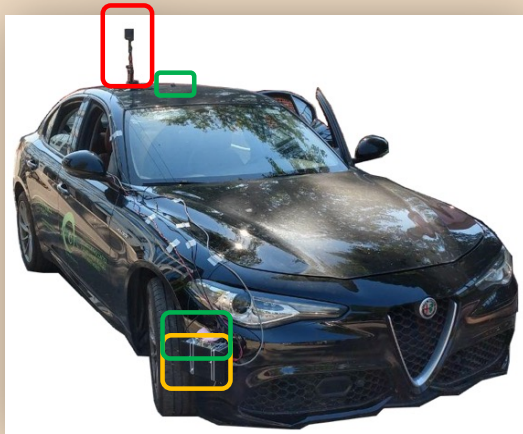


# ISAC experiments



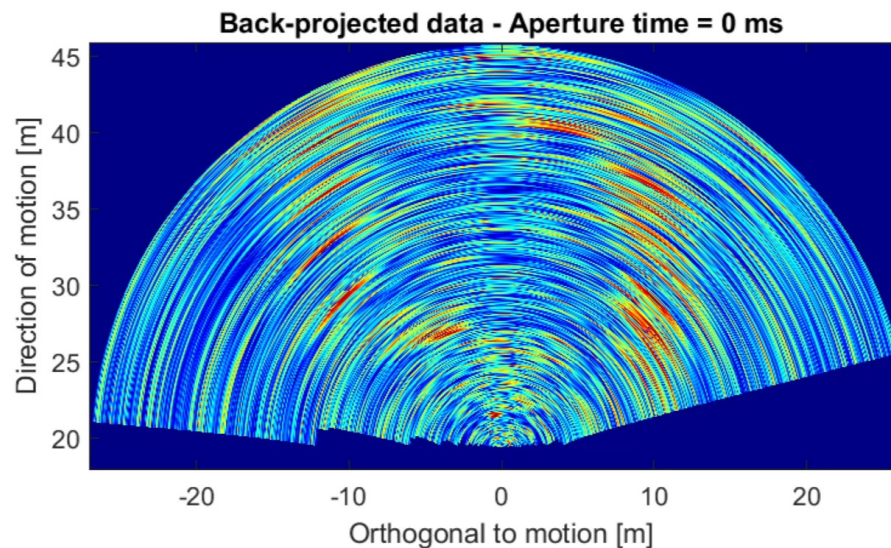
# Sensing while moving (Synthetic Aperture Radar)

*Real data from dedicated acquisition campaigns*



**Acquired data:**

- **Radar**
- **Navigational data**
  - On-board sensors
  - External IMU+GPS in the CoG
  - External IMU+GPS on the radar
- **Video**
  - 360° video capture GoPro





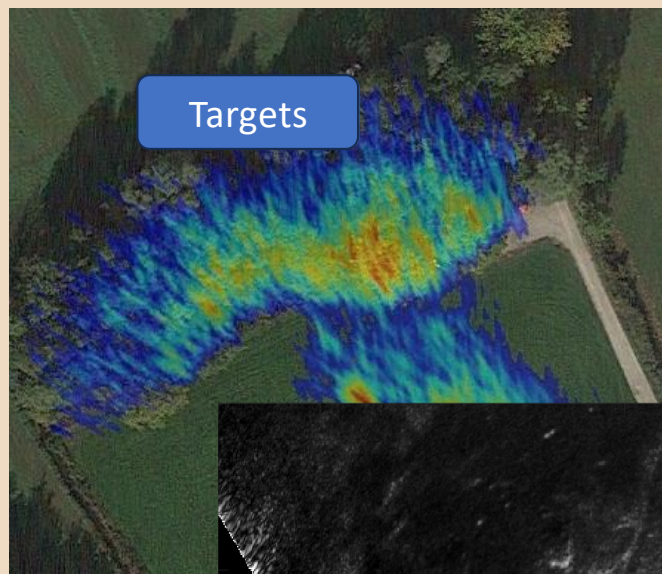
# UAV SAR imaging



Mono/Bistatic SAR



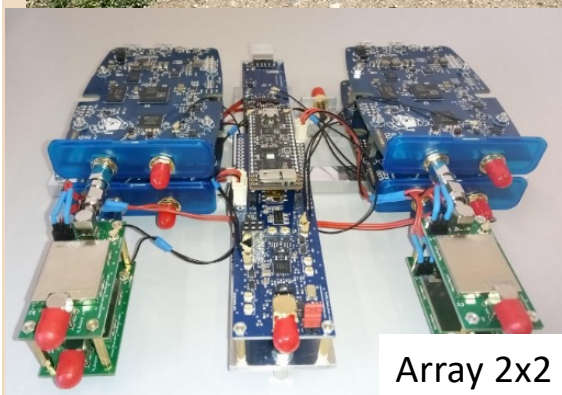
Targets



Objects/bodies buried under a few centimeters of snow

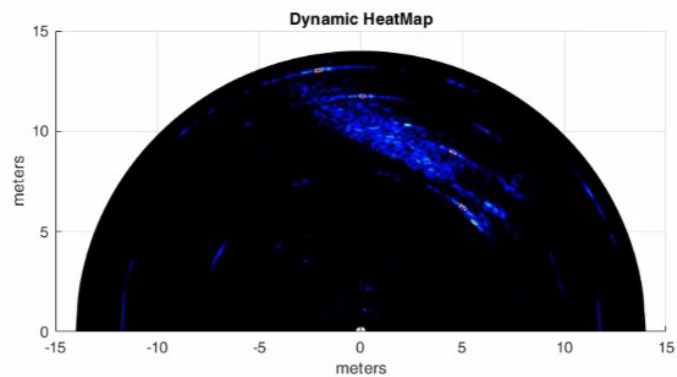
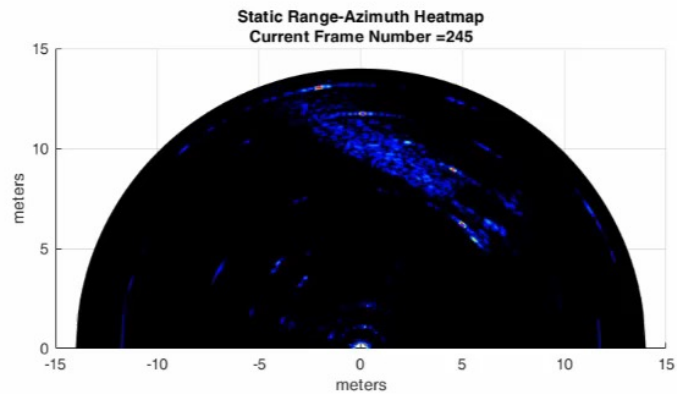


Array 2x2



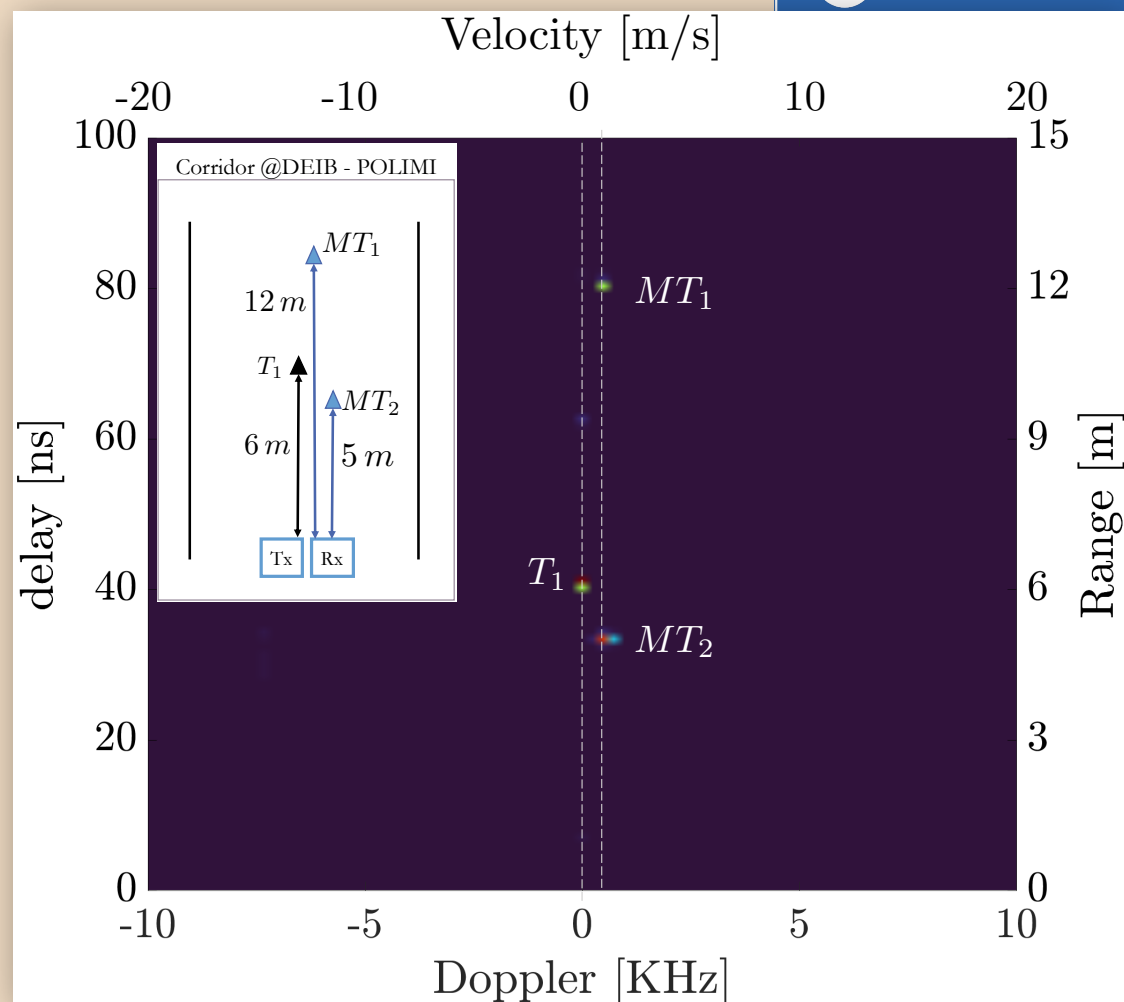
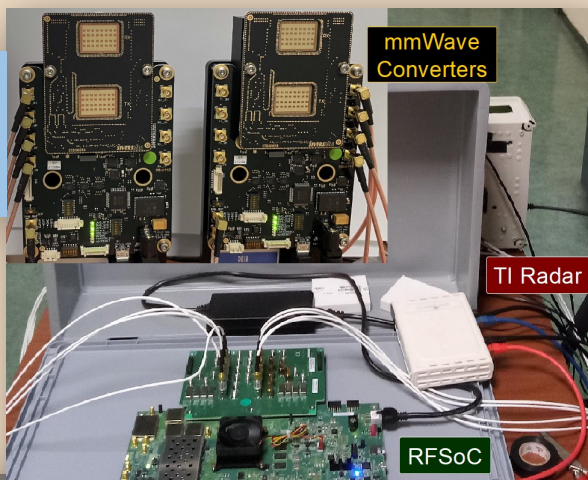


# Experimenting 12x16 MIMO sensing (86 ULA $\lambda/2$ , 70GHz)



# Dual Domain (DD) ISAC Waveform

DD improves range and Doppler resolution

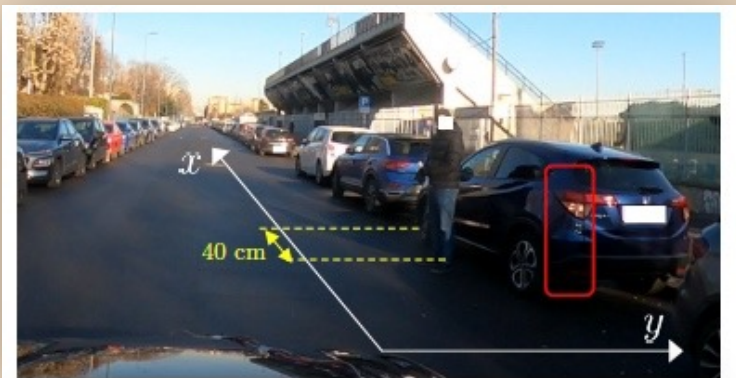


[1] D. Tagliaferri, et al. "Integrated sensing and communication system via dual-domain waveform superposition." IEEE Transactions on Wireless Communications, 2023.

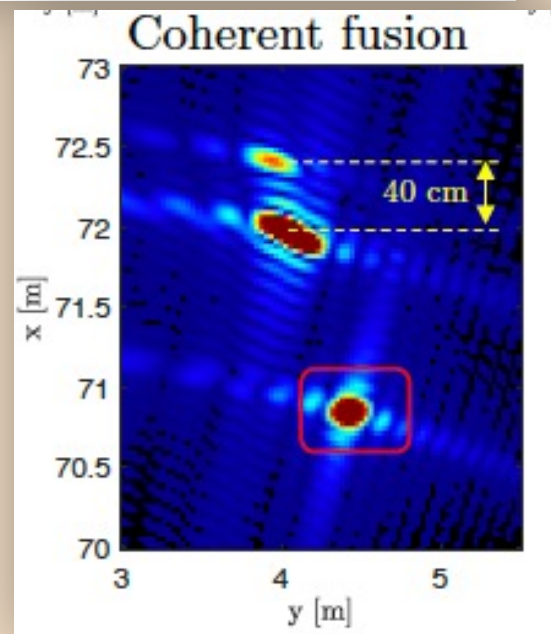
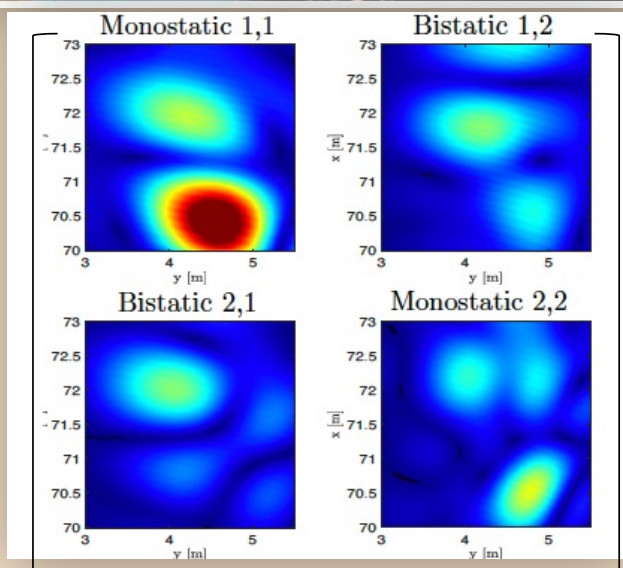
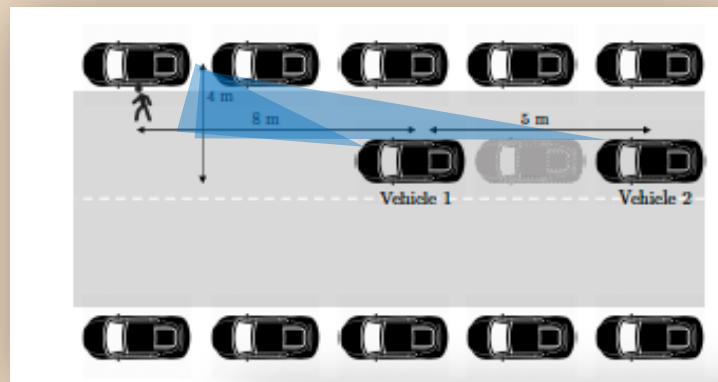
[2] S. Mura, et al. "Optimized waveform design for OFDM-based ISAC systems under limited resource occupancy." IEEE Transactions on Wireless Communications, 2025.



# Coherent Multistatic ISAC



2 vehicles multistatic



## Conclusion



- **6GWINET** mission is to innovate and validate toward 6G with a **joint industry and academia partnership**.
- Politecnico di Milano created RESTART-WISYNET Lab open to **share the new experimental platforms with other partners**.



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A large version of the RESTART logo, featuring a stylized blue 'R' with a small Italian flag integrated into its top curve, followed by the word 'ESTART' in blue, bold, sans-serif capital letters.