

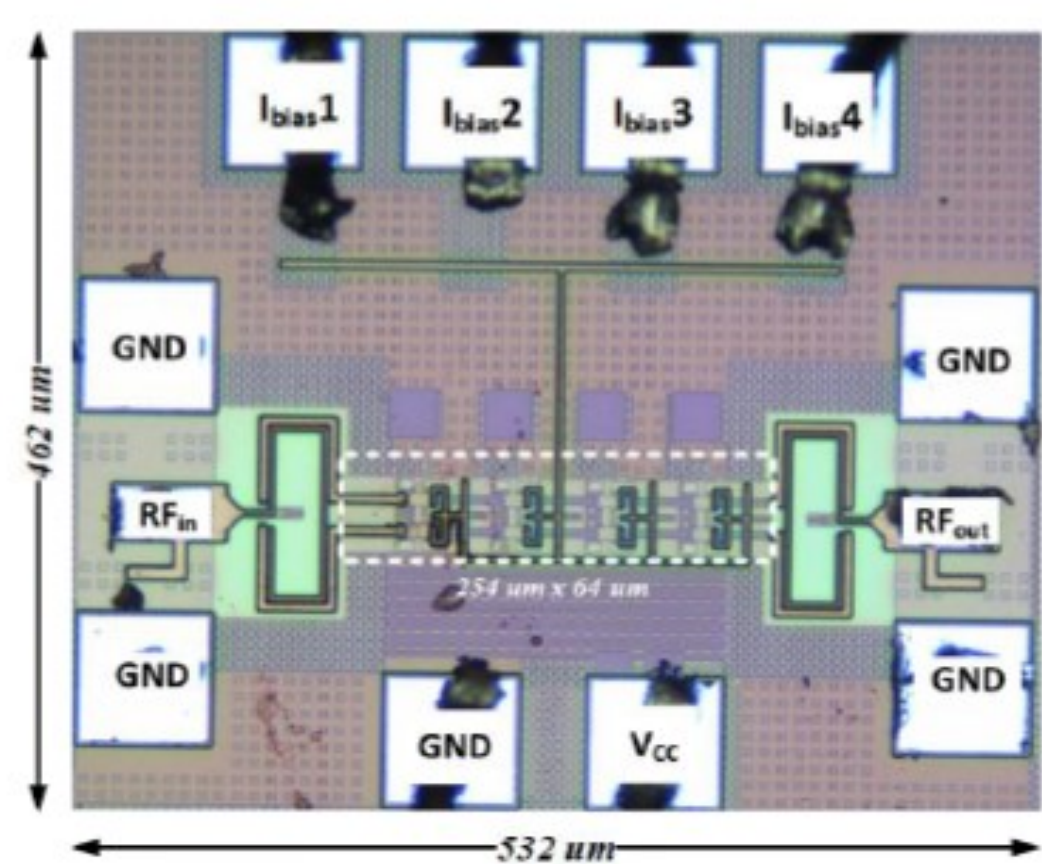
## Introduction

The 6G extreme datarate networks introduce new research and implementation challenges

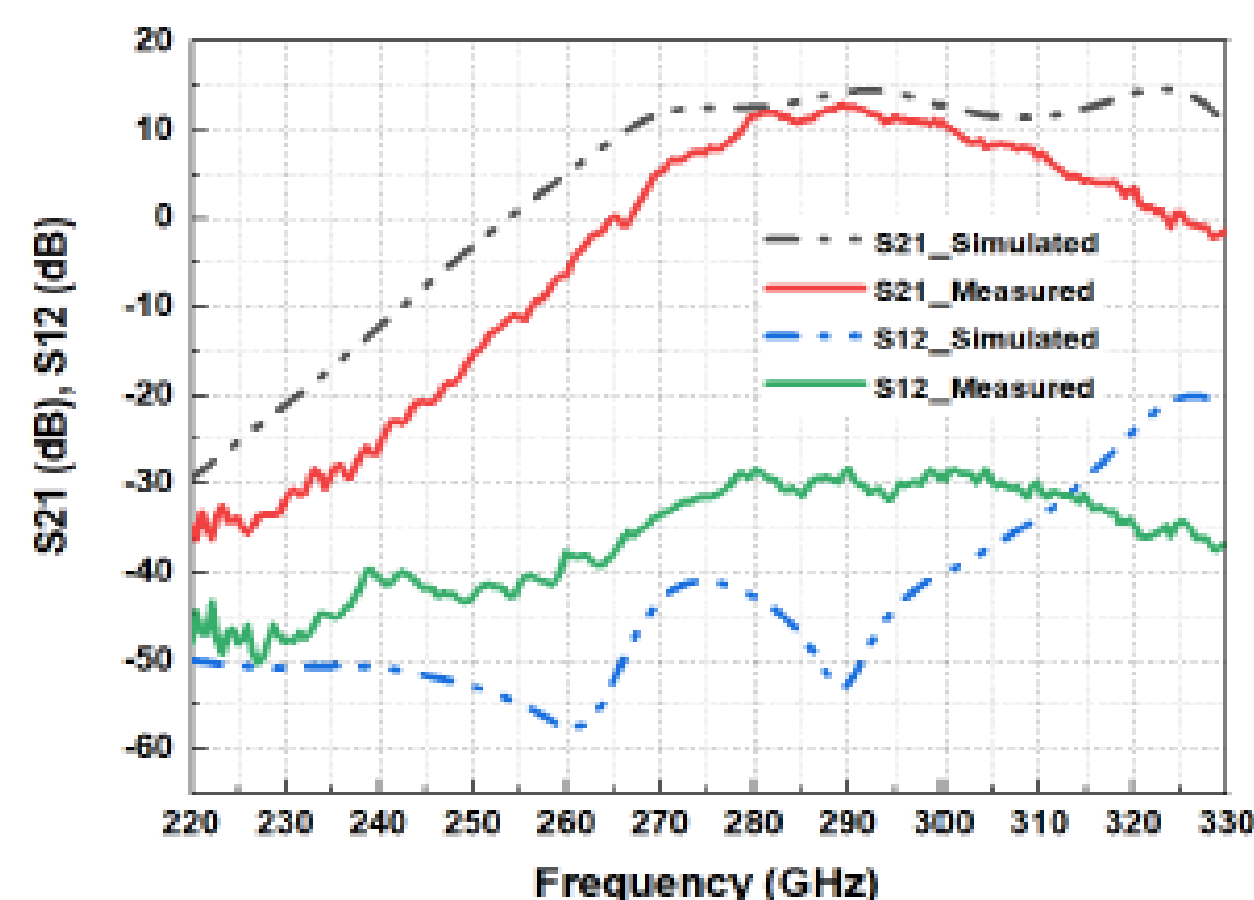
- Reduced sub-THz radio transceiver performance due to limitations of the available IC processes
- Directive antennas are needed to overcome excessive path loss
- RF parameter measurements at sub-THz frequency are significantly challenging compared to 5G FR1 and FR2

## Selected 300 GHz radio transceiver IP blocks:

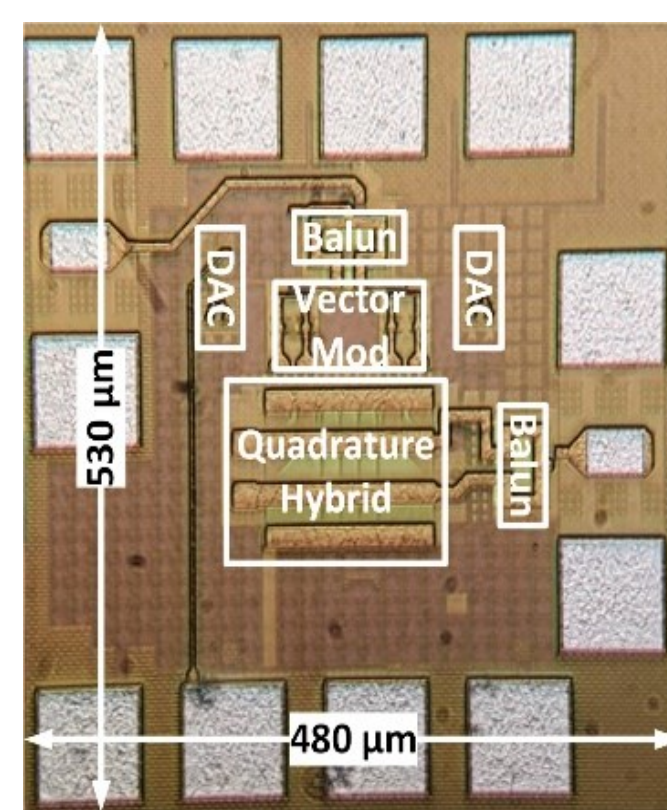
Single-ended 290 GHz LNA [1]



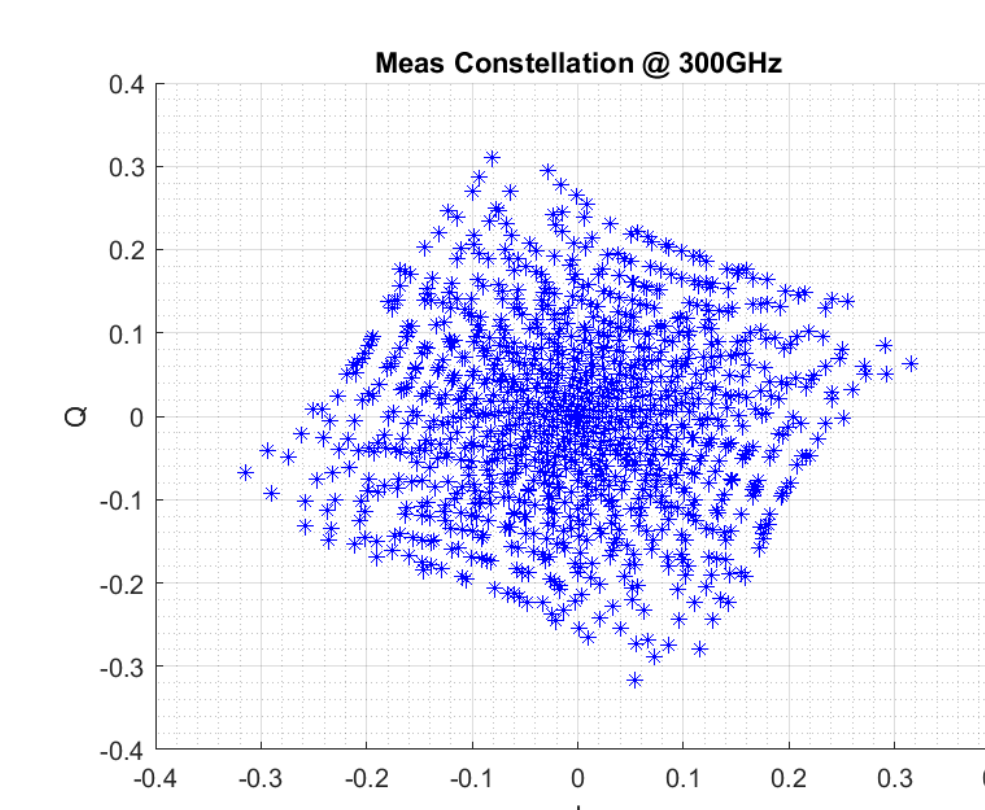
LNA gain: 12.9 dB @ 290 GHz  
-3 dB BW: 23 GHz [1]



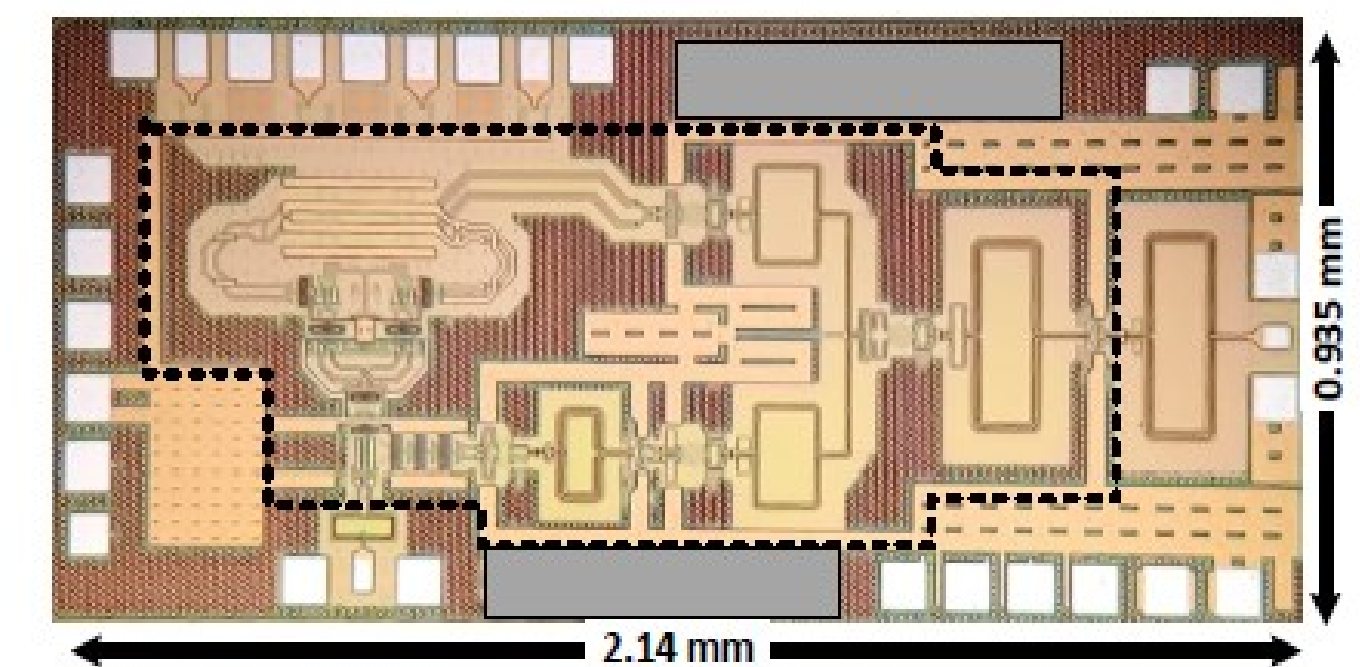
Vector modulator (VM) 270 -330 GHz [2]



Measured VM constellation @ 300 GHz [2]

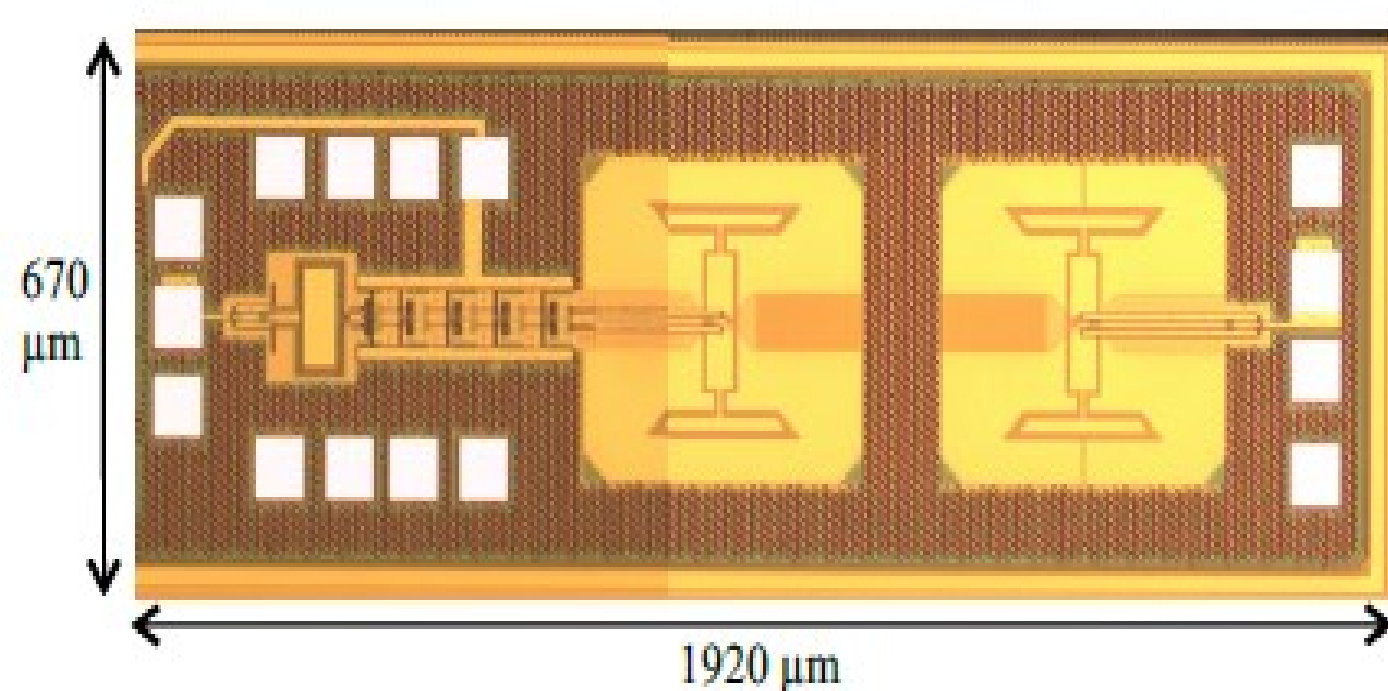


Sliding IF receiver 300-320 GHz [3]

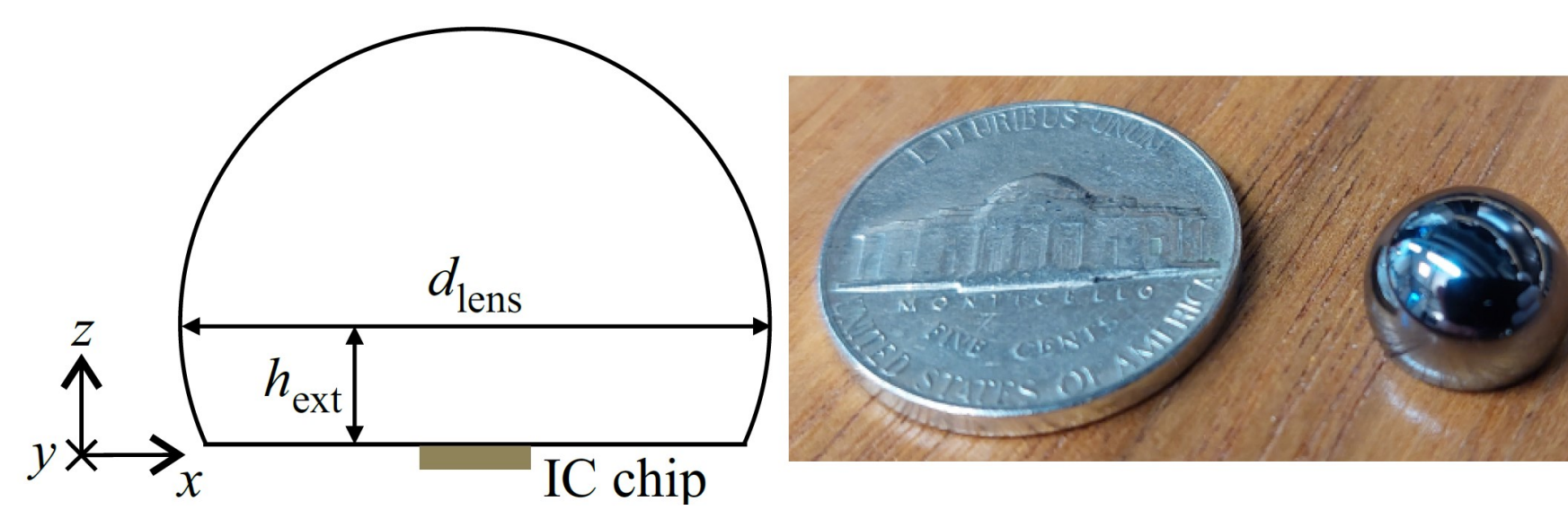


## Selected 6G antennas (300 GHz and 28 GHz):

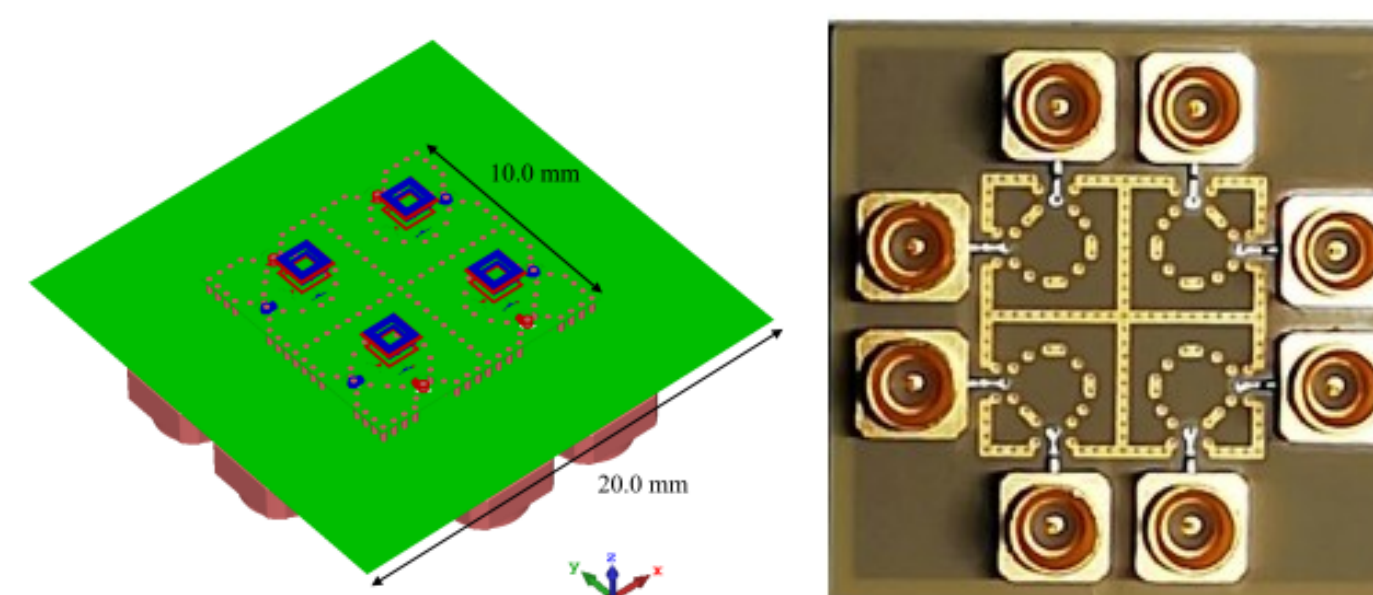
On-chip 300 GHz antenna, LNA & env. detector: [4]



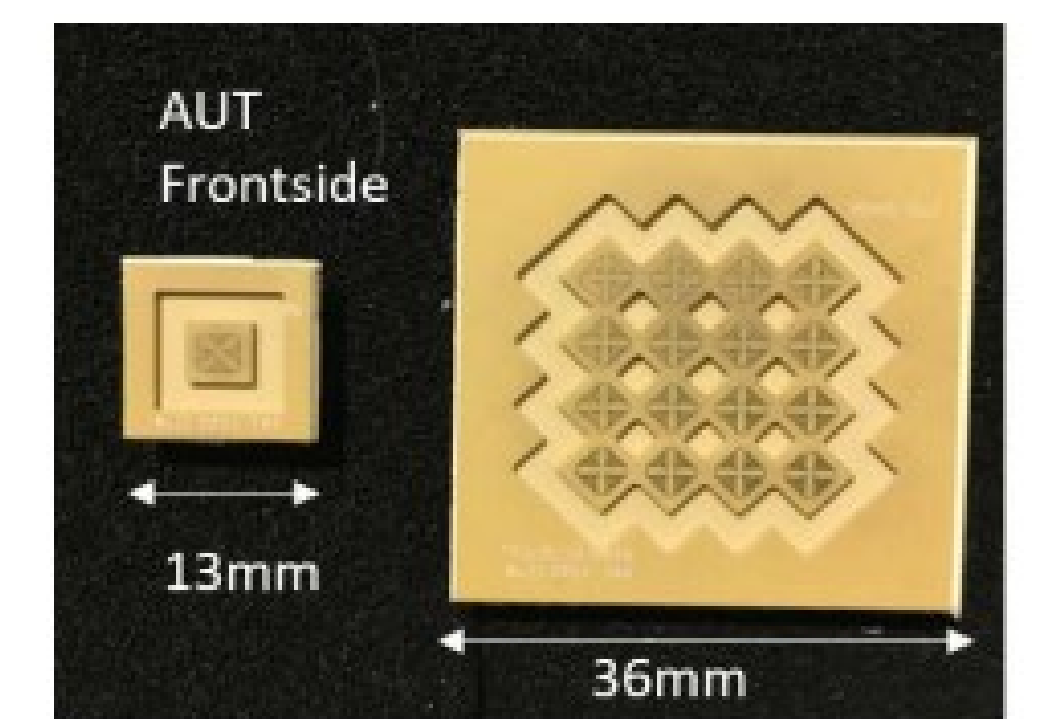
Si antenna for On-chip 300 GHz antenna [4]



Filtering antenna at 28 GHz [5]  
Most read paper in TAP 2023



Broadband antenna at 28 GHz [6]  
12<sup>th</sup> read paper in TAP 2023

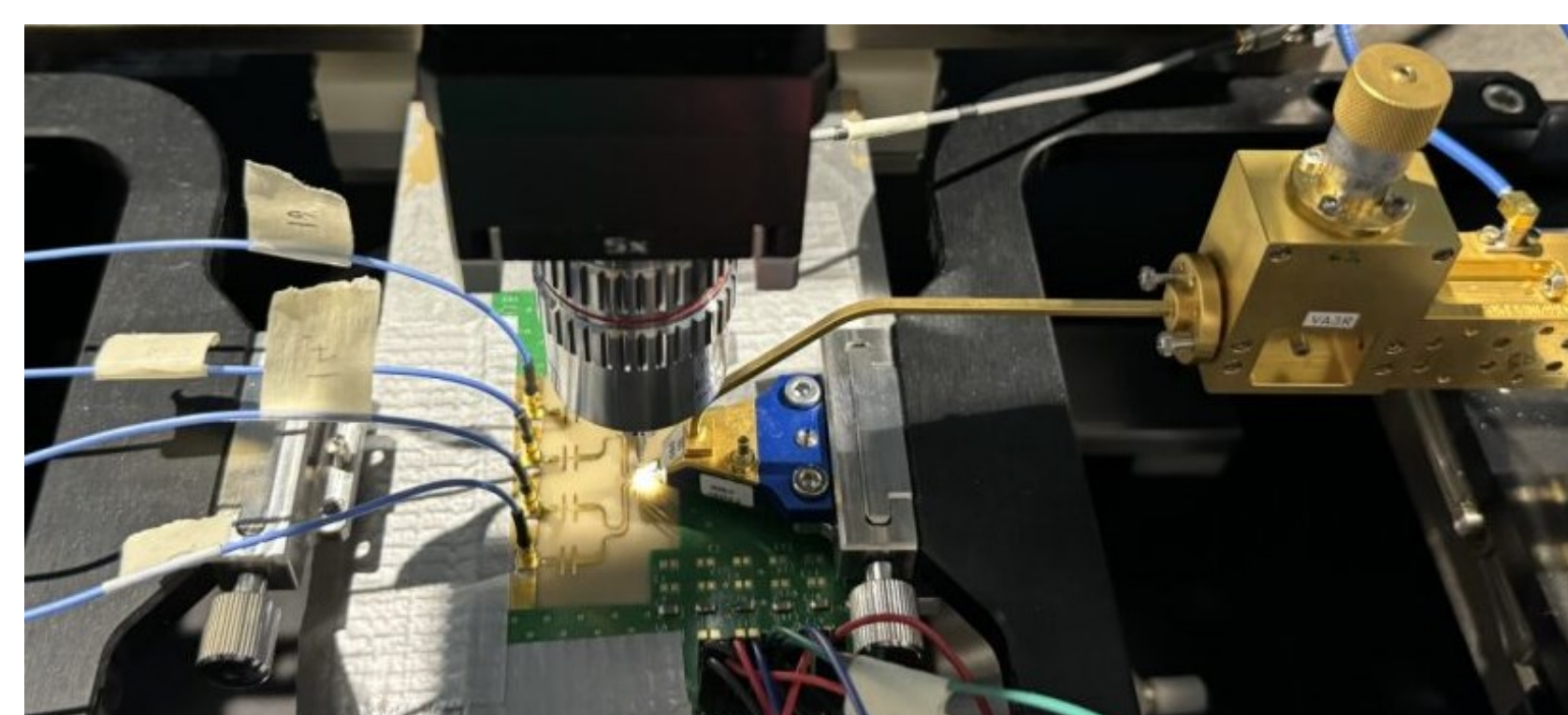


## Example RF measurement systems for 300 GHz radios:

Conducted RFIC measurement system:



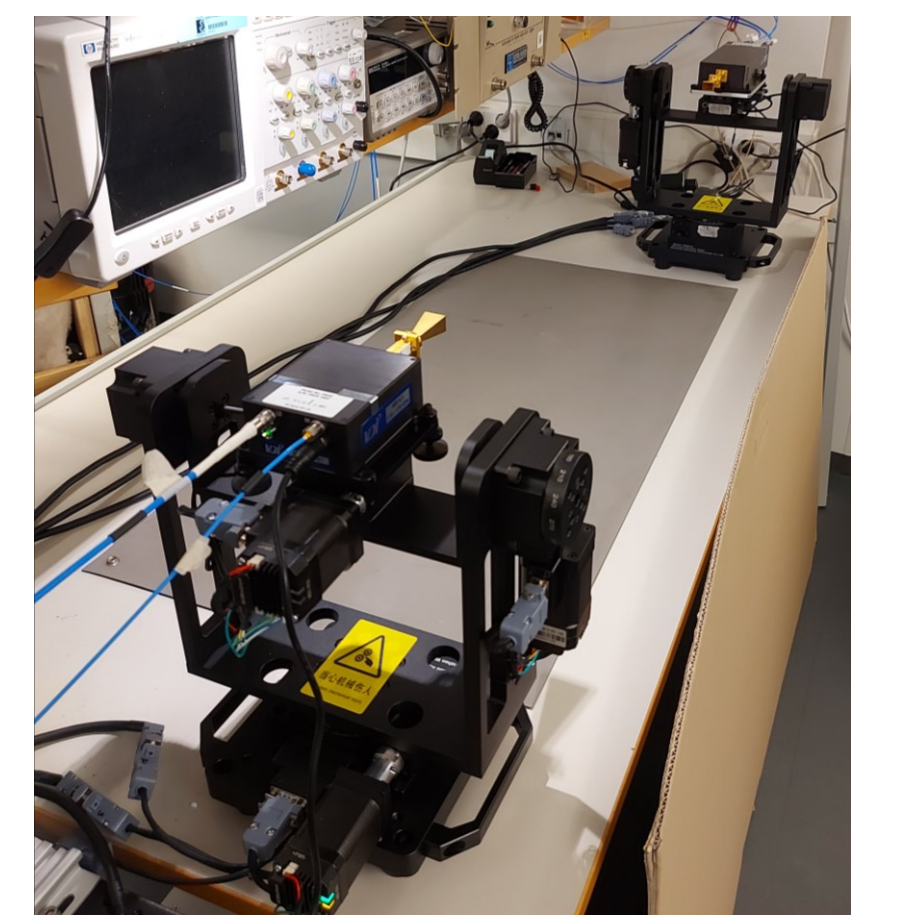
Close-up photo of RFIC probe station:



RIS measurement system



THz radio channel measurement system



## Conclusions

Current prototypes and experiments of 6G sub-THz radio are giving promising results

- Generally, 3D-Electromagnetic and RF simulations and measurements have good agreement at sub-THz
- Individual 300 GHz 6G RFIC transceiver blocks have been developed for a complete integration
- RF measurements at sub-THz require new measurement techniques before 6G standardization

## References

- [1] S. P. Singh, T. Rahkonen, M. E. Leinonen and A. Pärssinen, "Design Aspects of Single-Ended and Differential SiGe Low-Noise Amplifiers Operating Above  $f_{max}/2$  in Sub-THz/THz Frequencies," in IEEE J. of Solid-State Circuits, vol. 58, no. 9, pp. 2478-2488, Sept. 2023
- [2] M. H. Montaseri, et. al. "A 270 – 330 GHz Vector Modulator Phase Shifter in 130nm SiGe BiCMOS," EuMIC2022, London, United Kingdom, 2022, pp. 309-312.
- [3] S. P. Singh, M. J. Nokandi, M. H. Montaseri, T. Rahkonen, M. E. Leinonen and A. Pärssinen, "A 300-320 GHz Sliding-IF I/Q Receiver Front-End in 130 nm SiGe Technology," RFIC2023 San Diego, CA, USA, Jun. 2023, pp. 37-40.
- [4] K. Rasilainen et al., "Over-the-Air Characterization of a Steerable Sub-THz Si Lens and On-Chip Antenna System," in IEEE Trans. on Microw. Theory and Techniques, Nov. 2023
- [5] Z. Siddiqui et al., "Dual-Band Dual-Polarized Planar Antenna for 5G Millimeter-Wave Antenna-in-Package Applications," in IEEE Trans. on Ant. and Propag., vol. 71, no. 4, pp. 2908-2921, Apr. 2023
- [6] J. Chen et al., "Broadband Cross-Slotted Patch Antenna for 5G Millimeter-Wave Applications Based on Characteristic Mode Analysis," in IEEE Trans. on Antennas and Propag., vol. 70, no. 12, pp. 11277-11292, Dec. 2022