Smart antenna systems for future 6G wireless communications

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31 Maart 2021

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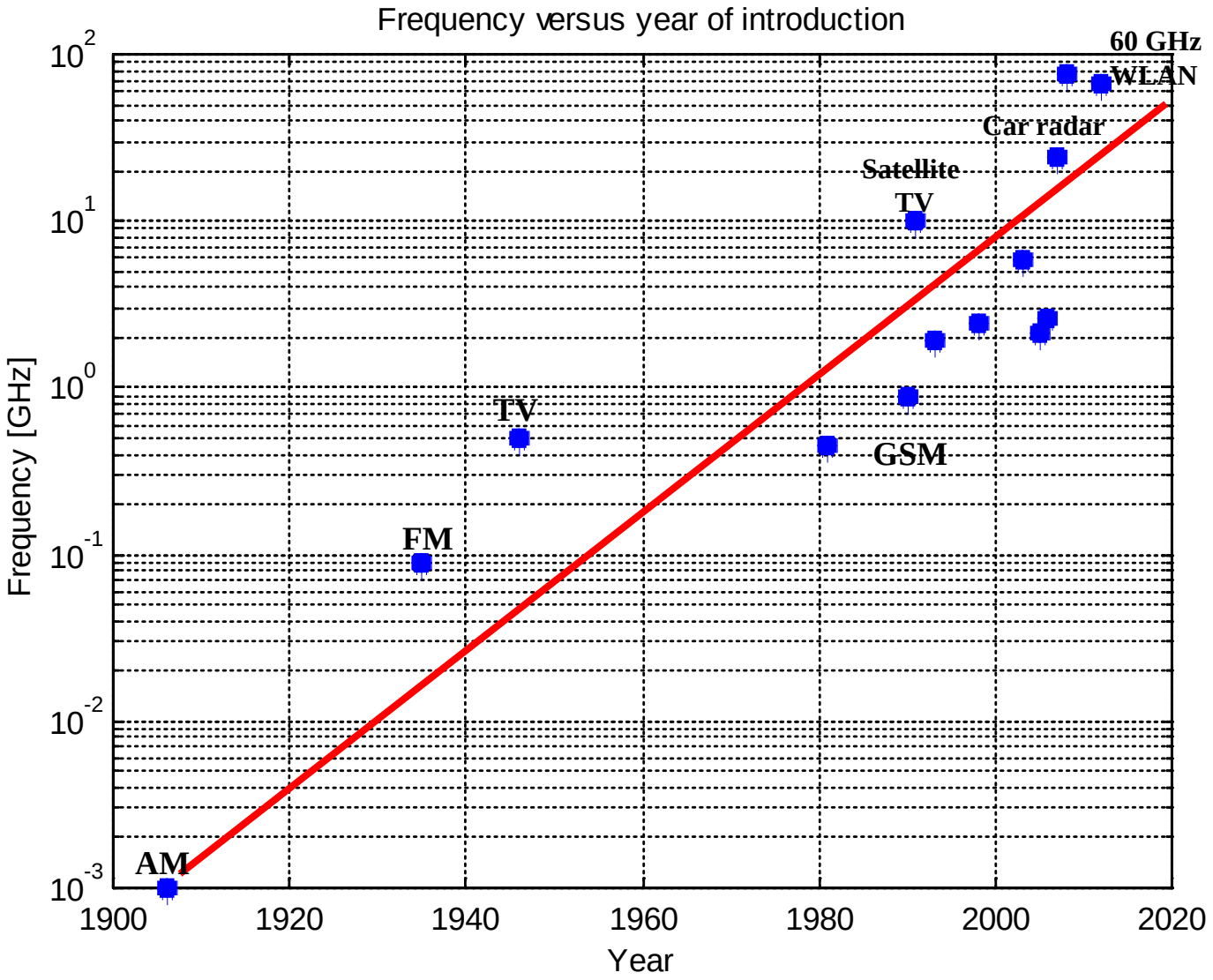
Content

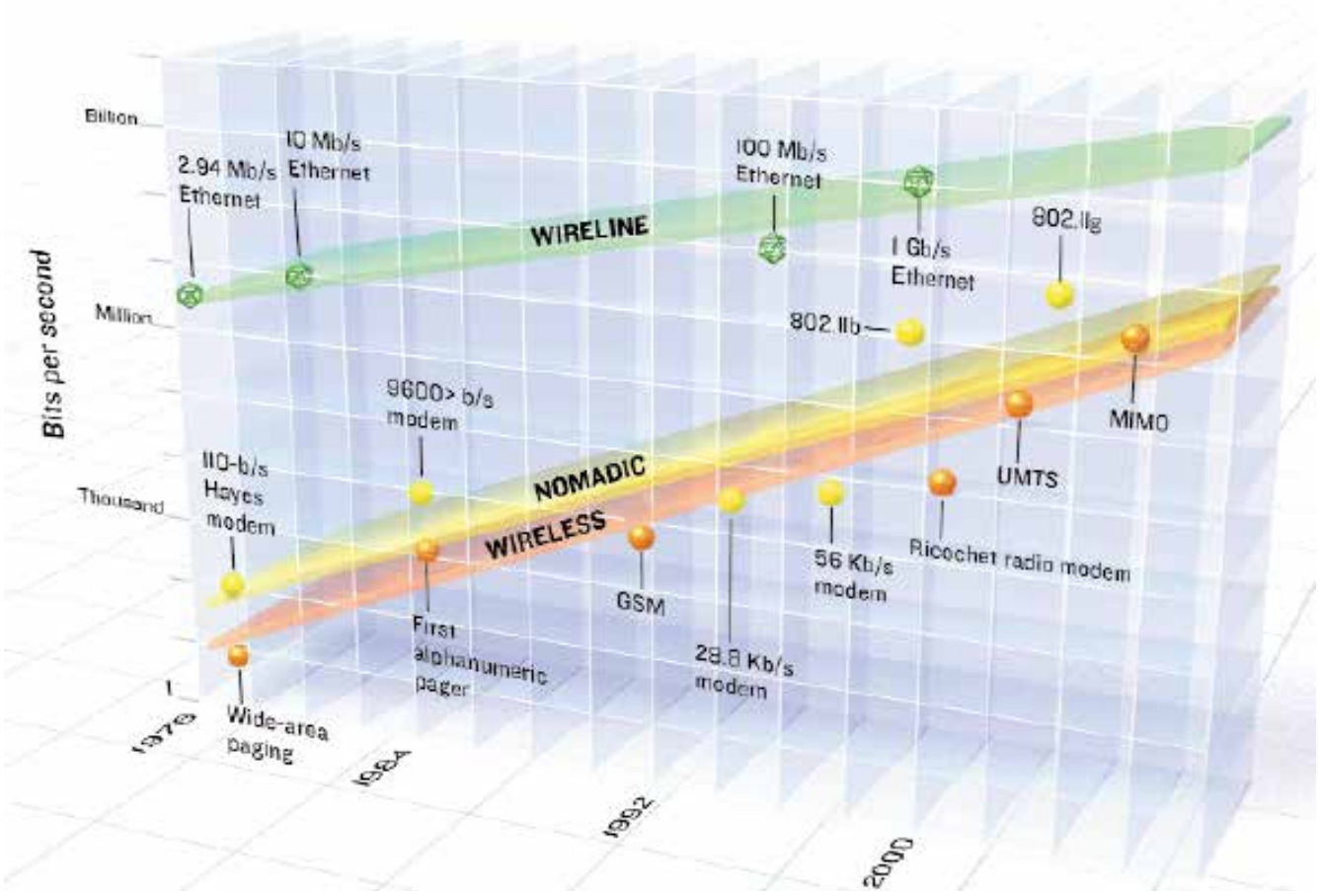
- Trends in wireless communication
- Overview research activities 5G New Radio
- Outlook towards 6G

Trends in Wireless communications

Trend 1: Increase of operational frequency



Trend 2: Increase in bandwidth:Edholm's Law

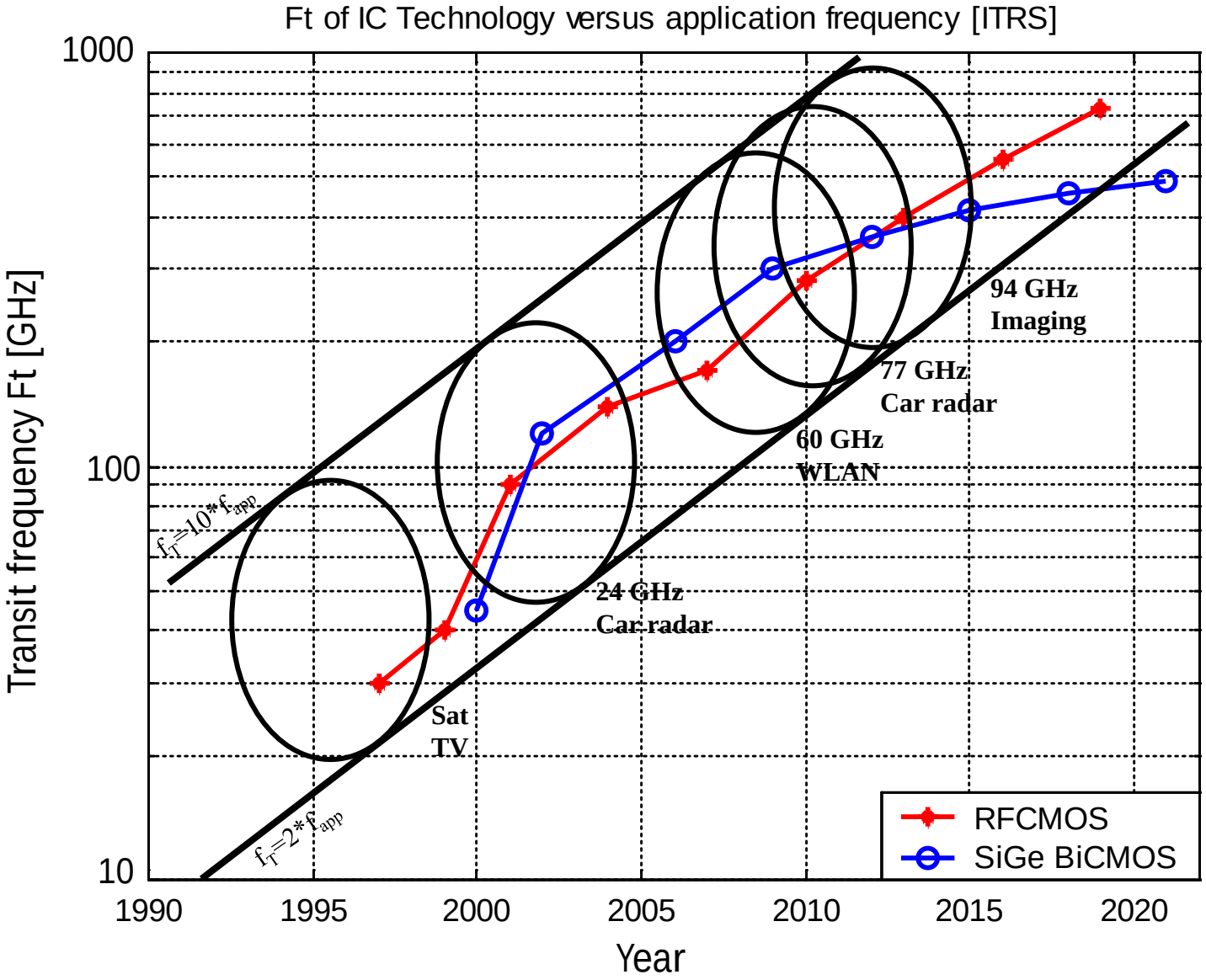


Wireless growing faster than wired

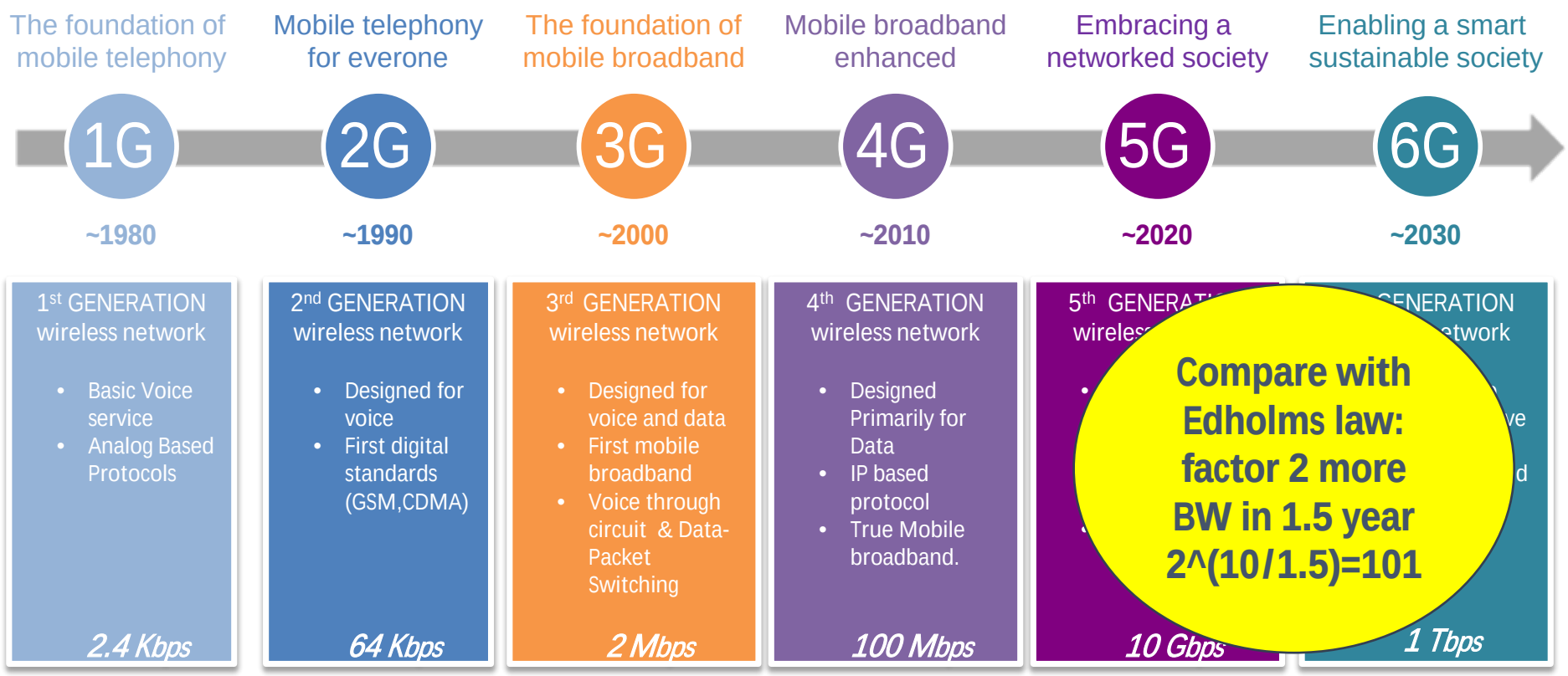
Required Bandwidth/datarate doubles each 18 months

Source: IEEE spectrum, 2004

Trend 3: Improved performance sililcon Technologies



Evolution of wireless standards



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Overview research activities 5G-NR

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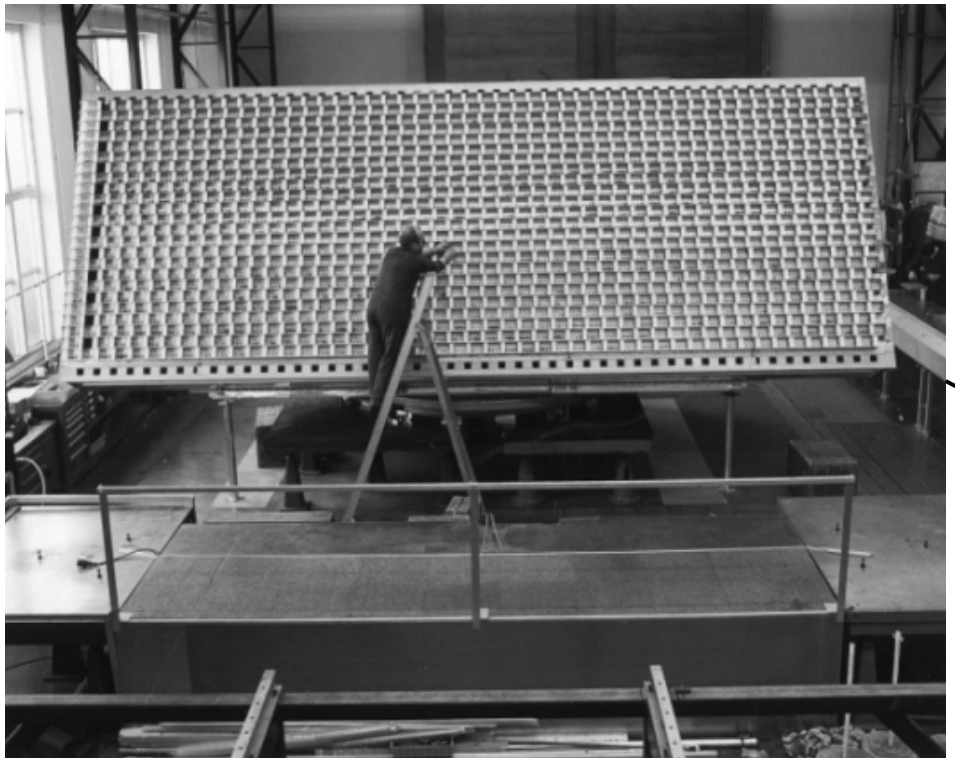
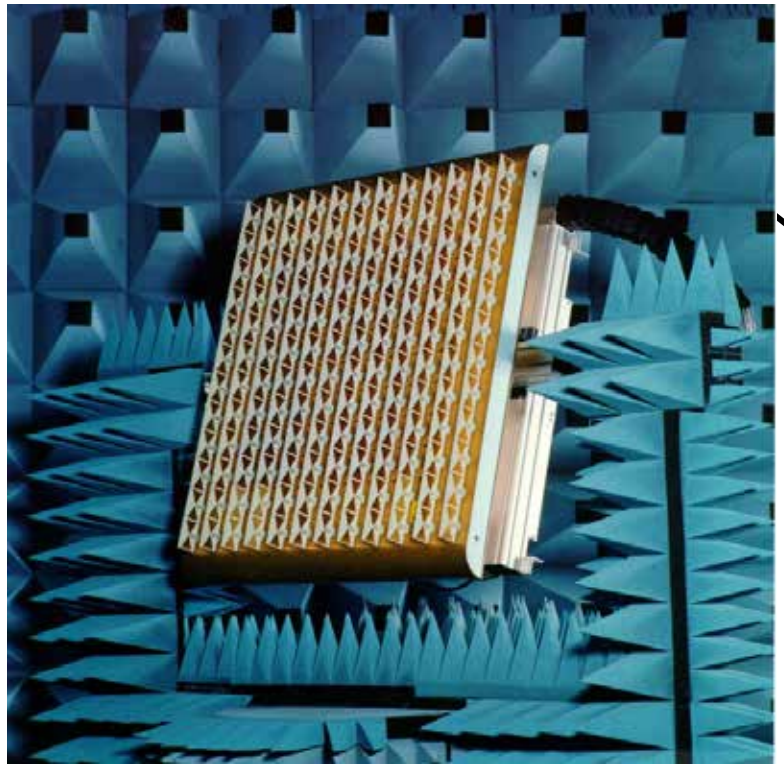
History of phased-arrays (1)



[1] M.C. Van Beurden, A.B. Smolders, IEEE Trans. AP, 2002, pp.1266-1273

History of phased-arrays (2)

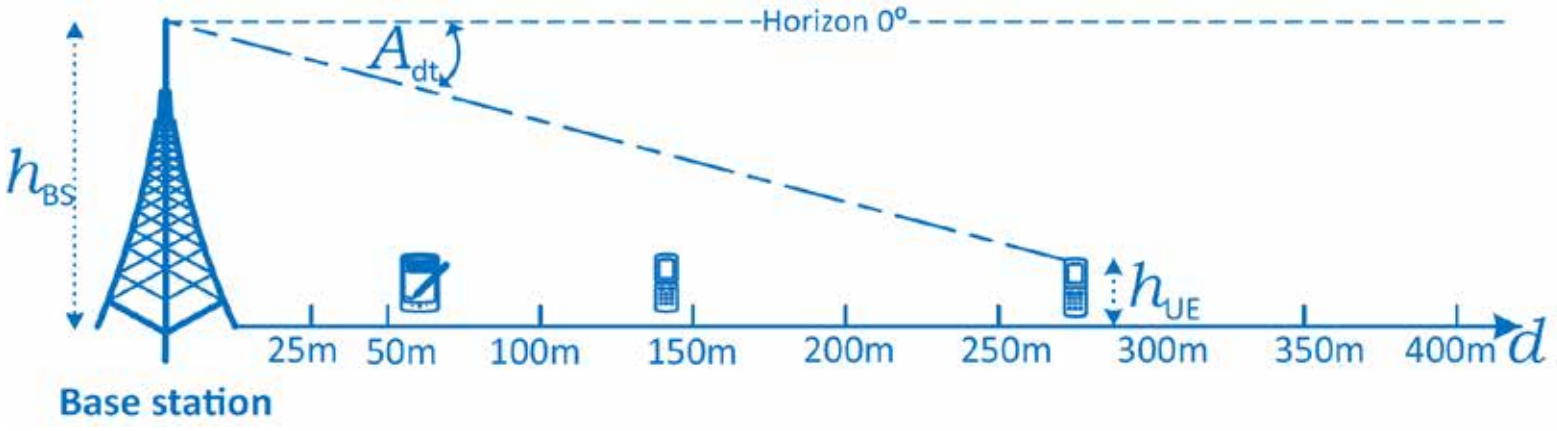
SKA Radio astronomy

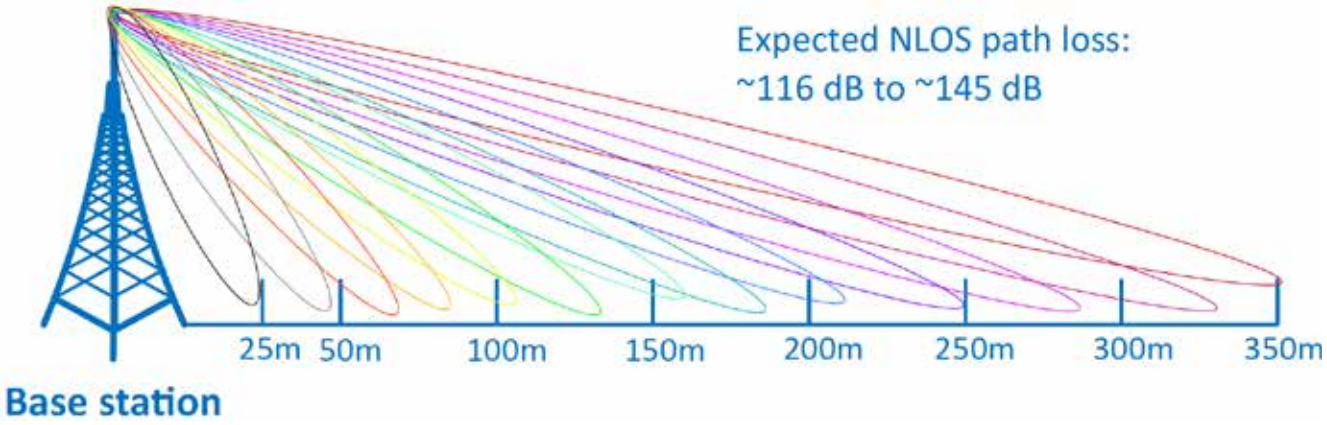


[1] SKA, www.astron.nl
[2] A.B. Smolders, G.Hampson, IEEE AP Magazine, 2002

Base station cell at mm-waves (28.5 GHz)

Scenario: Urban environment



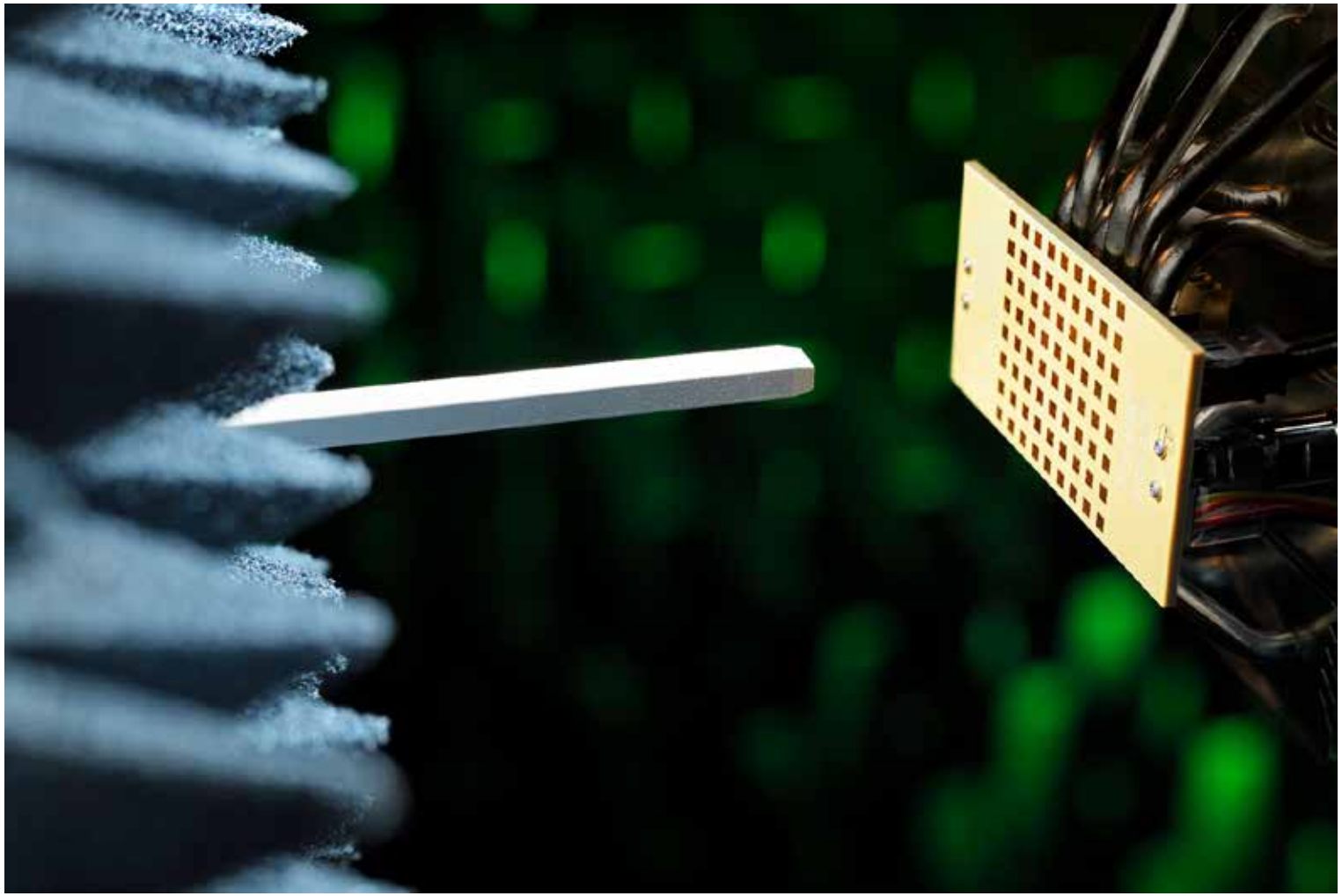


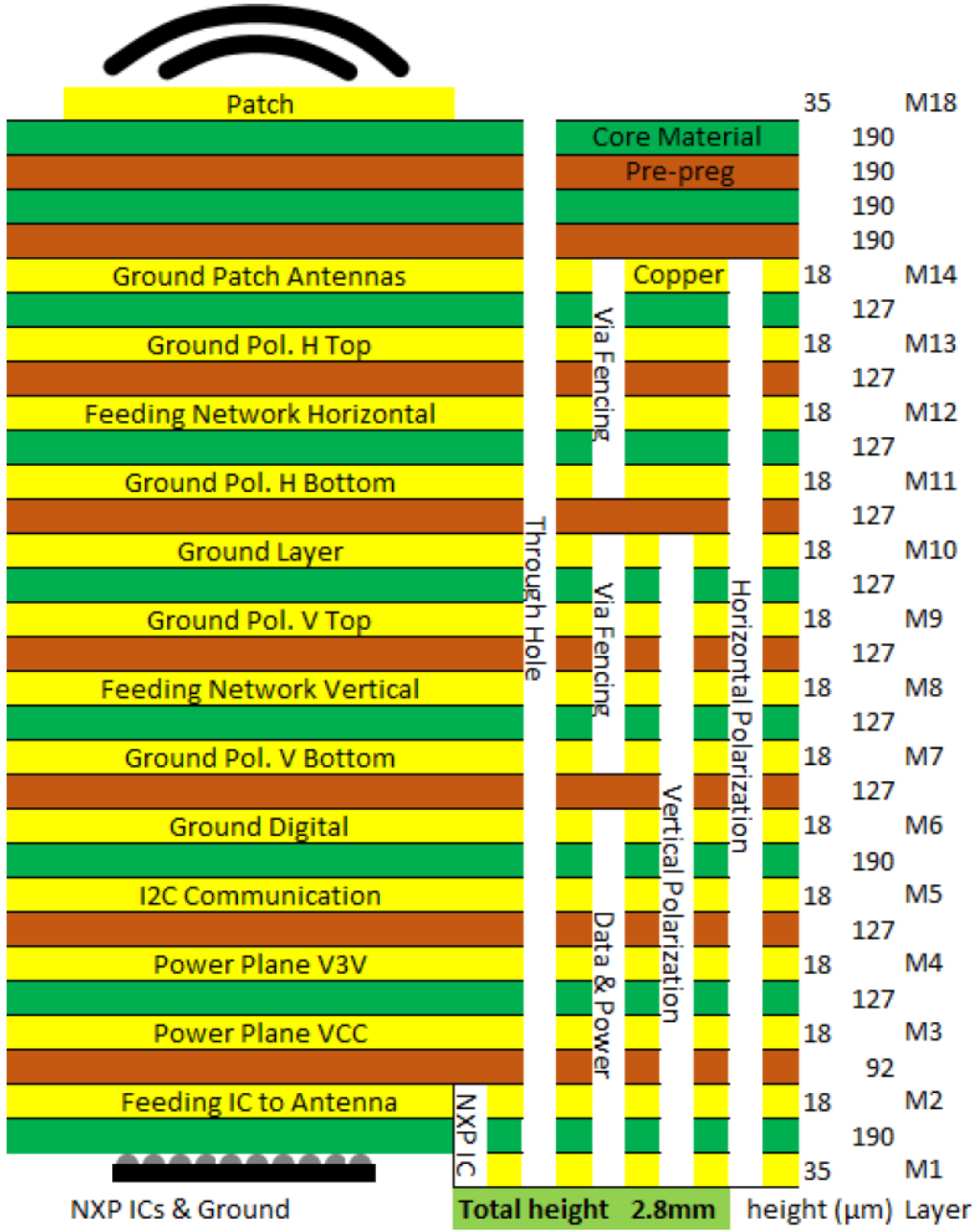
Base station concepts

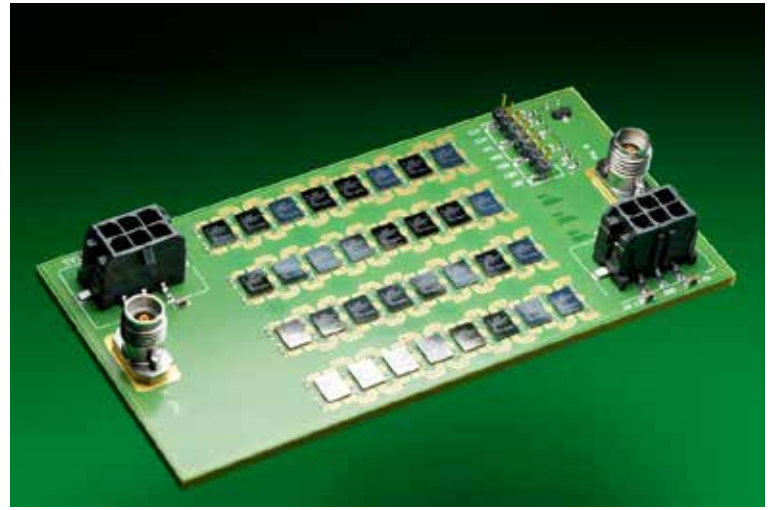
- Dense arrays
  - ++ Wide-scan, full beam control, massive MIMO
  - - - Expensive, power hungry, cooling problem (W/cm^2)
- Sparse arrays
  - ++ Reduced mutual coupling, better thermal management (W/m^2)
  - - - Grating lobes could occur, large in size
- Focal-plane arrays
  - ++ High gain from reflector, limited number of active elements
  - - - limited scan, 3D mechanical structure.

Dense Arrays

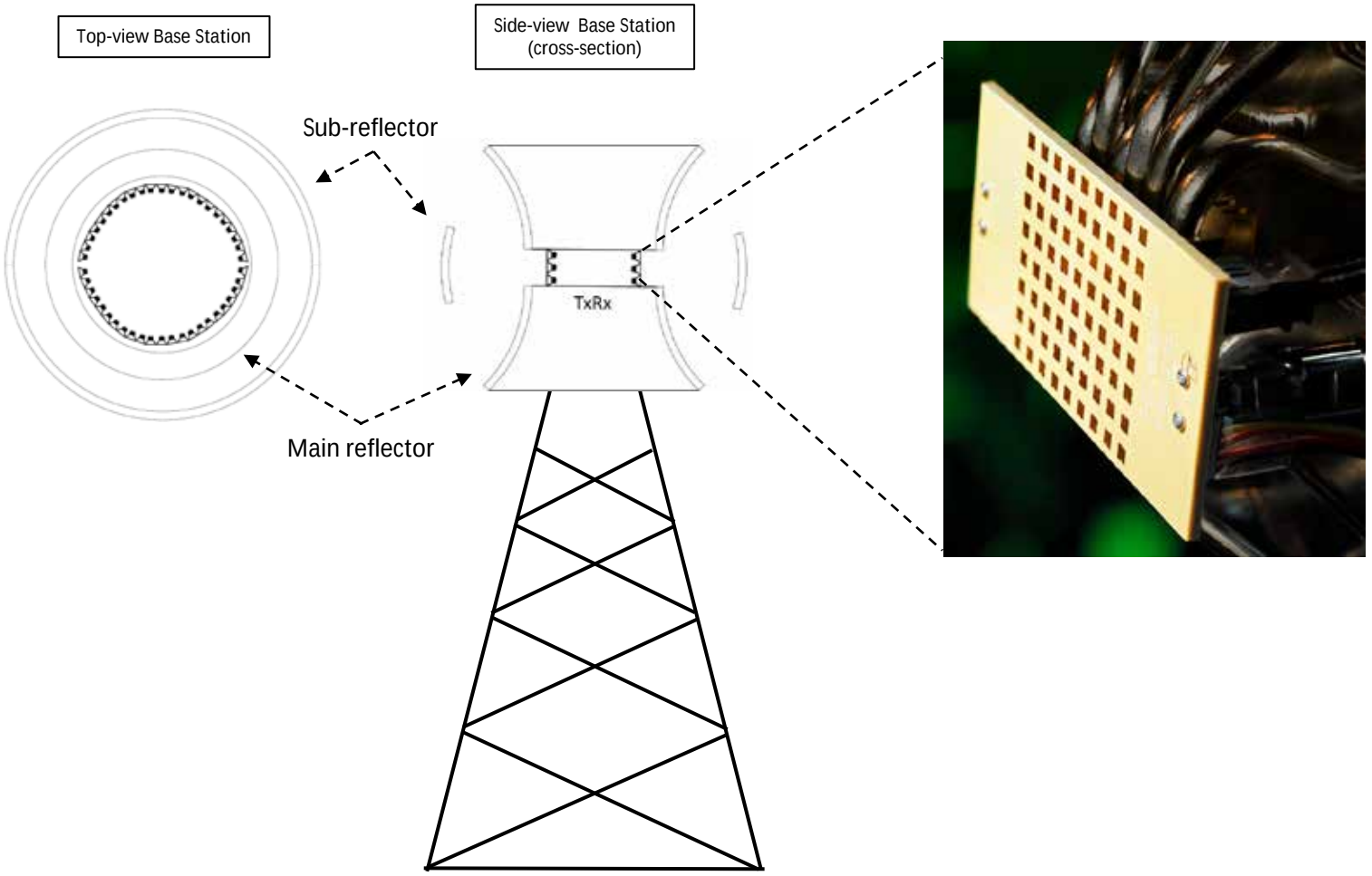
28 GHz dual-polarized active array with BiCMOS ICs




Patch
Core Material
Pre-prog
Ground Patch Antennas
Copper
Ground Pol. H Top
Feeding Network Horizontal
Ground Pol. H Bottom
Ground Layer
Ground Pol. V Top
Feeding Network Vertical
Ground Pol. V Bottom
Ground Digital
I2C Communication
Power Plane V3V
Power Plane VCC
Feeding IC to Antenna
NXP IC
Via Fencing
Via Fencing
Through Hole
Horizontal Polarization
Vertical Polarization
Data & Power
NXP ICs & Ground
35 M18
190
190
190
18 M14
127
18 M13
127
18 M12
127
18 M11
127
18 M10
127
18 M9
127
18 M8
127
18 M7
127
18 M6
190
18 M5
127
18 M4
127
18 M3
92
18 M2
190
35 M1
Total height 2.8mm
height (µm) Layer

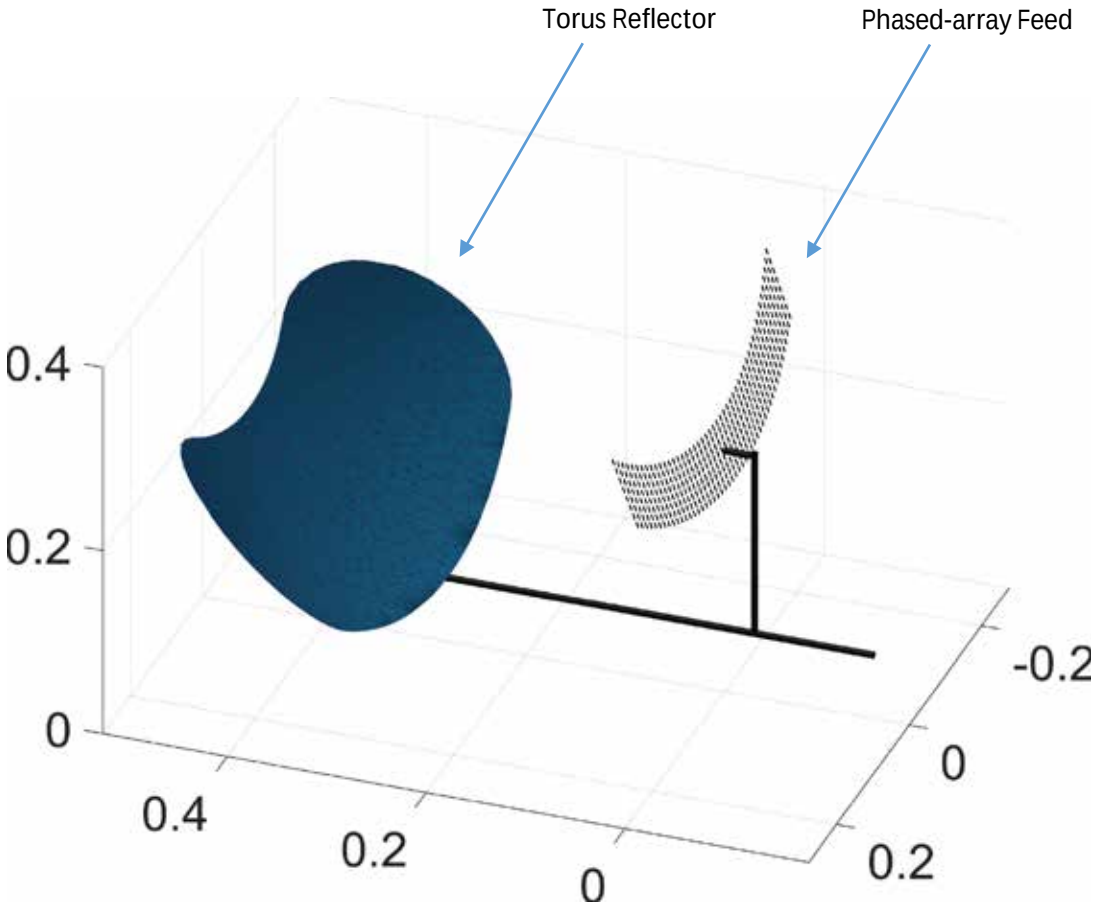


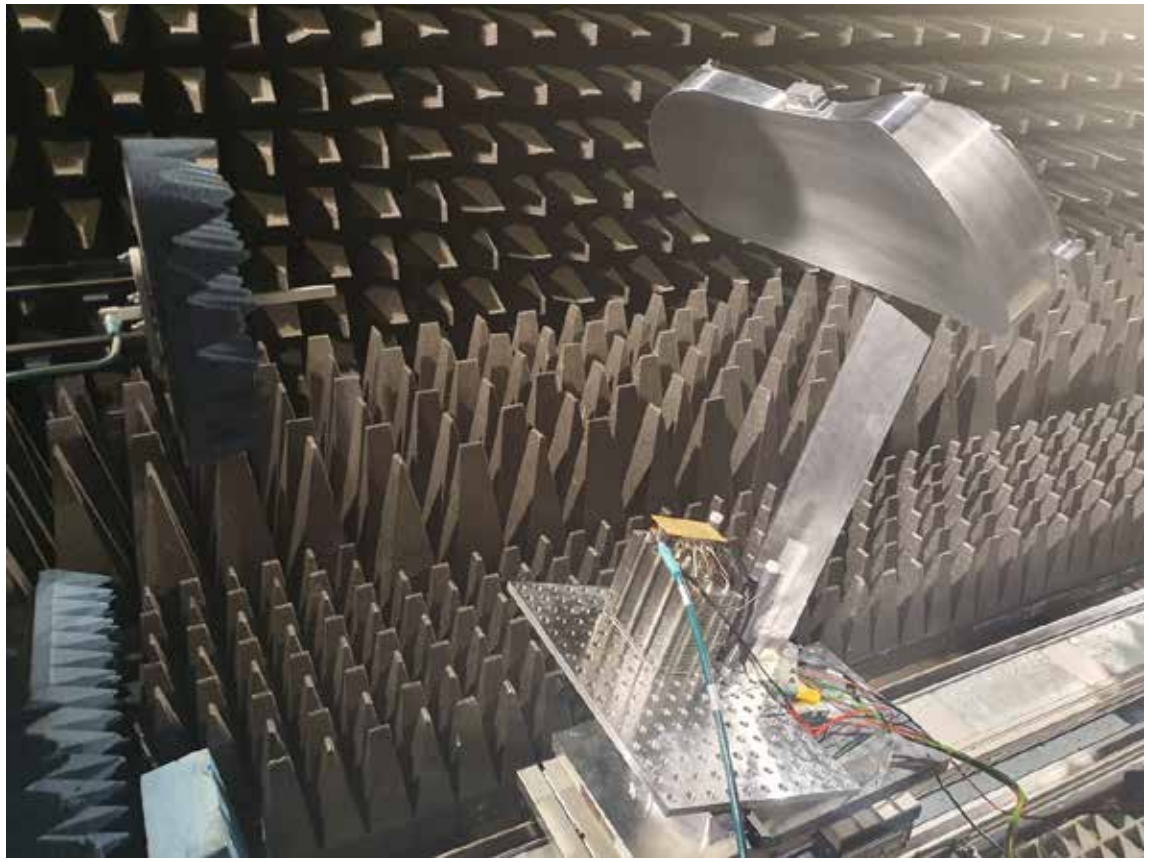
Focal-Plane Arrays



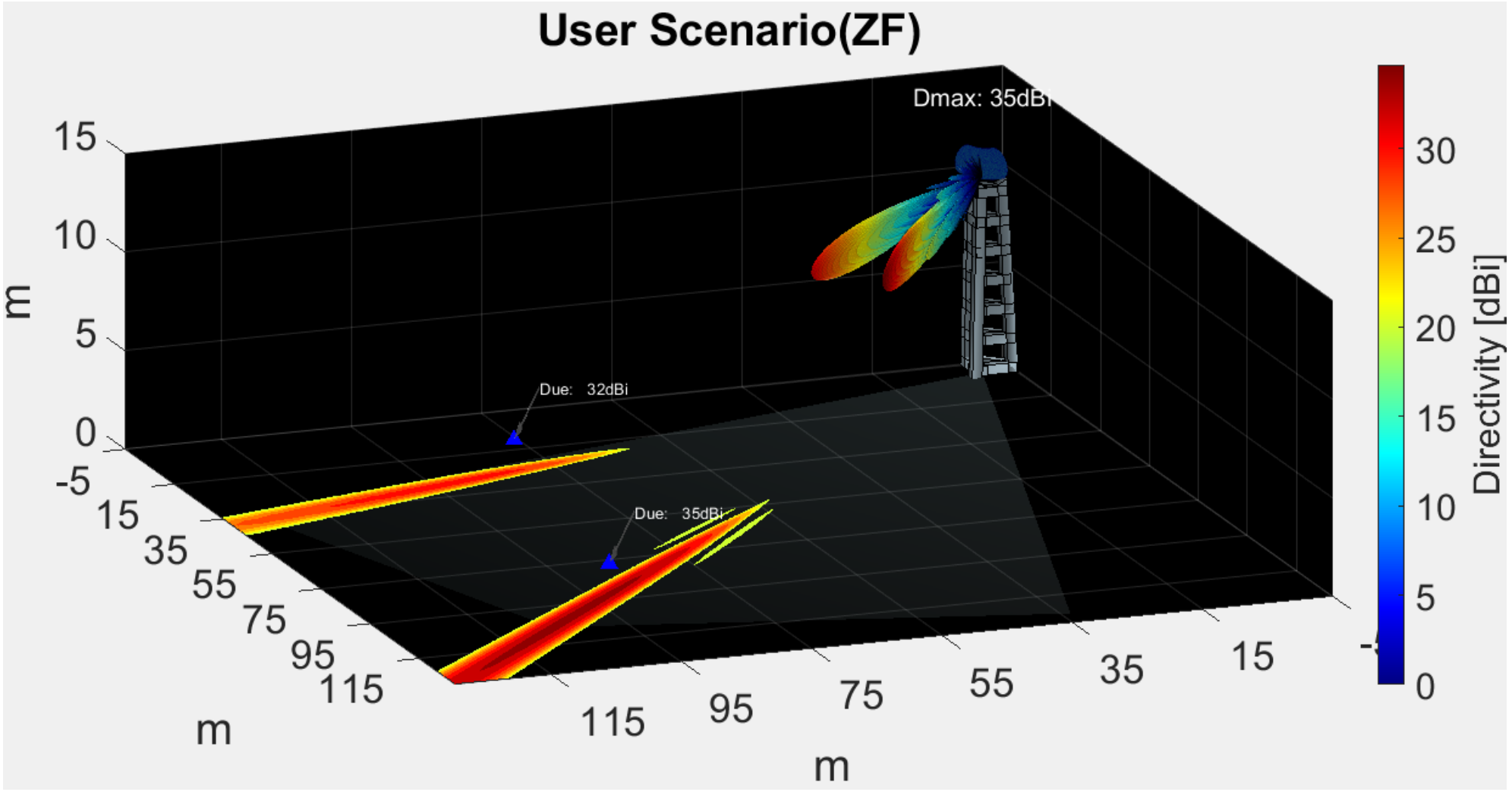
Focal-Plane Arrays

Torus wide-scan reflector operating at 28 GHz





System-level verification of concepts



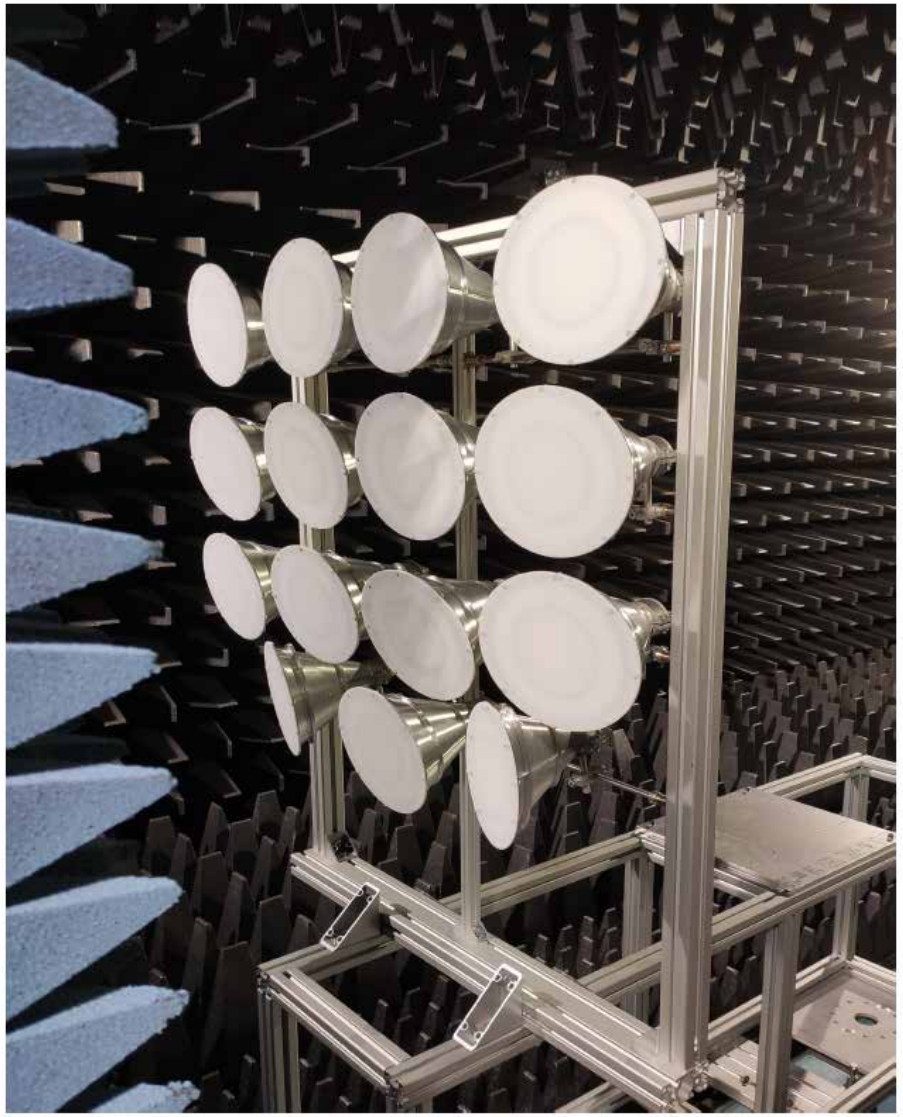
Sparse arrays using highly-directive antennas

Dual polarized lens-horn antenna
n257 band (26.5-29.5 GHz)

Fresnel-lens

Elliptical horn

Coax-to-waveguide adapter



Sparse arrays using highly-directive antennas

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Dual polarized lens-horn antenna
n257 band (26.5-29.5 GHz)

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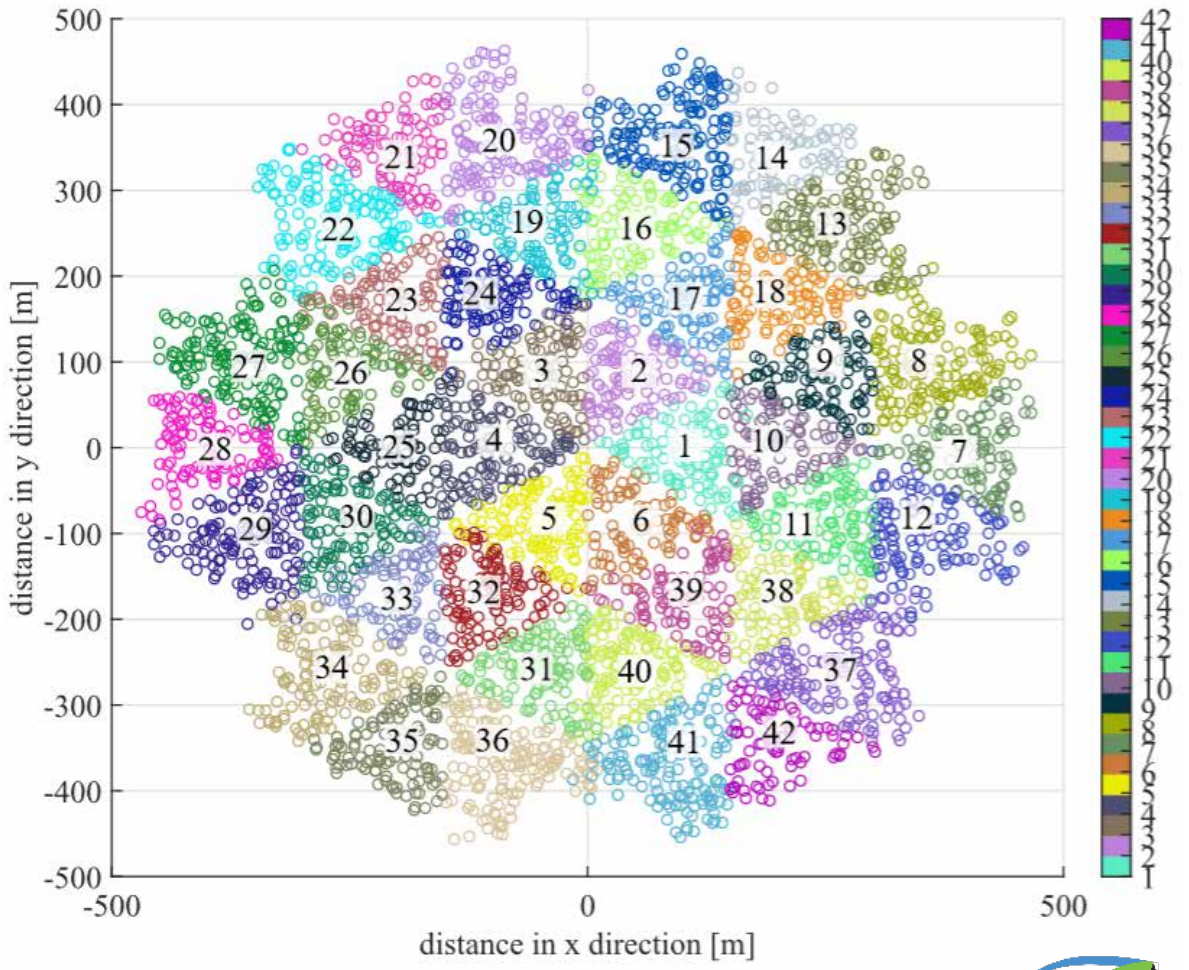

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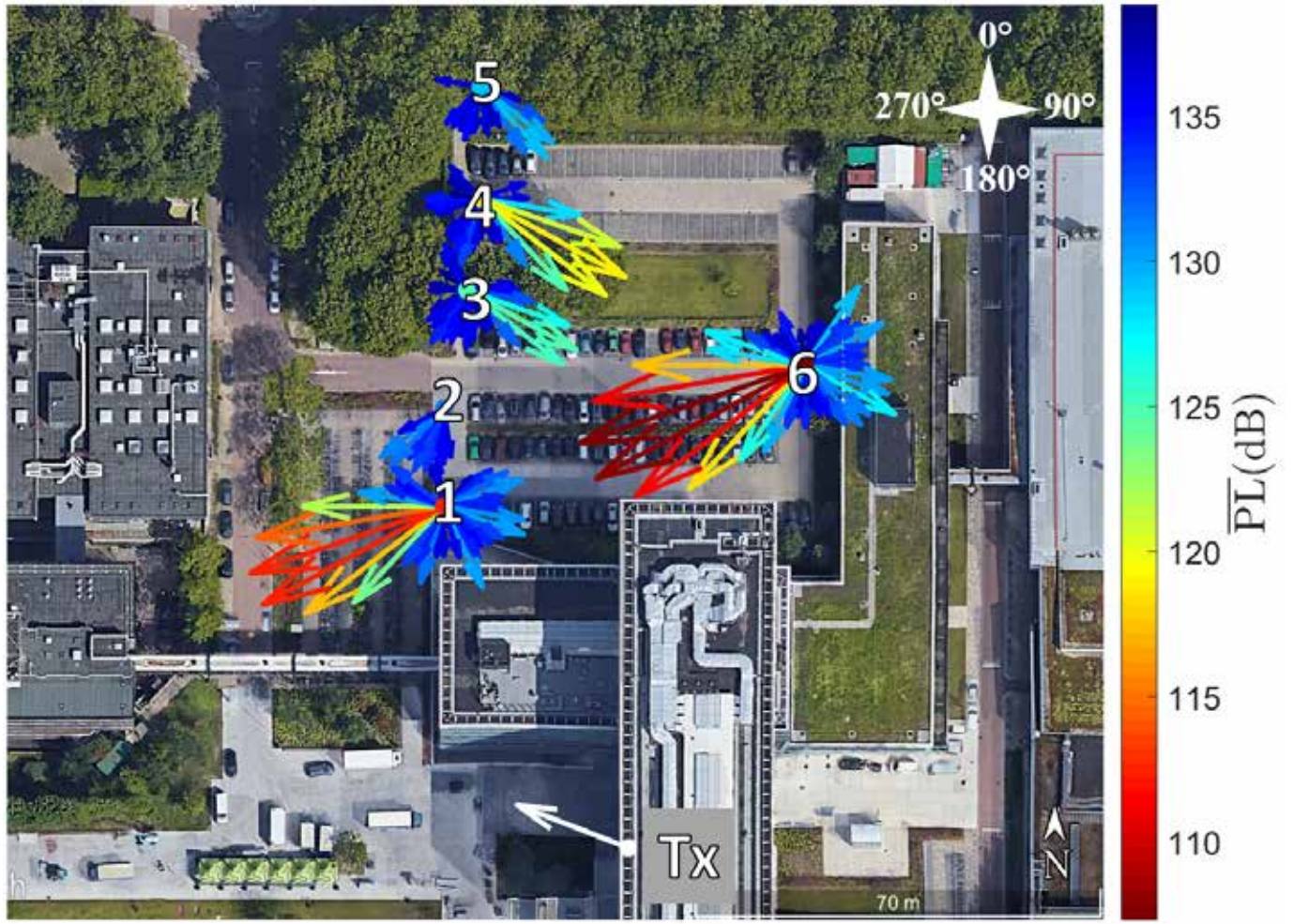
Millimetre-Wave Channel Sounding

Typical Performance:

- Three Tx channels at 49 dBm EIRP
- One omnidirectional receiver
- Unambiguous range: 3km
- Range resolution: 0.1m
- Dynamic Range: 20dB
- Max. speed: ~50km/h
- Speed resolution: ~2km/h
- Measurement interval: 0.2s

R. Schulpen et al., “5G Millimeter-Wave NLOS Coverage Using Specular Building Reflections,” EuCAP2020

Millimetre-Wave Channel Sounding



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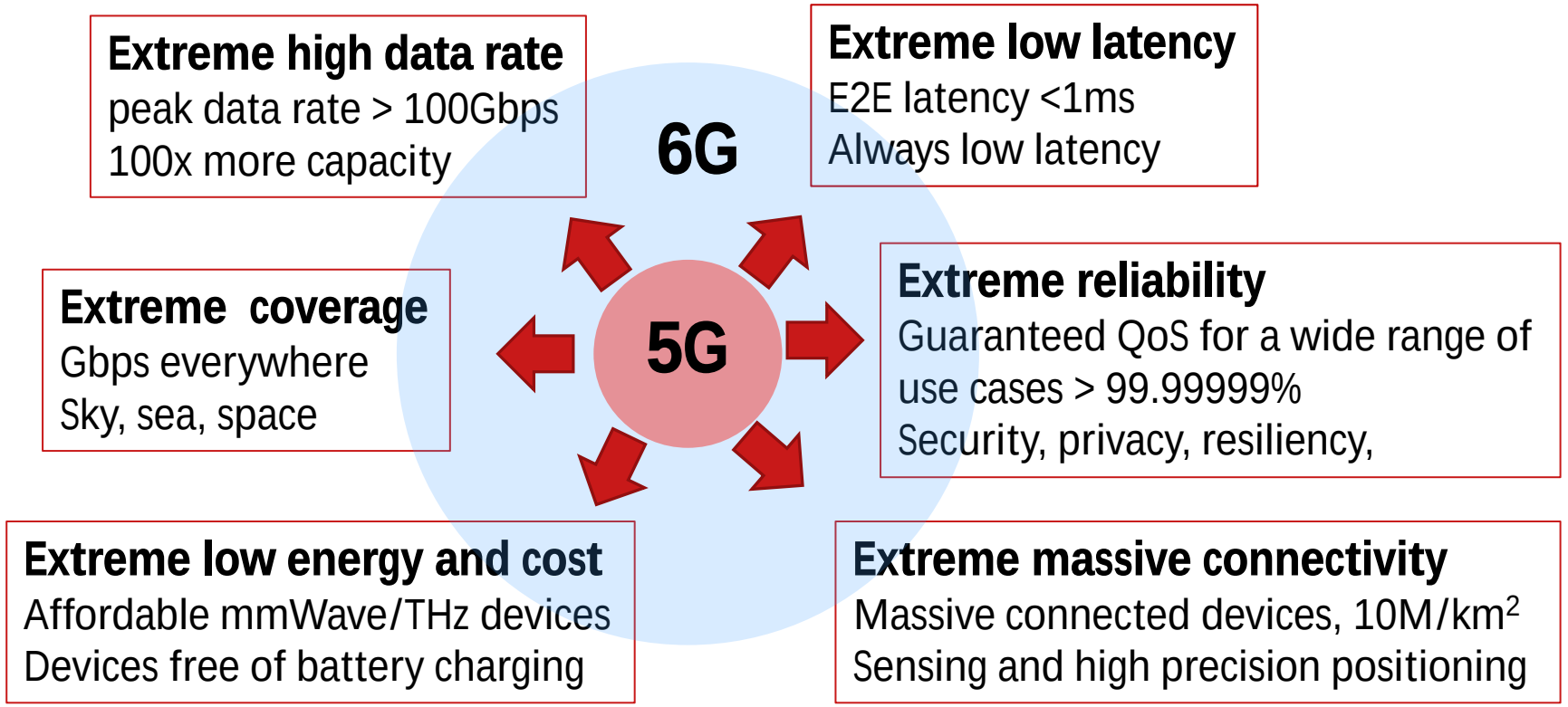
Outlook towards 6G

System and Requirements

Requirements for 6G



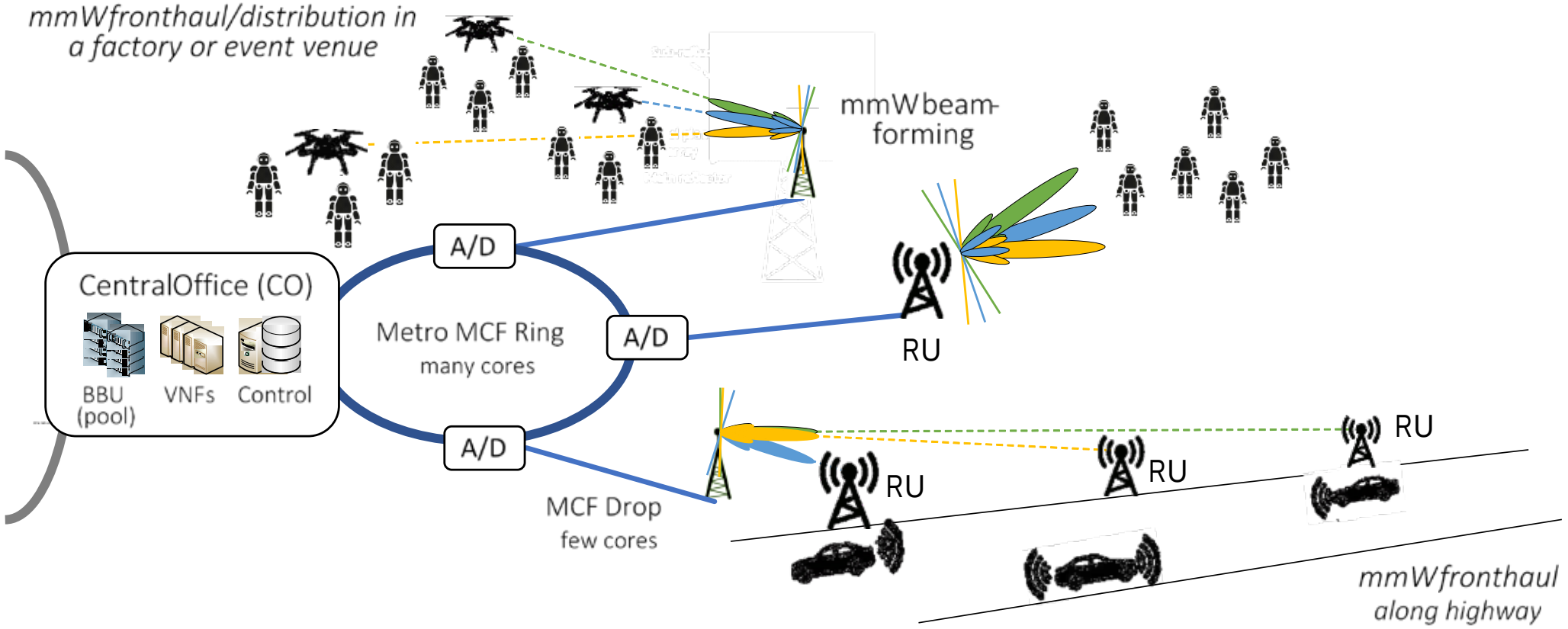
Source: 5G Evolution and 6G, NTT DOCOMO, 2020

Broadband Connectivity KPIs

KPI	5G	6G
Peak data rate	20 Gb/s	1 Tb/s
Experienced data rate	0.1 Gb/s	1 Gb/s
Peak spectral efficiency	30 b/s/Hz	60 b/s/Hz
Experienced spectral efficiency	0.3 b/s/Hz	3 b/s/Hz
Maximum bandwidth	1 GHz	100 GHz
Area traffic capacity	10 Mb/s/m^2	1 Gb/s/m^2
Connection density	10^6 devices/km^2	10^7 devices/km^2
Energy efficiency	not specified	1 Tb/J
Latency	1 ms	100 µs
Reliability	$1\text{-}10^{-5}$	$1\text{-}10^{-9}$
Jitter	not specified	1 µs
Mobility	500 km/h	1000 km/h

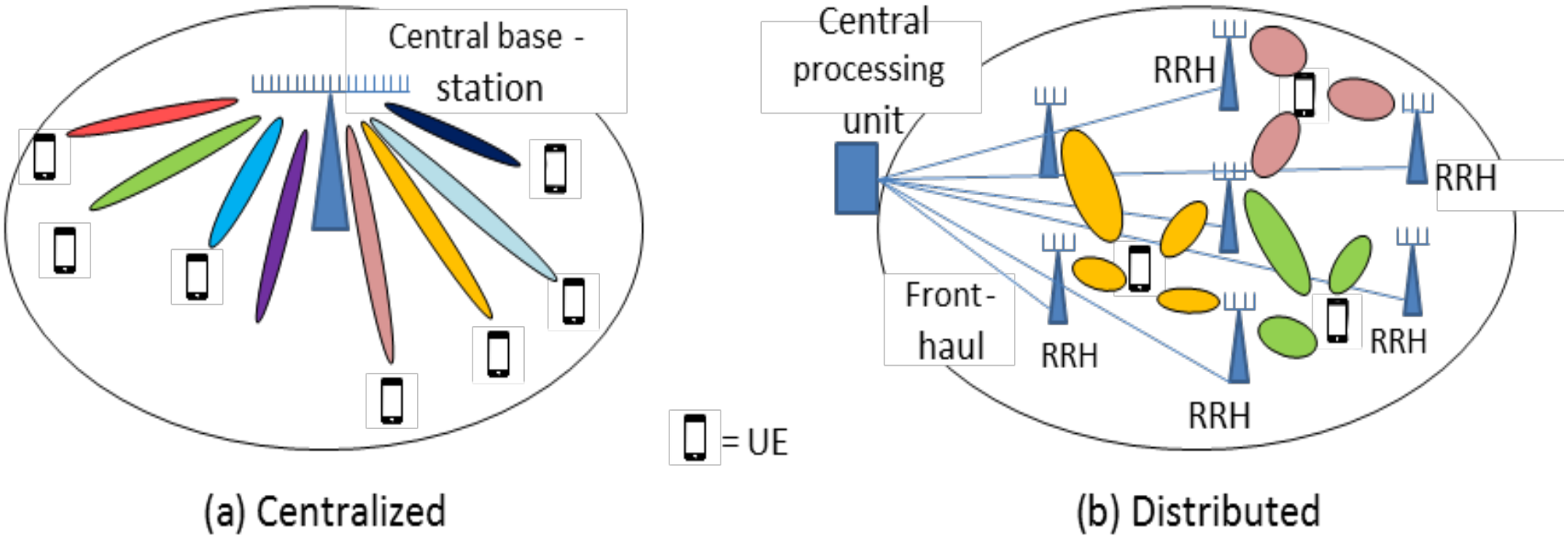
Source: N. Rajatheva et al., "*White Paper on Broadband Connectivity in 6G,*" 6G Research Visions, No. 10, University of Oulu. June 2020

Future mm-wave 5G-NR/6G infrastructure

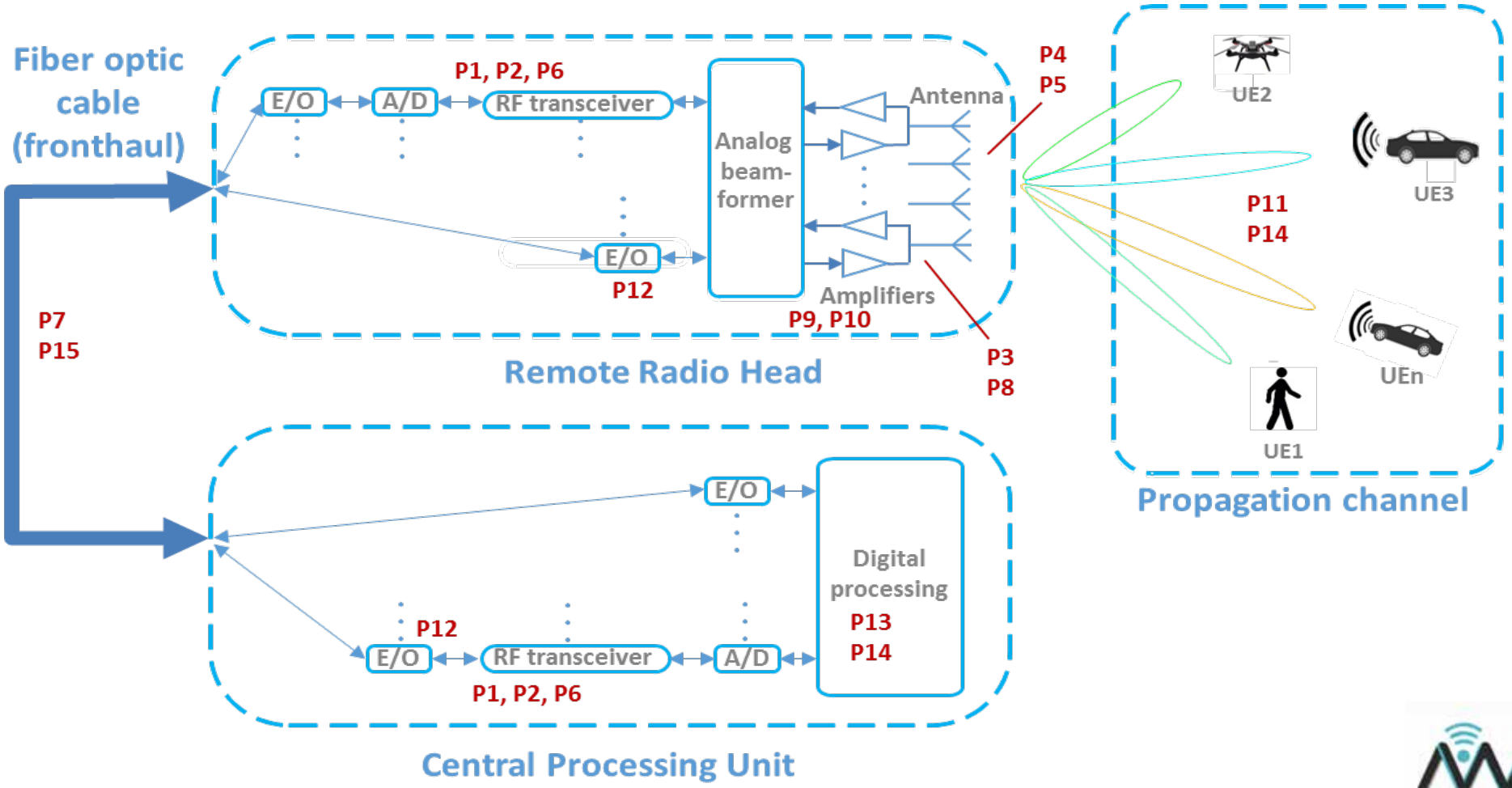


Freepower project

Distributed Massive MIMO



MyWave – Project Overview



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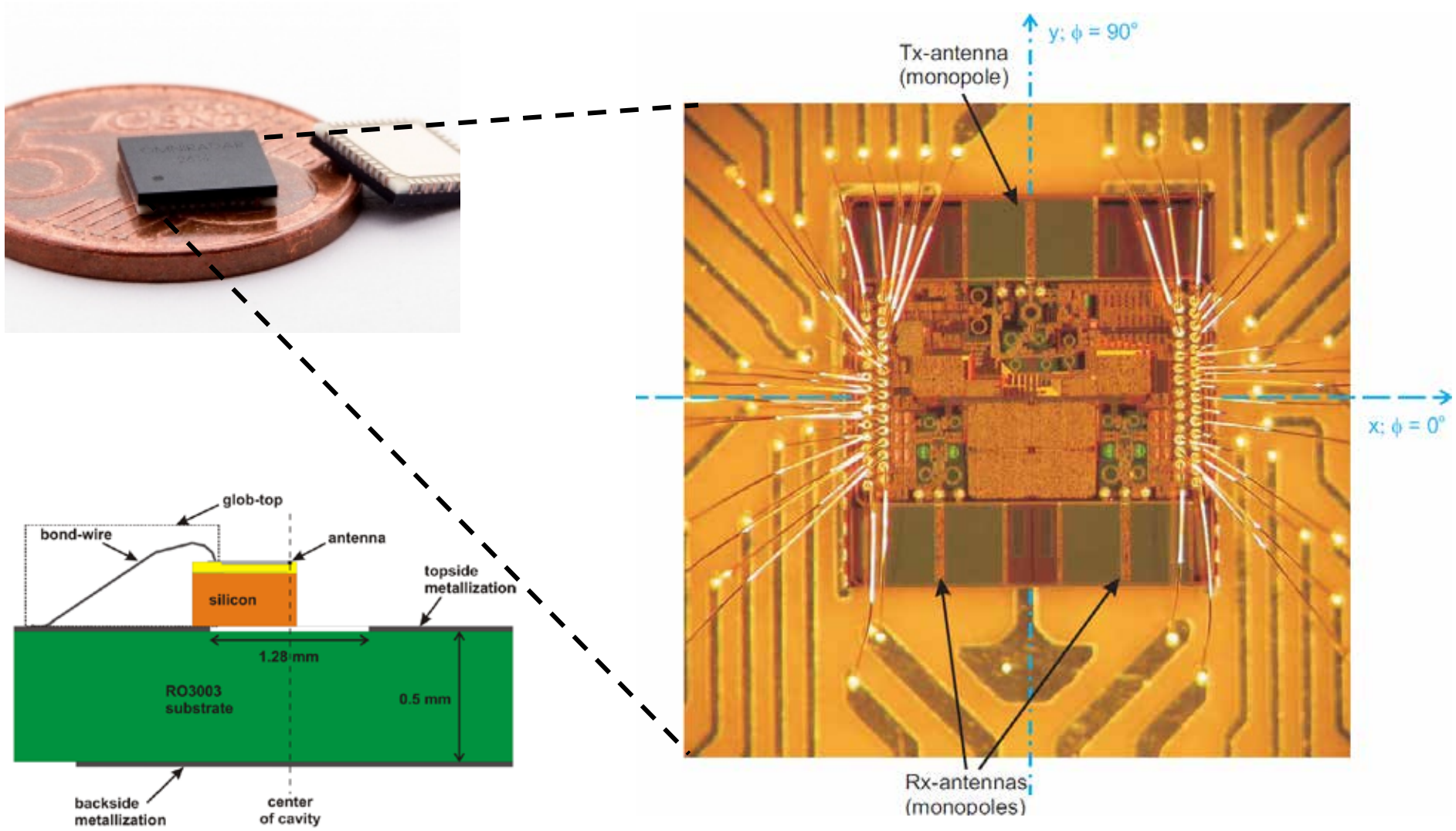
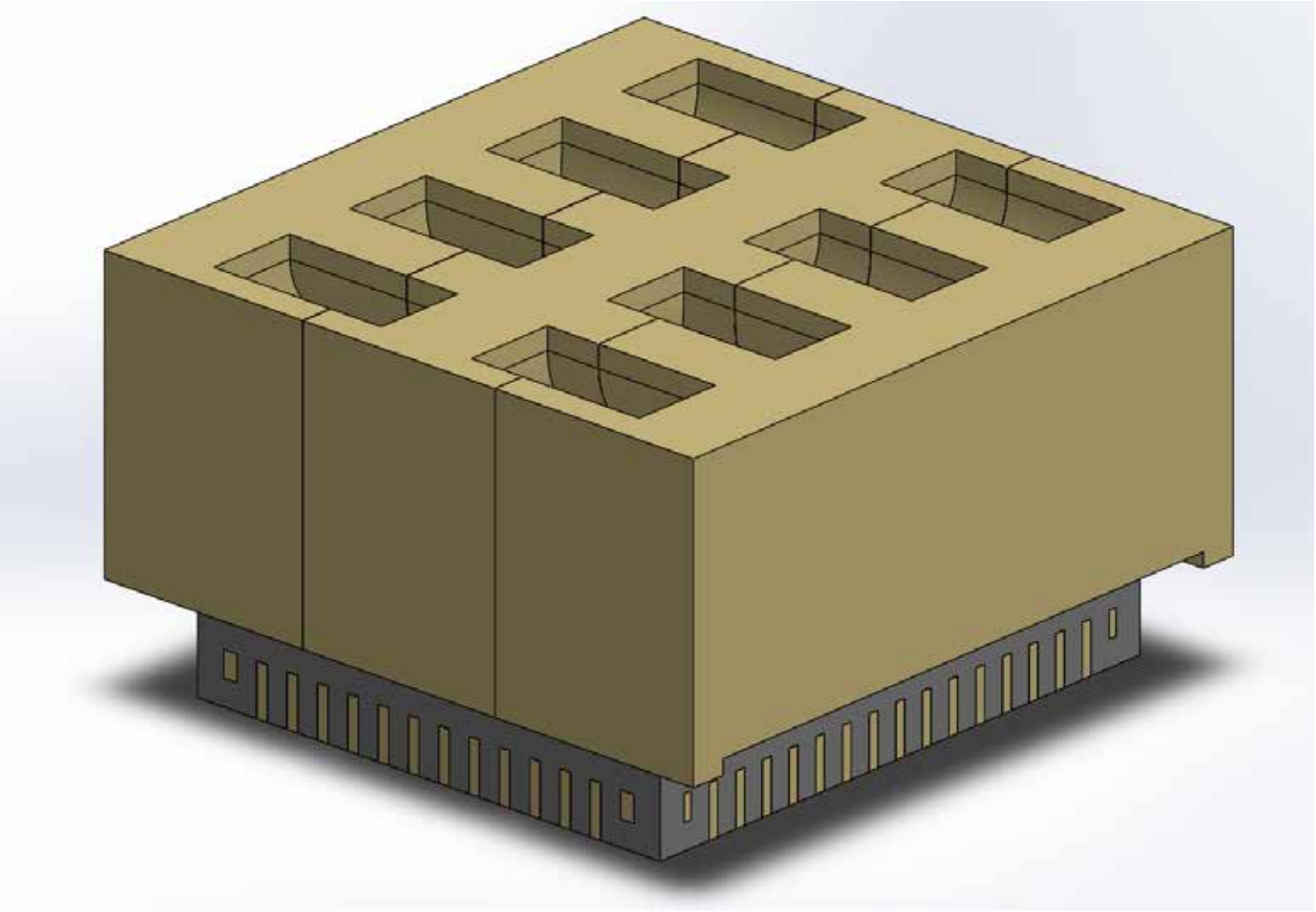
Antenna Integration Technologies

Single-chip 60 GHz FMCW radar

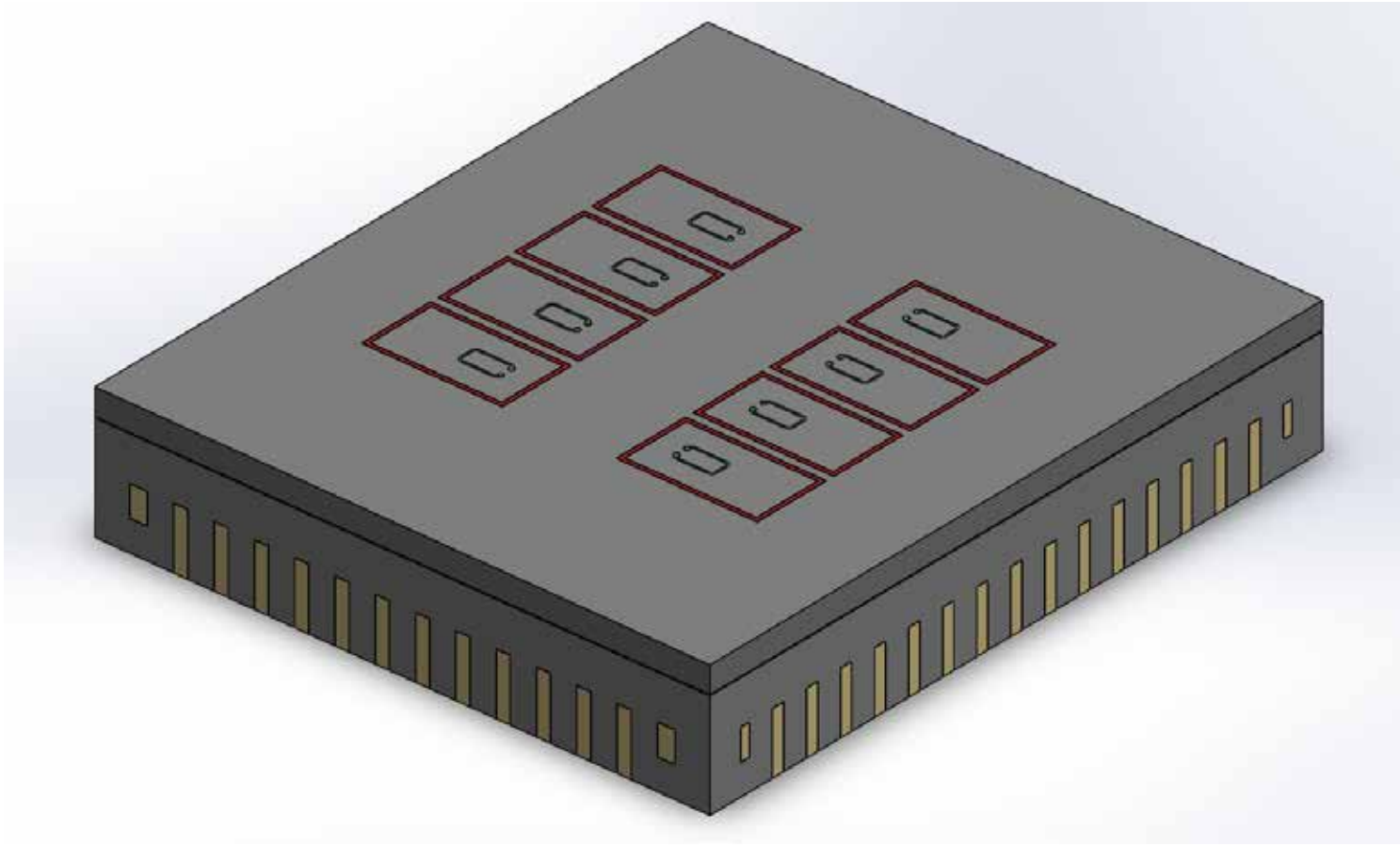


B. Adela; P.van Zeijl; U. Johannsen; A. B. Smolders "On-chip Antenna Integration for Millimeter-wave Single-chip FMCW Radar, Providing High Efficiency and Isolation" IEEE Transactions on Antennas and Propagation Year: 2016.

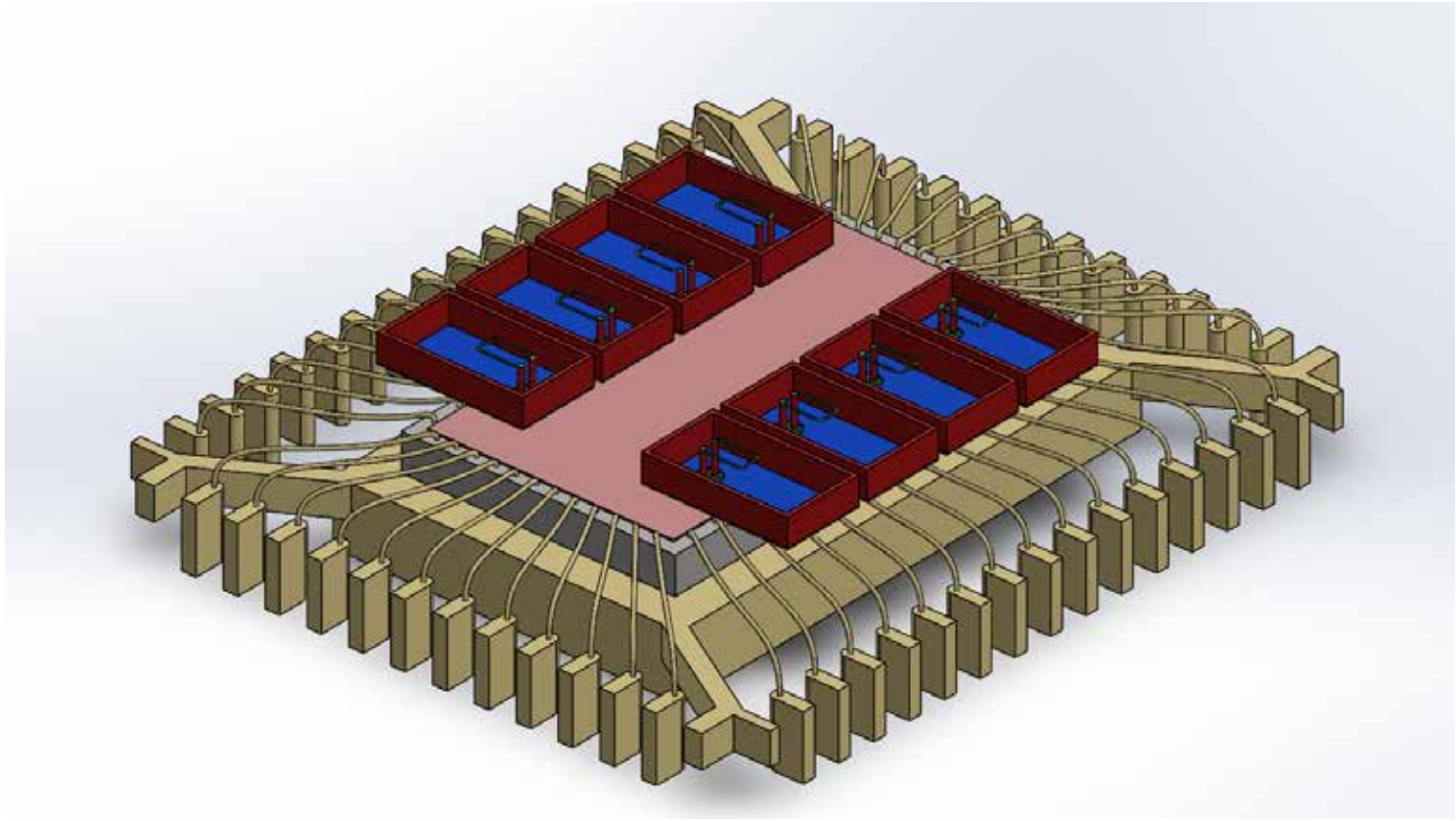
Low loss transition: Integrating waveguides



Low loss transition: Integrating waveguides



Low loss transition: Integrating waveguides



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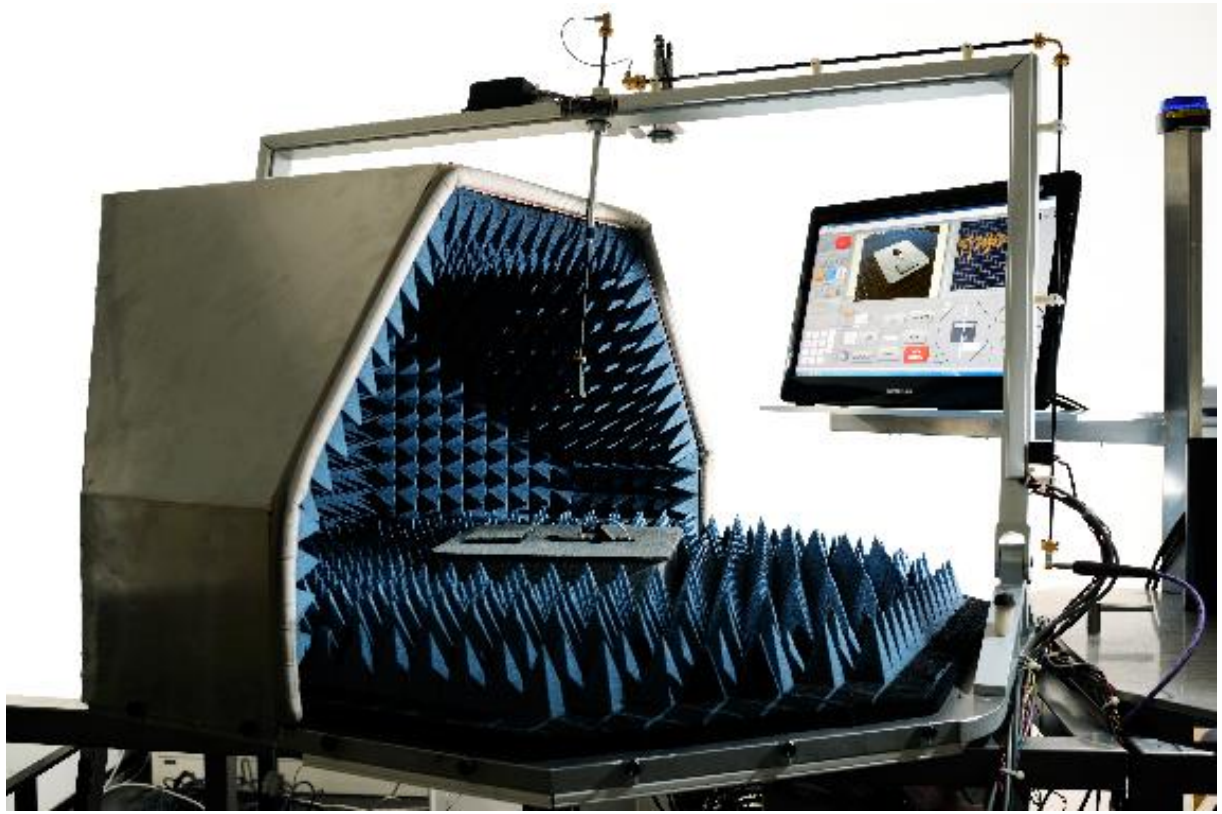
Test and characterization facilities

Integrated antenna test-facility

2012 Version (5G)



2021 Version (6G)

Summary

- 6G will use mm-wave frequencies up to 100 GHz and beyond
- Distributed Massive-MIMO
- Highly integrated antenna concepts are required
  - Existing concepts are too power hungry and far to expensive
  - Aperture sharing
- Measurement of integrated antennas is research topic

Thank you !

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Back-up