FTF 2016
TECHNOLOGY FORUM

INTERNET EVERYWHERE – SMART ANTENNA SOLUTIONS

PAVING THE ROAD FROM 4G AND WIFI TO 5G

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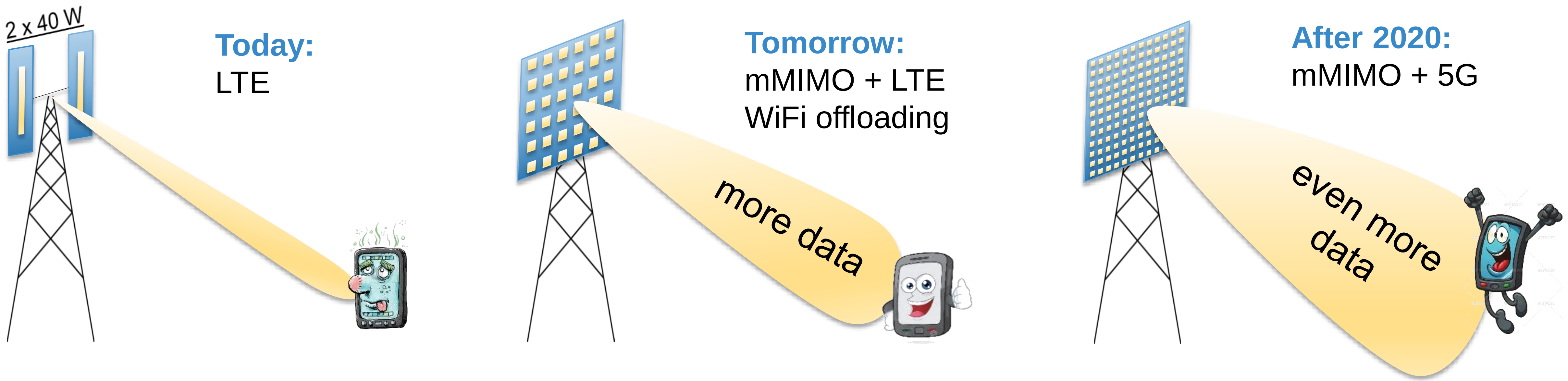
AGENDA

- Network evolution 4G to 5G
- 5G system overview
- Low Earth Orbit systems
- 5G mmWave
- mmWave communication
- NXP
  - Proofpoints
  - 5G approach
- Conclusion

NETWORK EVOLUTION

Throughput Evolution



Massive MIMO

- Used in Macro BTS
- Existing spectrum + new bands below 6 GHz
- More data with LTE and existing handsets
- Possible now
- Least expensive option to increase throughput, even at increased equipment cost

Microwave & Millimeterwave Frequencies

- > 6 GHz on WRC-2019 agenda
- GHz bandwidth has potential to carry a lot of data
- Propagation and building penetration issues force “small cell” deployments – many of them needed
- Significant increase of throughput – will see use starting 2020

Radio Access Network Evolution

Macro BTS
LTE, MIMO
2-8 Tx
10-40 Watt per PA
0.7-2.7 GHz

Macro BTS
LTE, massive MU MIMO
(fully digital)
16-64 Tx
1-10 Watt per PA
2.3-3.8 GHz

Macro BTS
5G, massive MU MIMO
(fully digital)
2-64 Tx
1-40 Watt per PA
0.5-6.0 GHz

2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 | 2021 | 2022 | 2023 | 2024 | 2025

Small Cells
LTE, MIMO
2 Tx
20-250 mW per PA
0.7-2.7 GHz

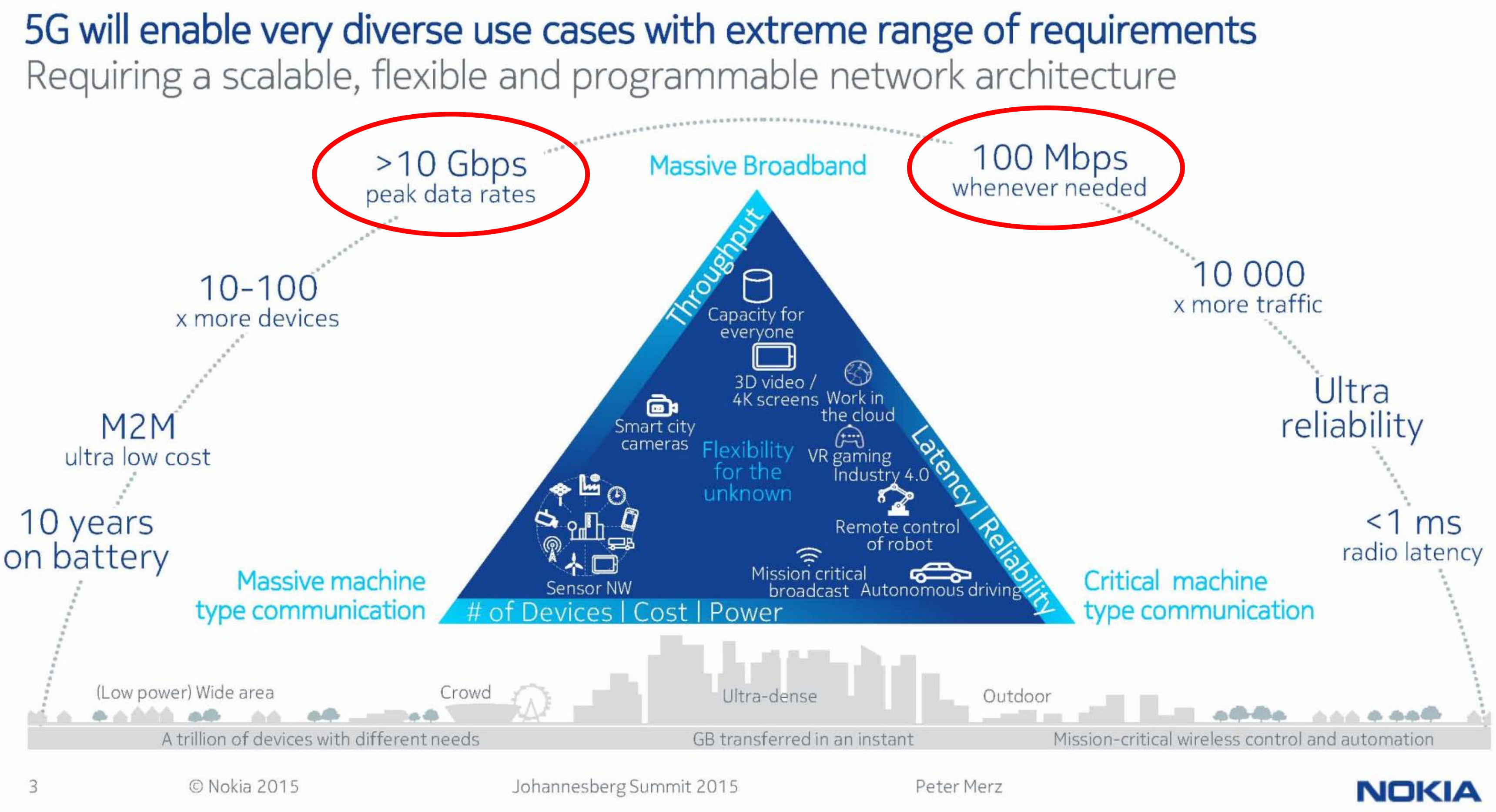
Small Cells
LTE, MIMO
2-8 Tx
20-250 mW per PA
0.7-6.0 GHz

cm & mm-Wave Small Cells
5G, beam forming, MIMO
(hybrid beamforming)
up to 256 Tx (perhaps more)
up to double digit mW per PA
> 6 GHz + < 6 GHz anchor

- Macro BTS and Small Cell deployments, LTE moving to new 5G waveform, some re-farming after 2020
- More frequency bands @ higher frequency will be added, old bands stay, larger SBW @ higher frequency bands
- Continuous increase in antenna elements ► lower power per antenna element ► higher level of integration

5G SYSTEM OVERVIEW

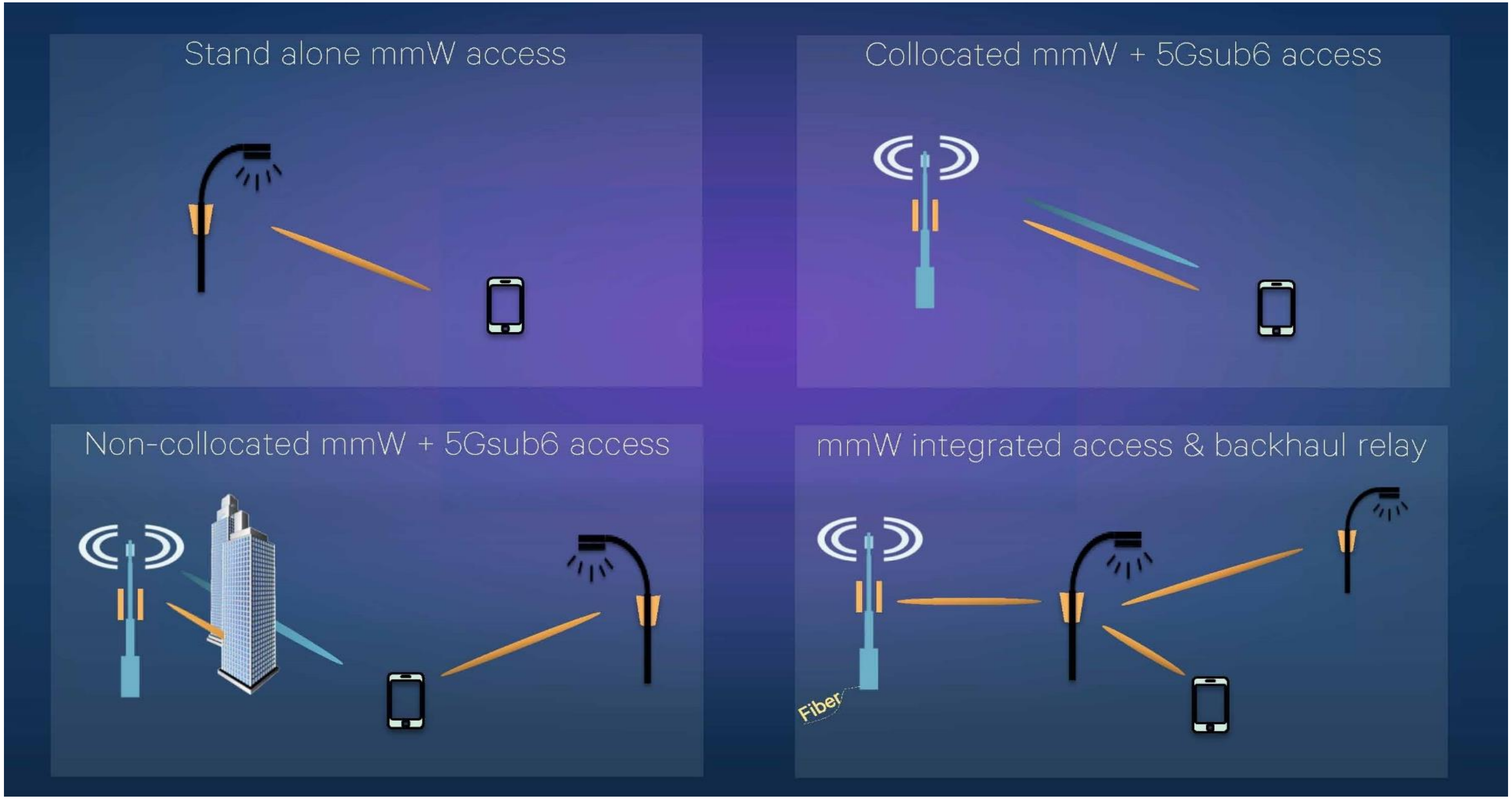
5G – System Overview



5G scope. 30 GHz links support >10 Gbps peak data rates and 100 Mbps whenever needed

Source: Nokia

mmWave & 5Gsub6 Access



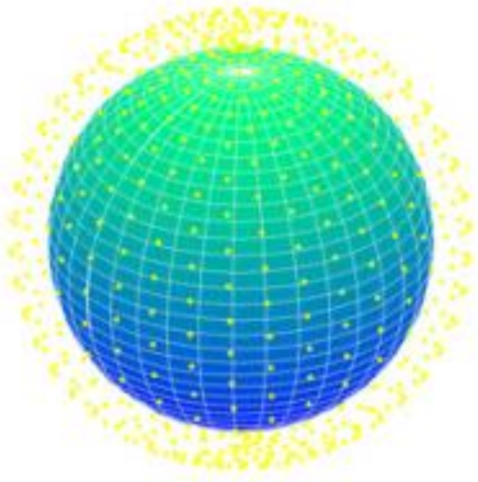
Source: Qualcomm

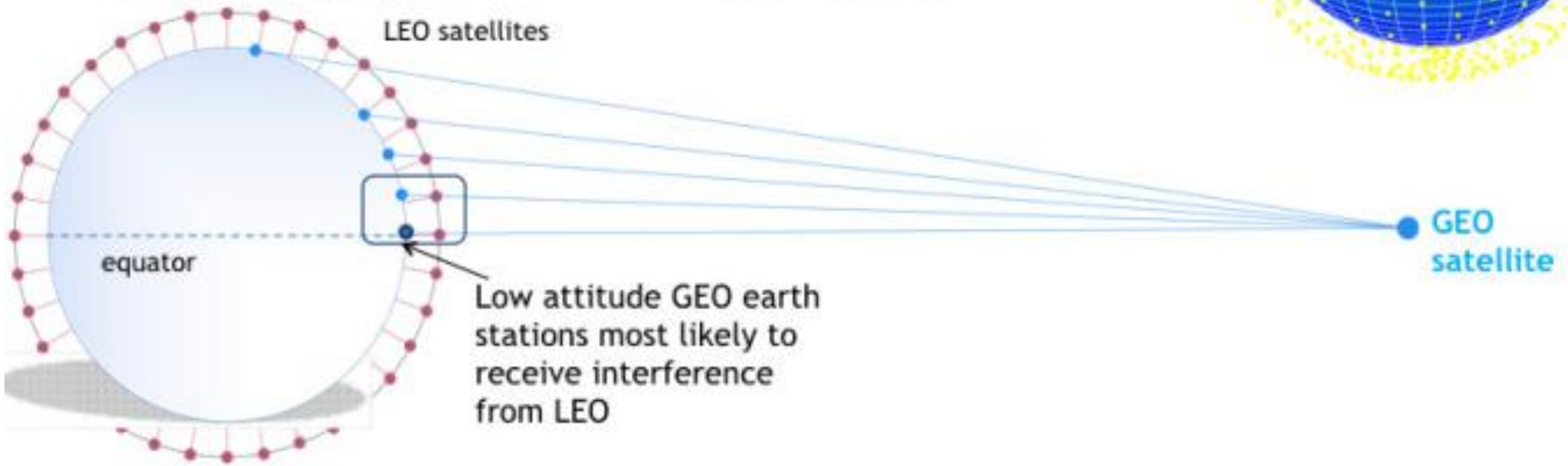
LOW EARTH ORBIT SYSTEMS

Low Earth Orbit – One Web Example

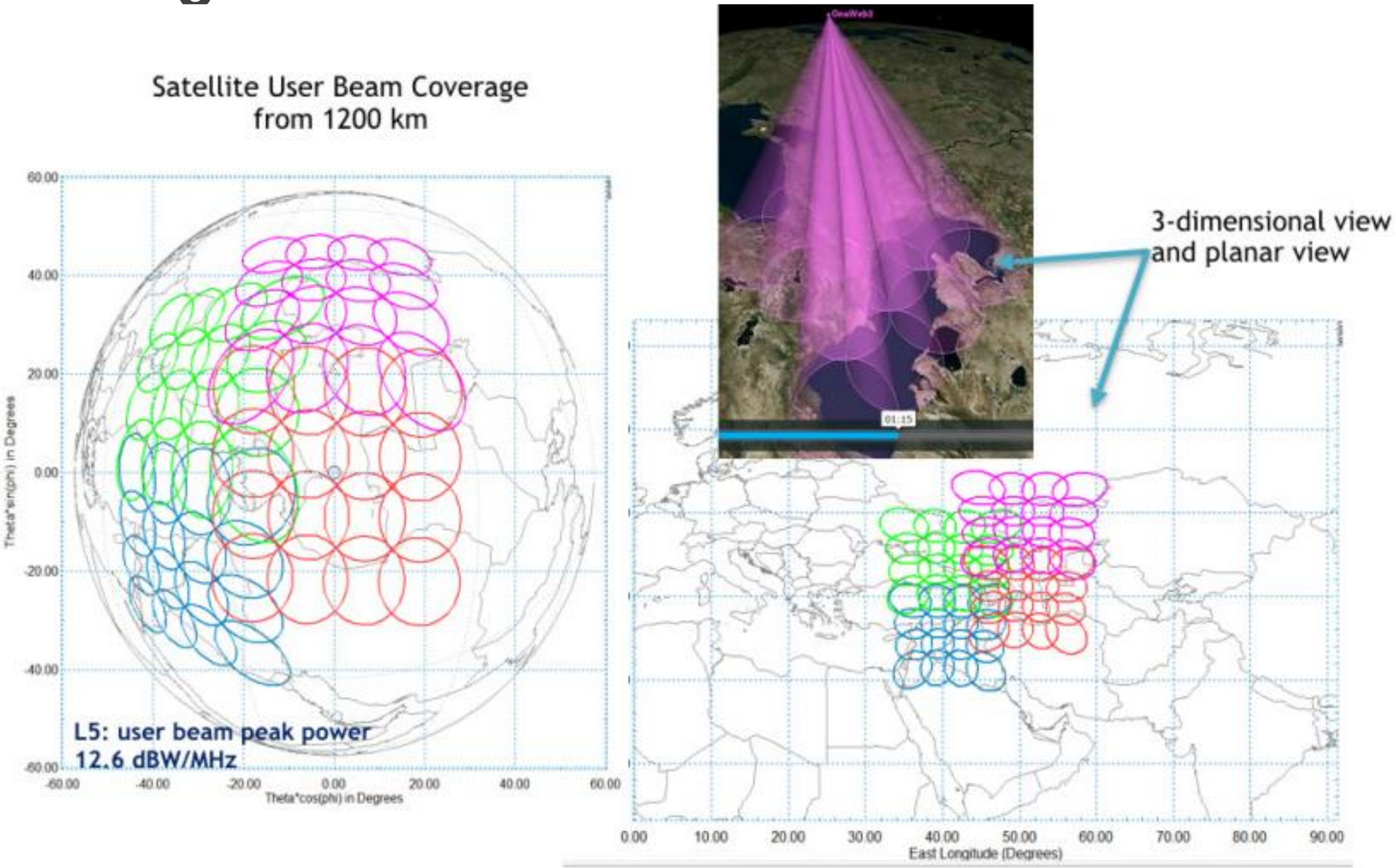
LEO Parameters		
LEO Satelite Period	110	min
LEO Satelite Altitude	1200	km
Mean Earth Radius	6371	km
LEO Orbit Circumference	47570	km
No. of LEOs in 1 plane	40	
Distance between 2 LEOs in 1 plane	1,189.2	km
Time between 2 LEOs in 1 plane	165	sec
LEO Satelite Velocity	7.21	km/sec

1200 km Altitude
720 Satellites
Ku Bands:
Standard FSS and Plan
Ka Band





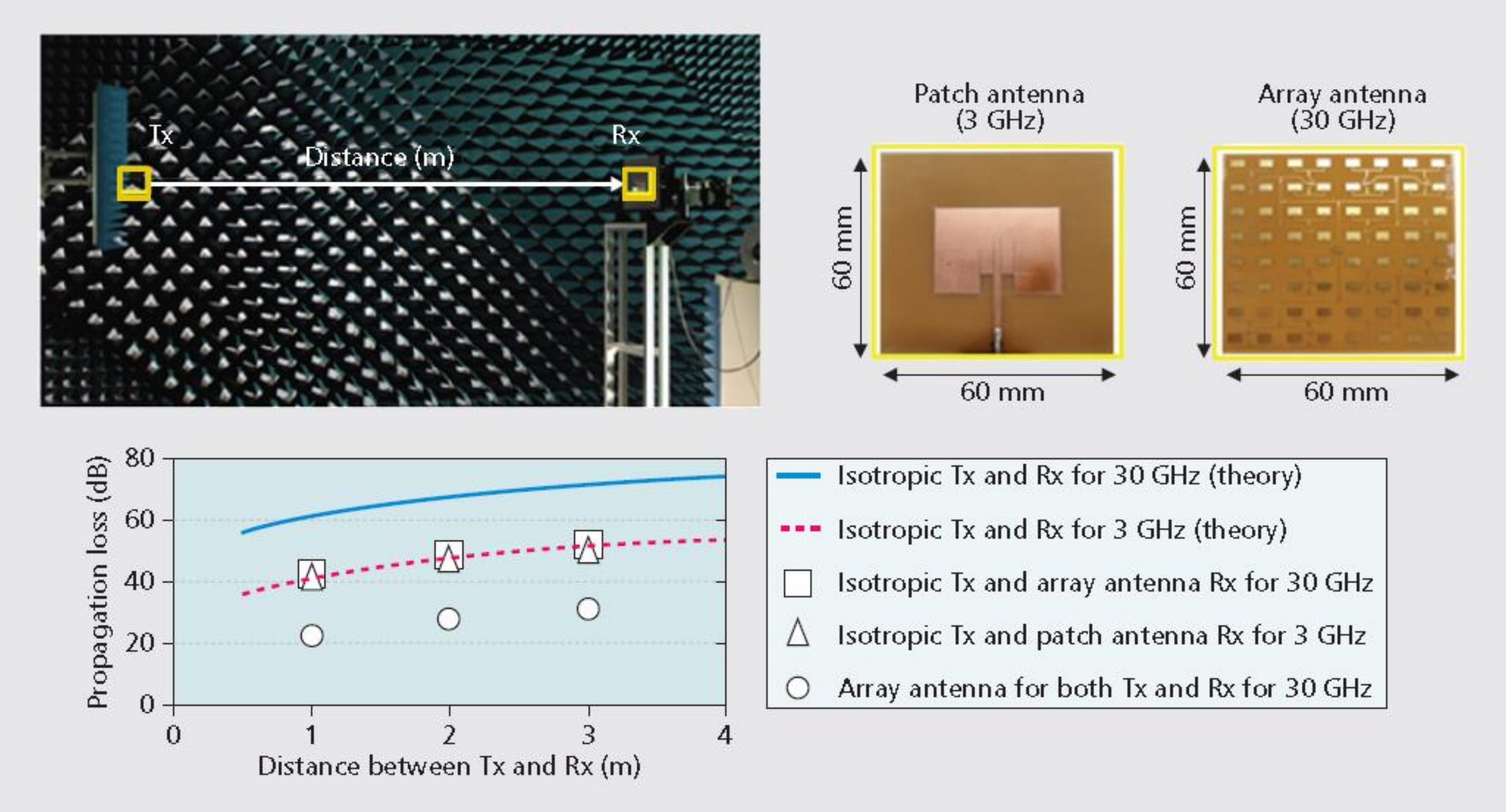
OneWeb Coverage



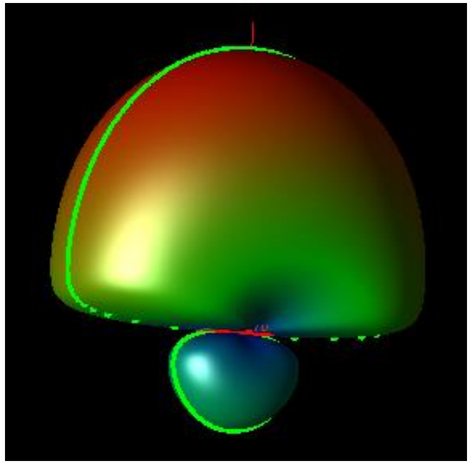
- Simultaneous footprints of 4 satellites are shown from the point of view of one (red) satellite. Note that 12 out of 16 beams of each satellite overlap with the other satellites footprints

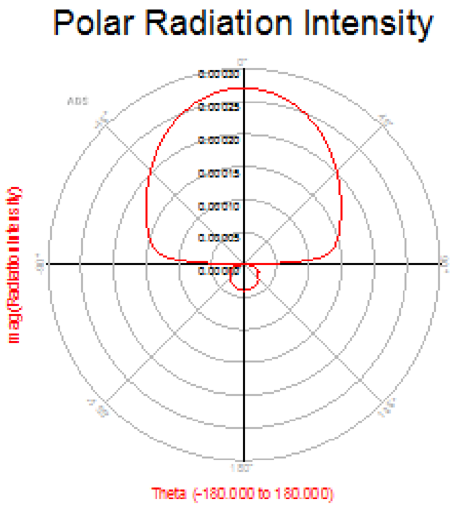
mmWave COMMUNICATION

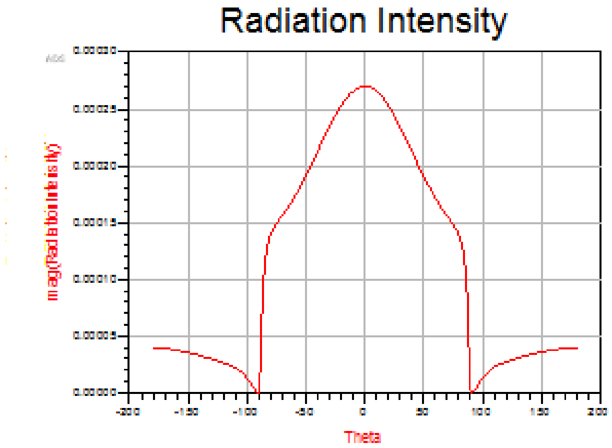
mmWave → Flux → Array Antennas

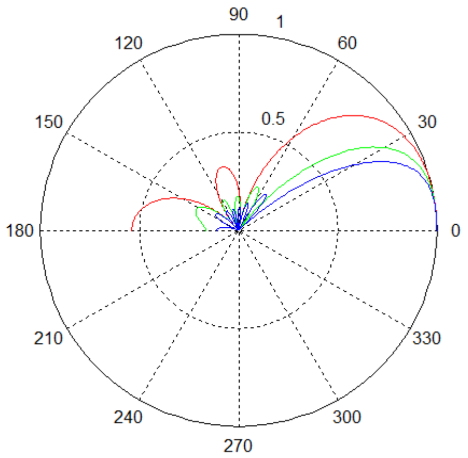


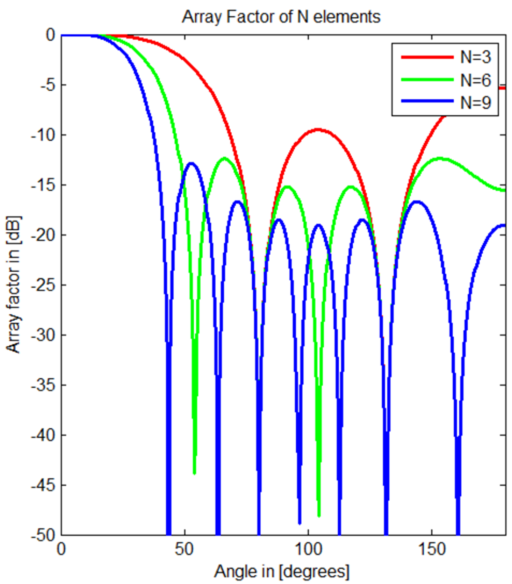
Array Antenna → Antenna Gain → Phased Array



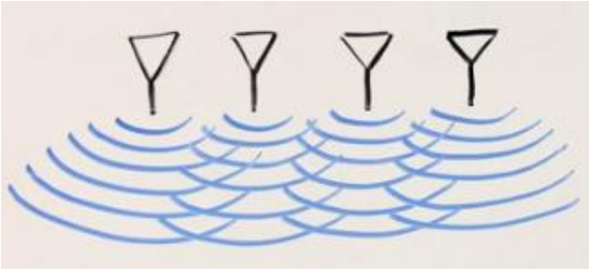




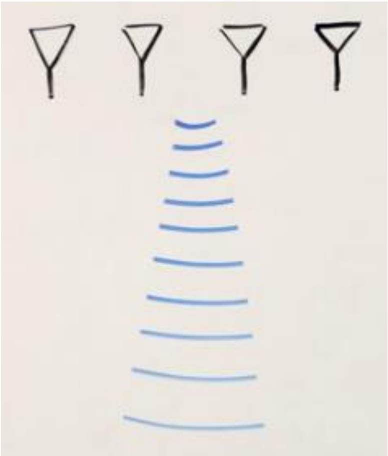




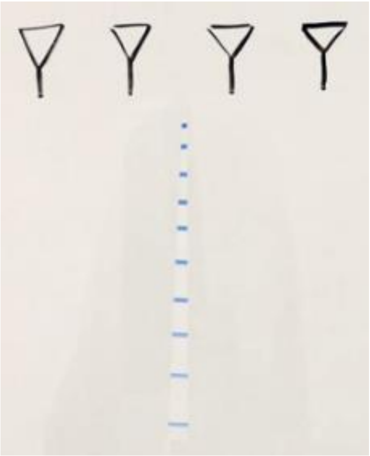
Phased Array Antenna



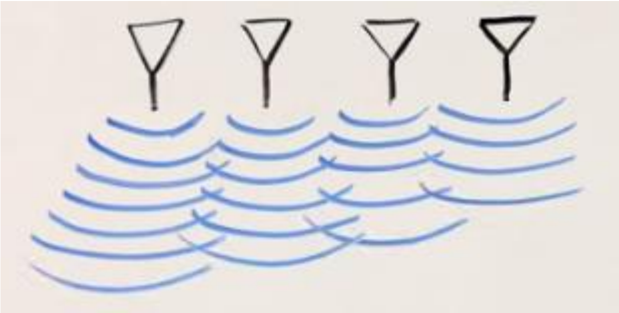
Line source



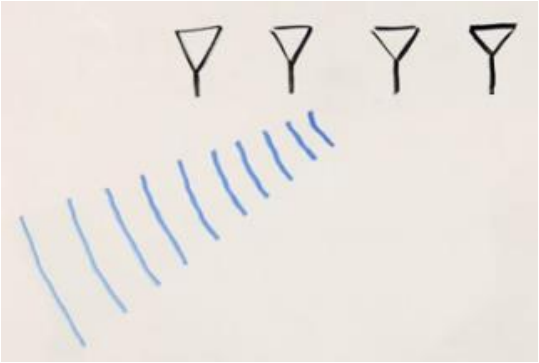
Narrow beam



More elements, narrower



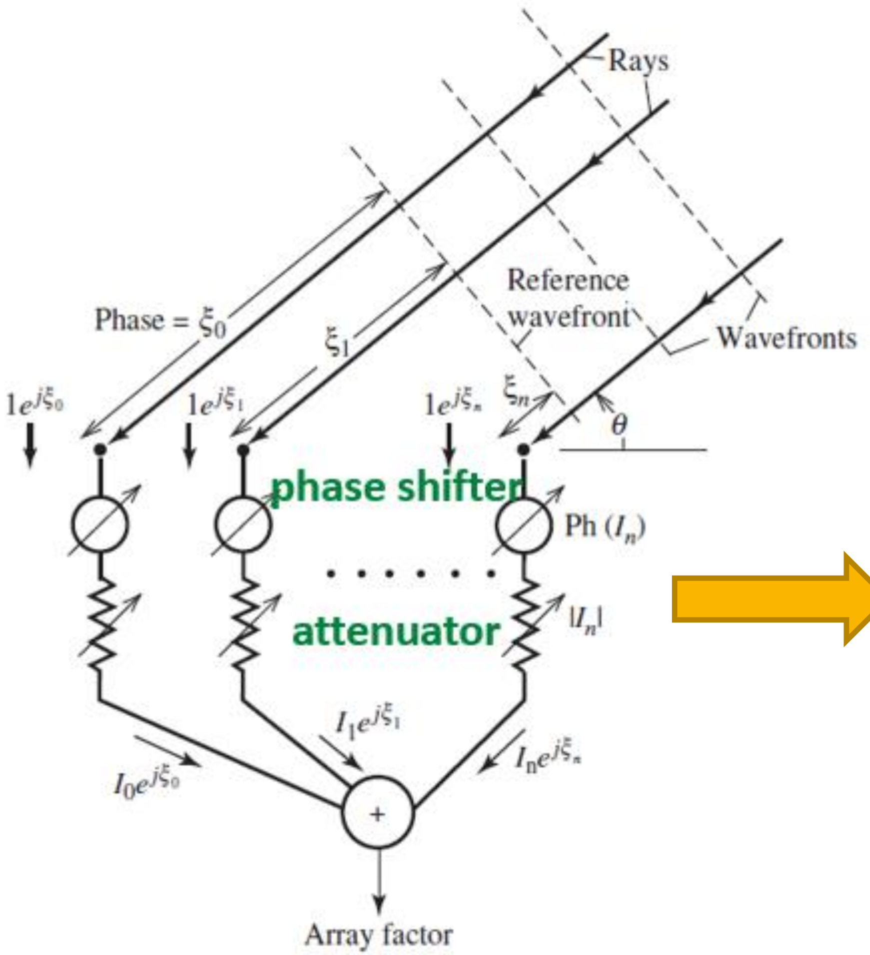
Excitation with time delays



Main beam scan

Planar array

Array Factor for Linear Case



$AF = I_0 e^{j\xi_0} + I_1 e^{j\xi_1} + I_2 e^{j\xi_2} + \cdots$

ξ_n: phase delay of the n′th element

$I_n = A_n e^{jn\alpha}$

I_n: complex current excitation

A_n: amplitude weight (attenuator)

α: phase shift weight (phase shifter)

$$AF = \sum_{n=0}^{N-1} A_n e^{jk_0 dn(\cos\theta - \cos\theta_0)}$$

θ: angle of the incident wave

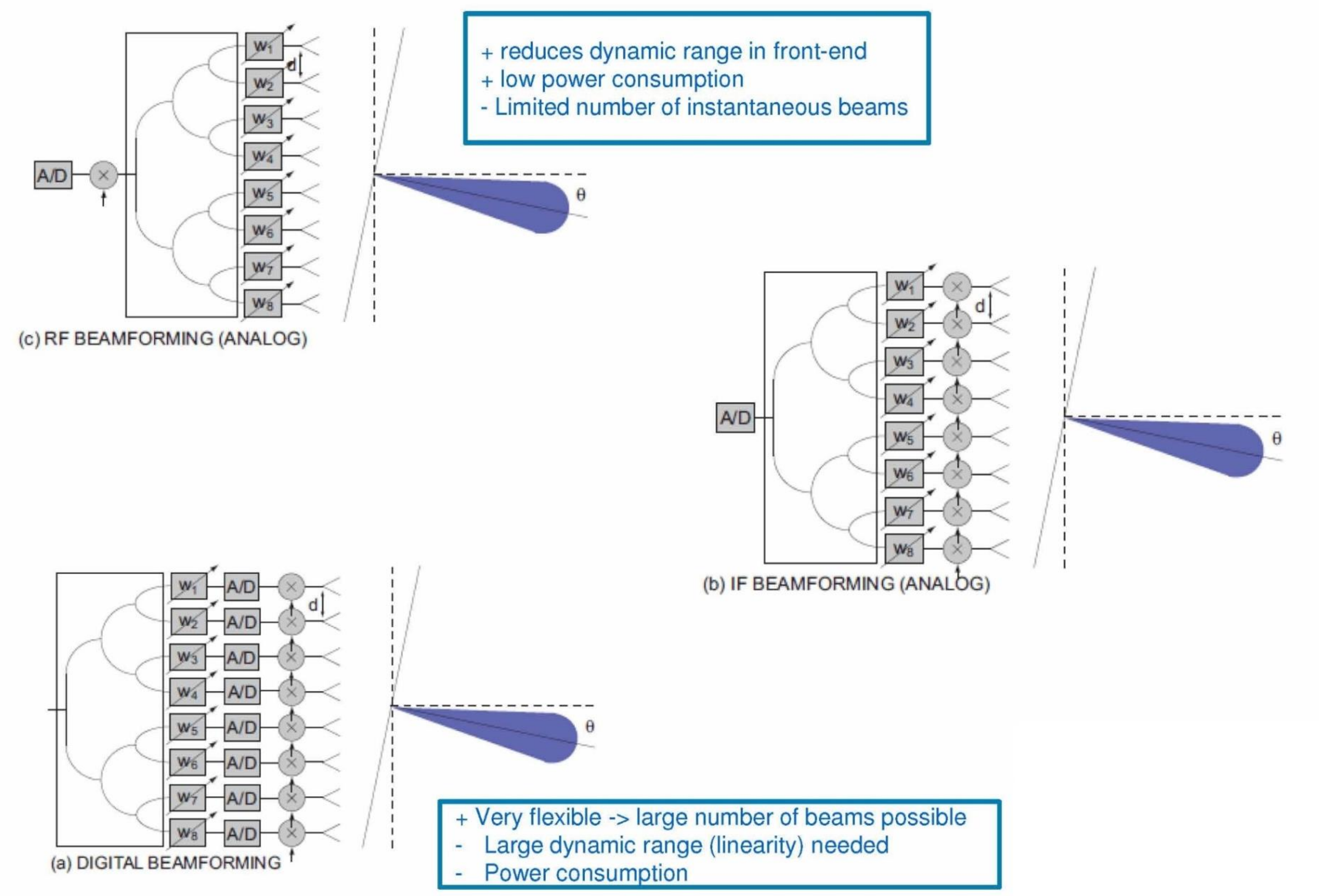
θ_0: scanning angle

d: distance between elements

N: number of elements

All these parameters help to shape the pattern

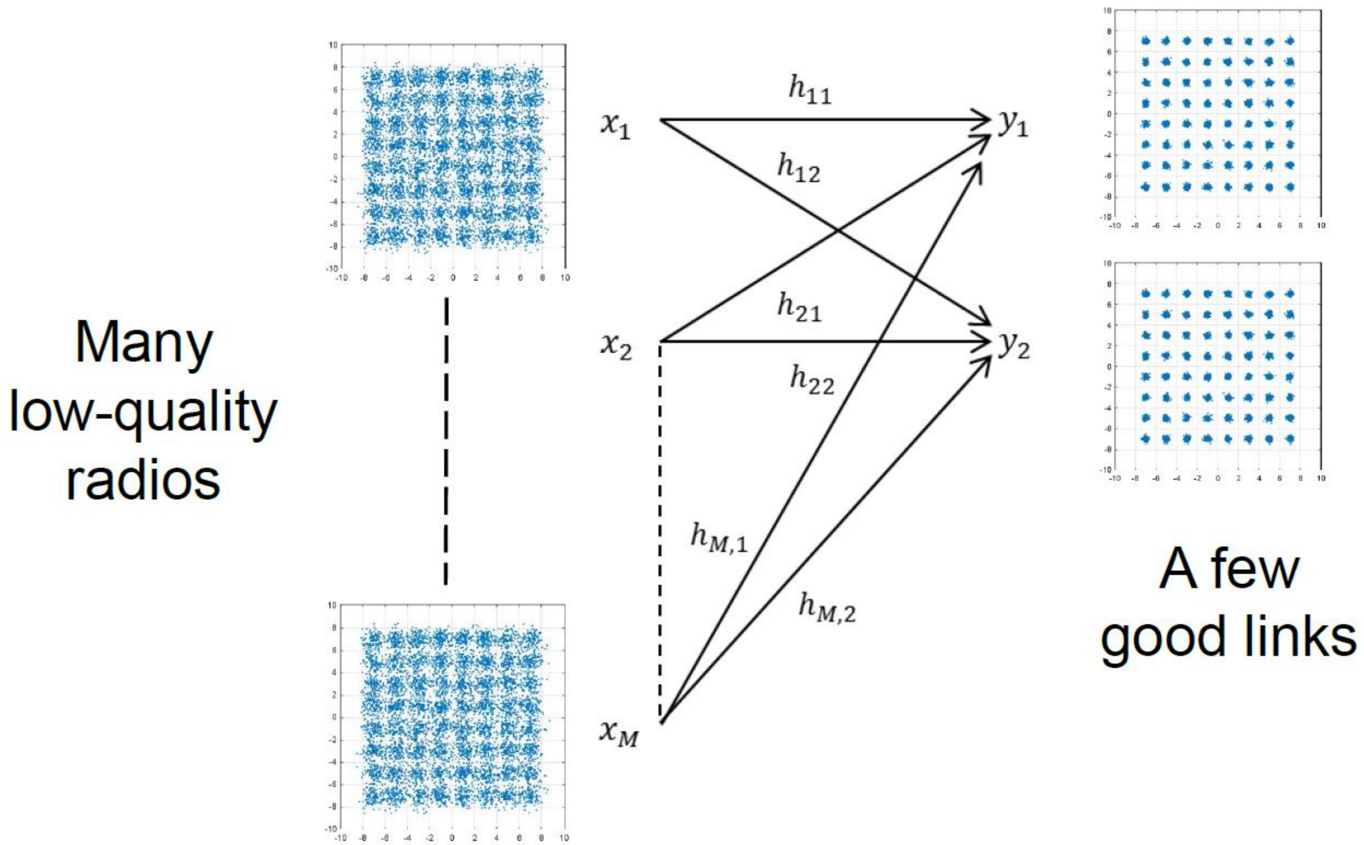
Beamforming Options



+ reduces dynamic range in front-end
+ low power consumption
- Limited number of instantaneous beams

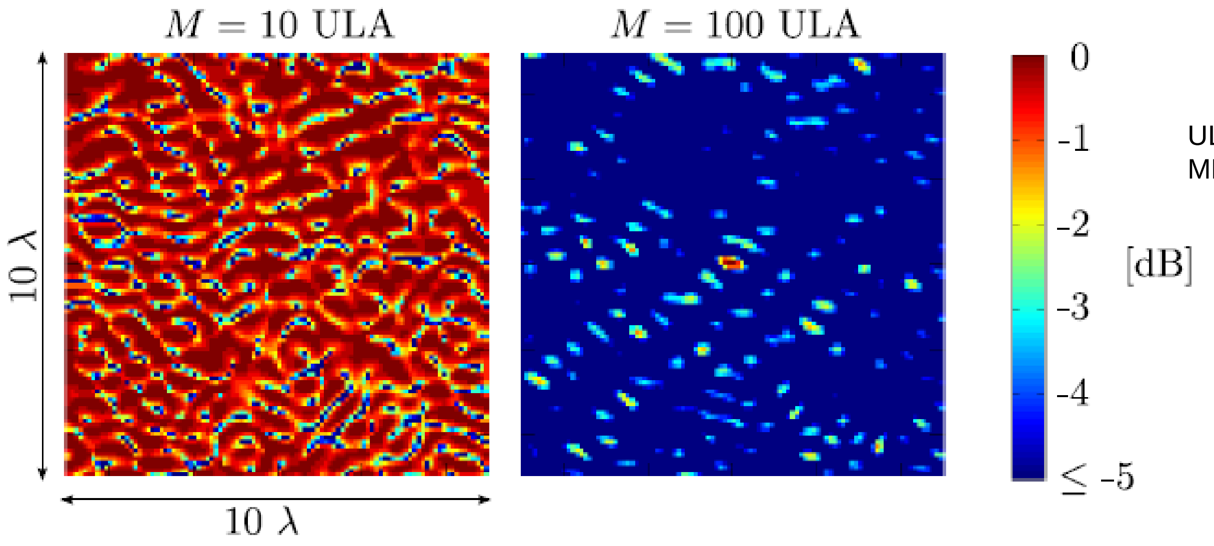
+ Very flexible -> large number of beams possible
- Large dynamic range (linearity) needed
- Power consumption

Massive MIMO – Effect of Parameters on SNR



Spatial averaging holds for all non correlated non-idealities
Noise Figure, Phase noise, IMD products, converter quantization noise

Massive MIMO – in Multi Scattering Environment



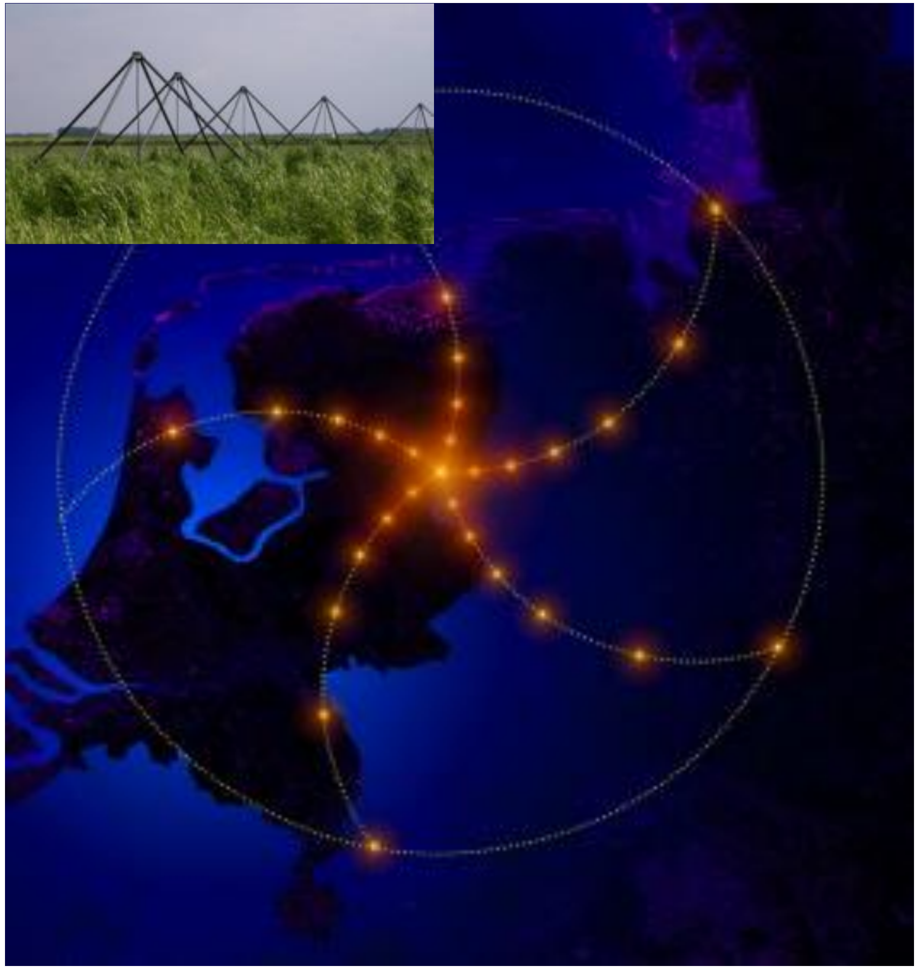
ULA = Uniform Linear Array
MF = Matched Filter

Fig. 2. Normalized fieldstrength in a $10 \times 10\ \lambda$ area centered around the receiver to which the beamforming is done. The left and right pseudo color plots show the field strength when an $M = 10$ and an $M = 100$ ULA are used together with MF precoding to focus the signal to a receiver in the center of the area.

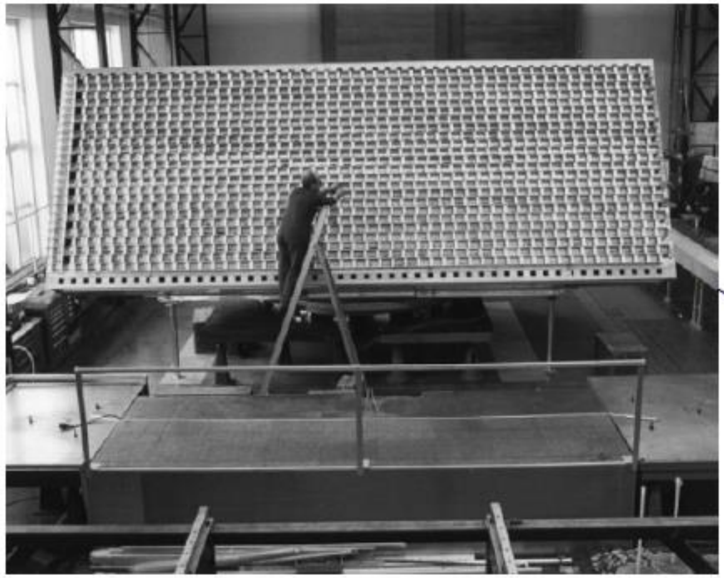
Using multi-scattering environment allows spot forming iso beam forming
⇒ Less interference between users. All users can use the full band width.

Source: F. Rusek
Lund Uni.

Existing Array Systems: Radio Observatory



Existing Array Systems: L-band Radar

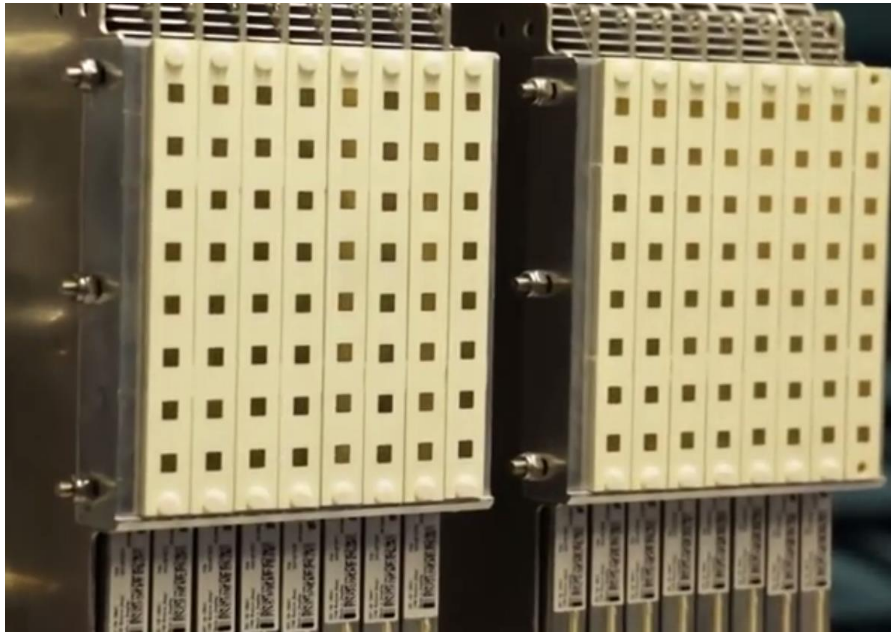


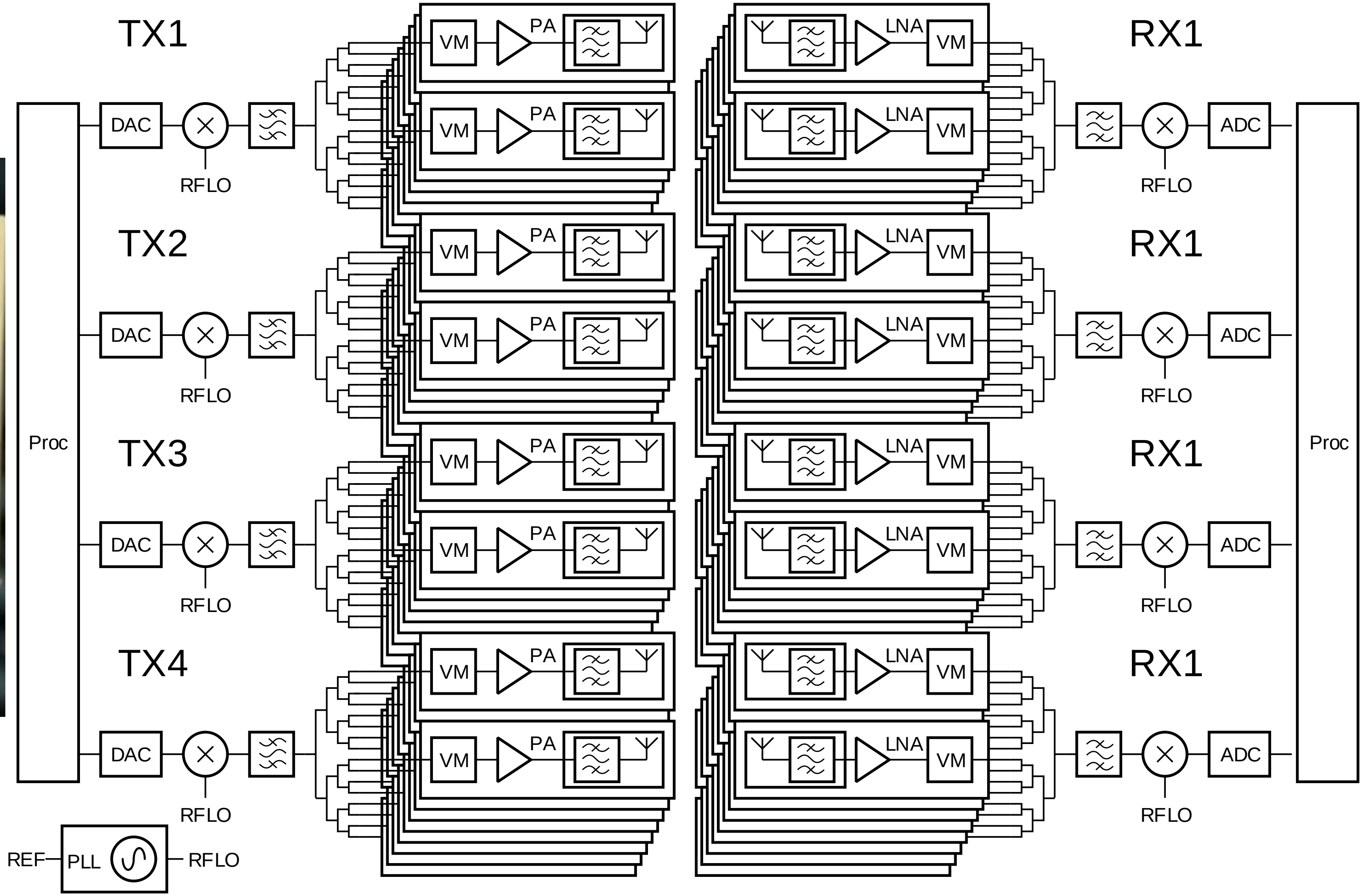
Long range L-band surveillance

With secondary radar (IFF)

ef: M.C. Van Beurden, A.B. Smolders, IEEE Trans. AP,
)02, pp.1266-1273

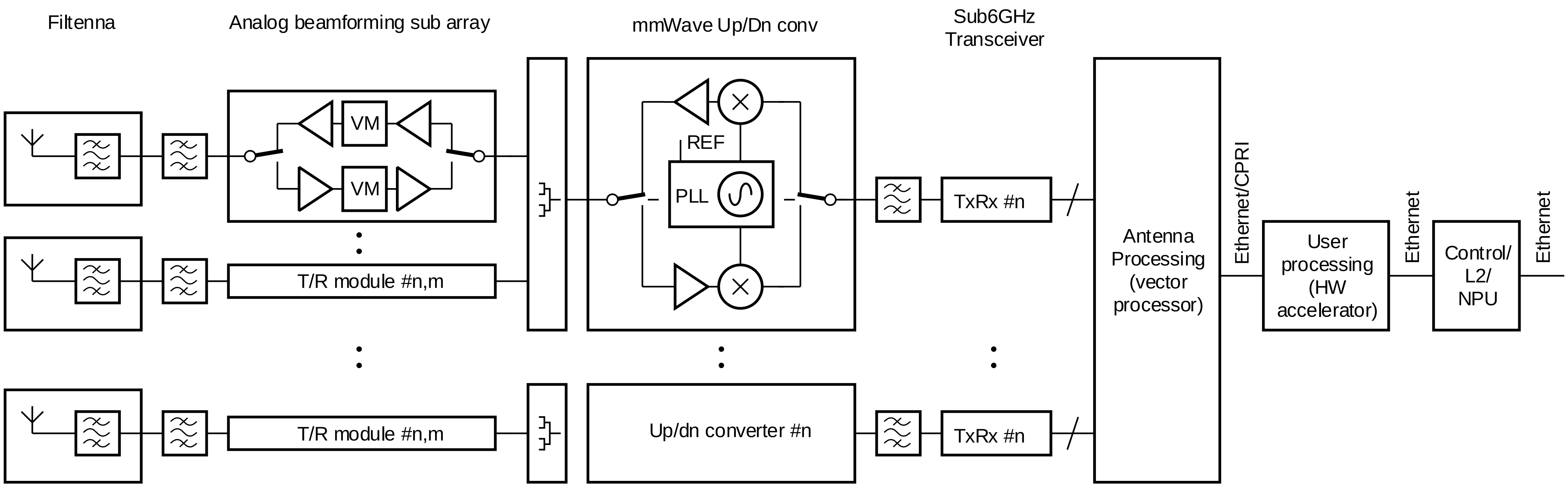
Trial Systems: Ericsson 15 GHz System



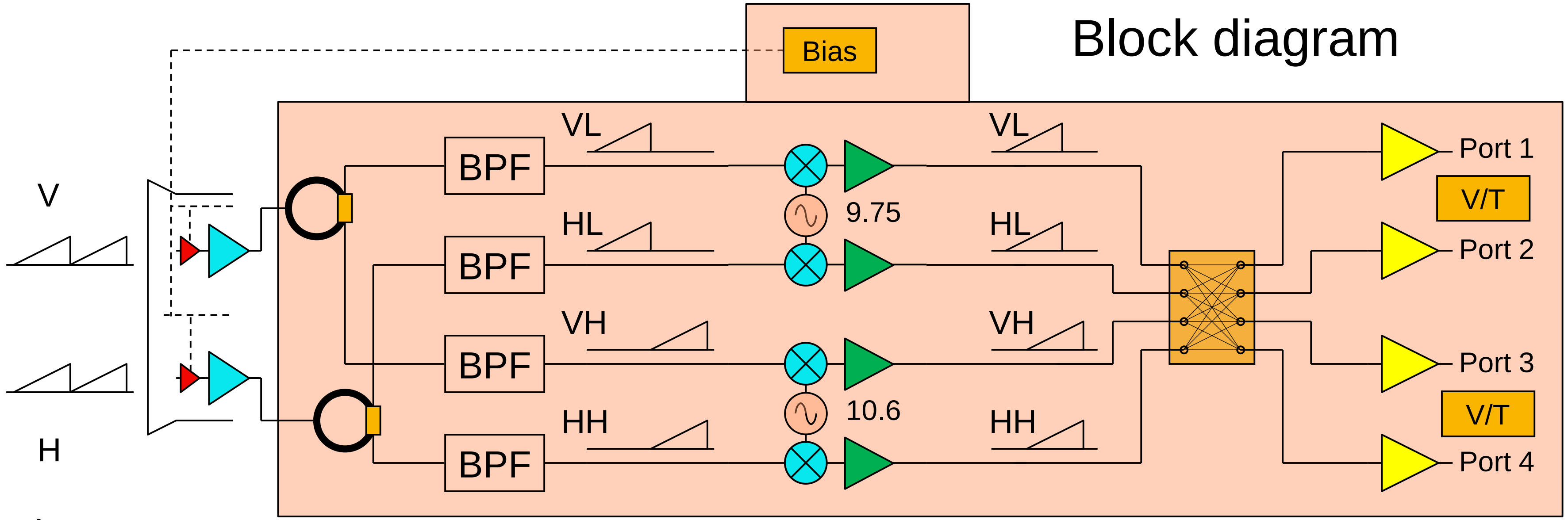


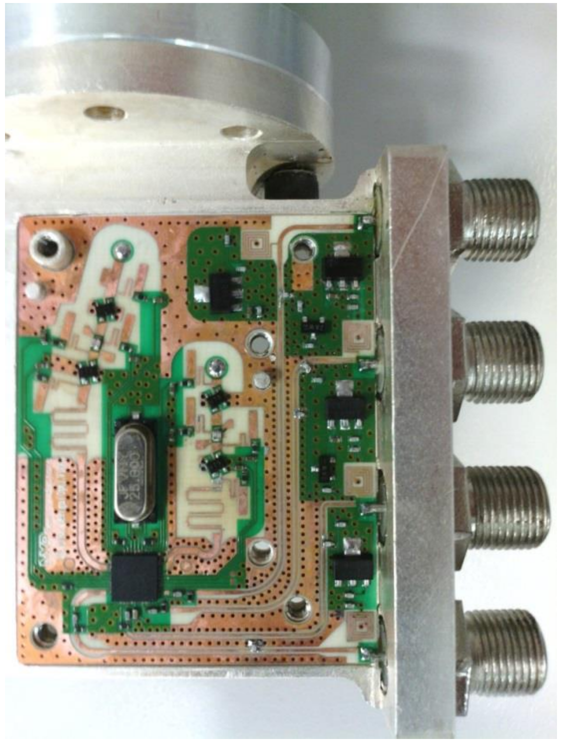
NXP

NXP Capabilities



2 RF in 4 IF out Ku Downconverter TFF1044

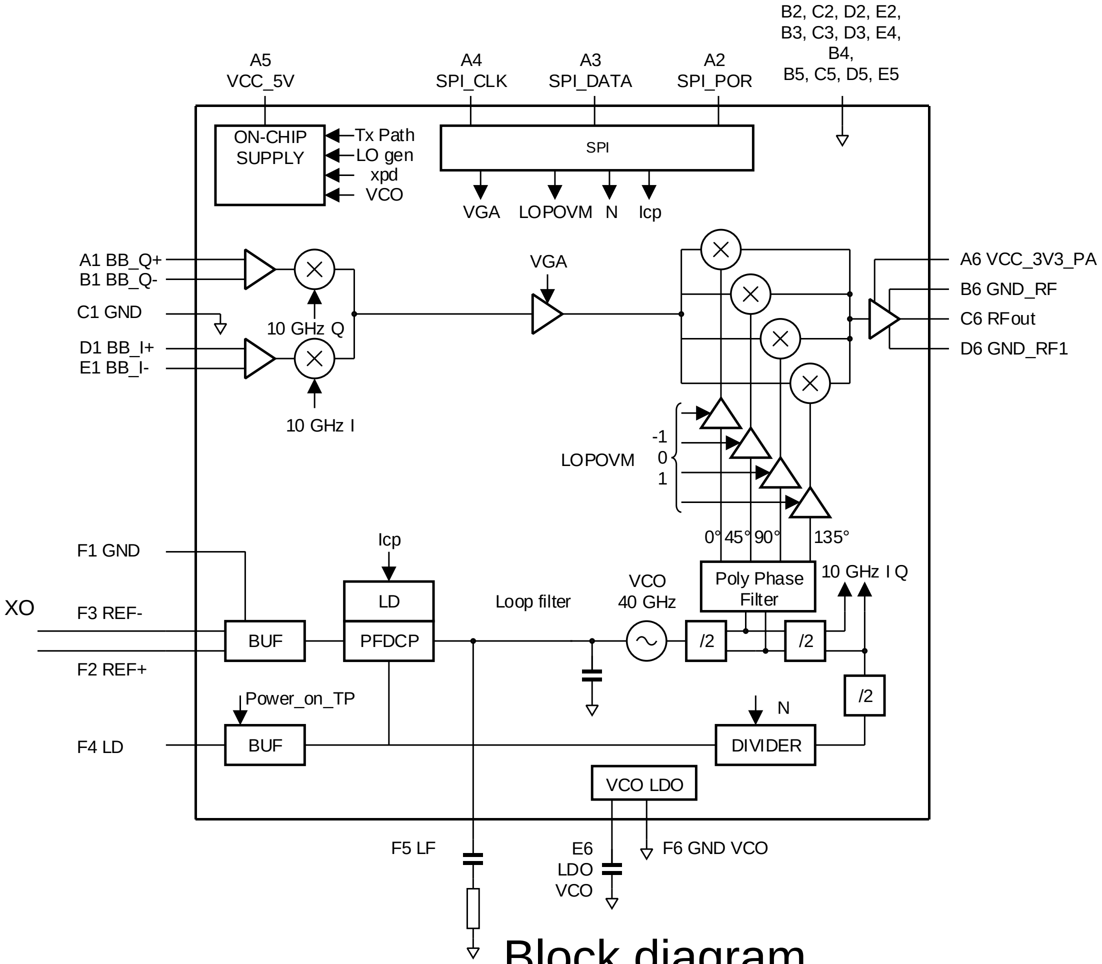




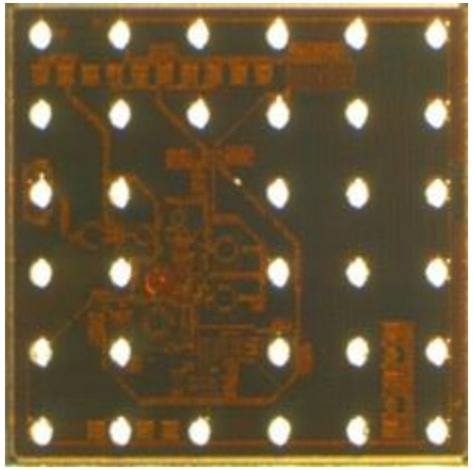
Features

- 2 RF inputs: horizontal and vertical
- On chip LO generation from 25 MHz crystal
- Alignment free LO – PLL based
- Integrated low band – high band splitter
- Integrated switch function
- Integrated V/T detection on each output
- Strong board reduction (IC 5x5 mm2)
- Very low component count

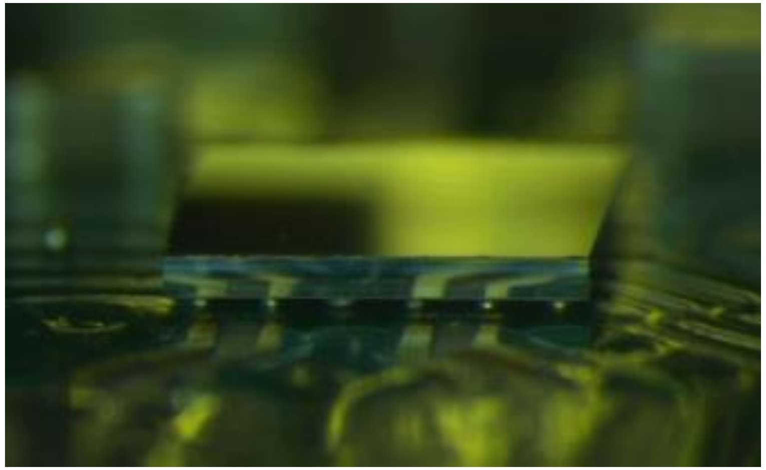
5G mmWave TX: Ka IQ Mod with LO POVM in CSP Package



Block diagram



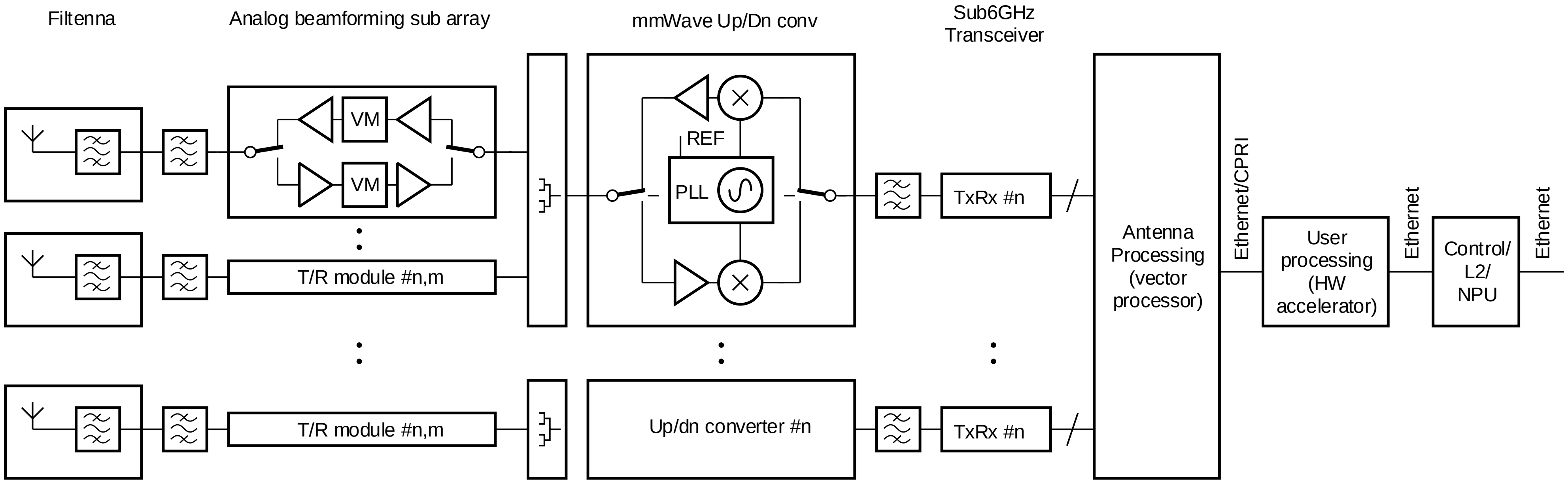
Die photo with bumps



Detailed soldered product

Evaluation board

NXP Approach to 5G



Frequencies

- 24.5 – 27.5 GHz
- 26.5 – 28.5 GHz
- 27 – 30 GHz
- 37 – 43.5 GHz
- 57 – 64 GHz
- 64 – 71 GHz

CONCLUSION

The New NXP – Your Ideal Partner for 5G

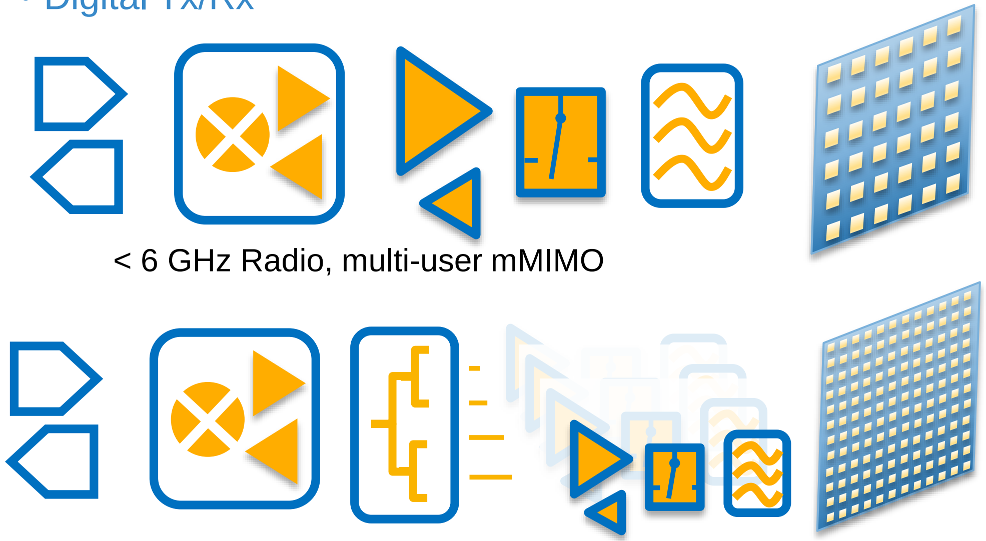
- Wireless HW acceleration
- ARM+NPU

Base Band Processor

- Signal converters
- Vector Processors

Digital Front-End, Antenna Processor

- Digital Tx/Rx



< 6 GHz Radio, multi-user mMIMO

> 6 GHz Radio, hybrid beamforming/ mMIMO

- Power Amplifier
- Low Noise Amplifiers
- Voltage Control Amplifiers
- T/R switches
- Modules

- Hybrid beamforming (analog + digital)
- Vector modulators
- PAs, LNAs.
- Up and down conversion from cm/ mm-wave frequency

- Macro BTS with < 6 GHz radio only, multi-user massive MIMO
- Small Cells with > 6 GHz radio, hybrid beam forming, MIMO and < 6 GHz anchor radio, multi-user massive MIMO

SECURE CONNECTIONS
FOR A SMARTER WORLD

ATTRIBUTION STATEMENT