Modern Active Antenna Technologies and Design Optimization for Base Stations

Short version of the presentation by

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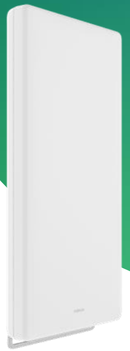
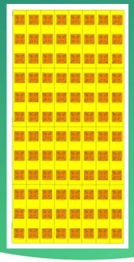
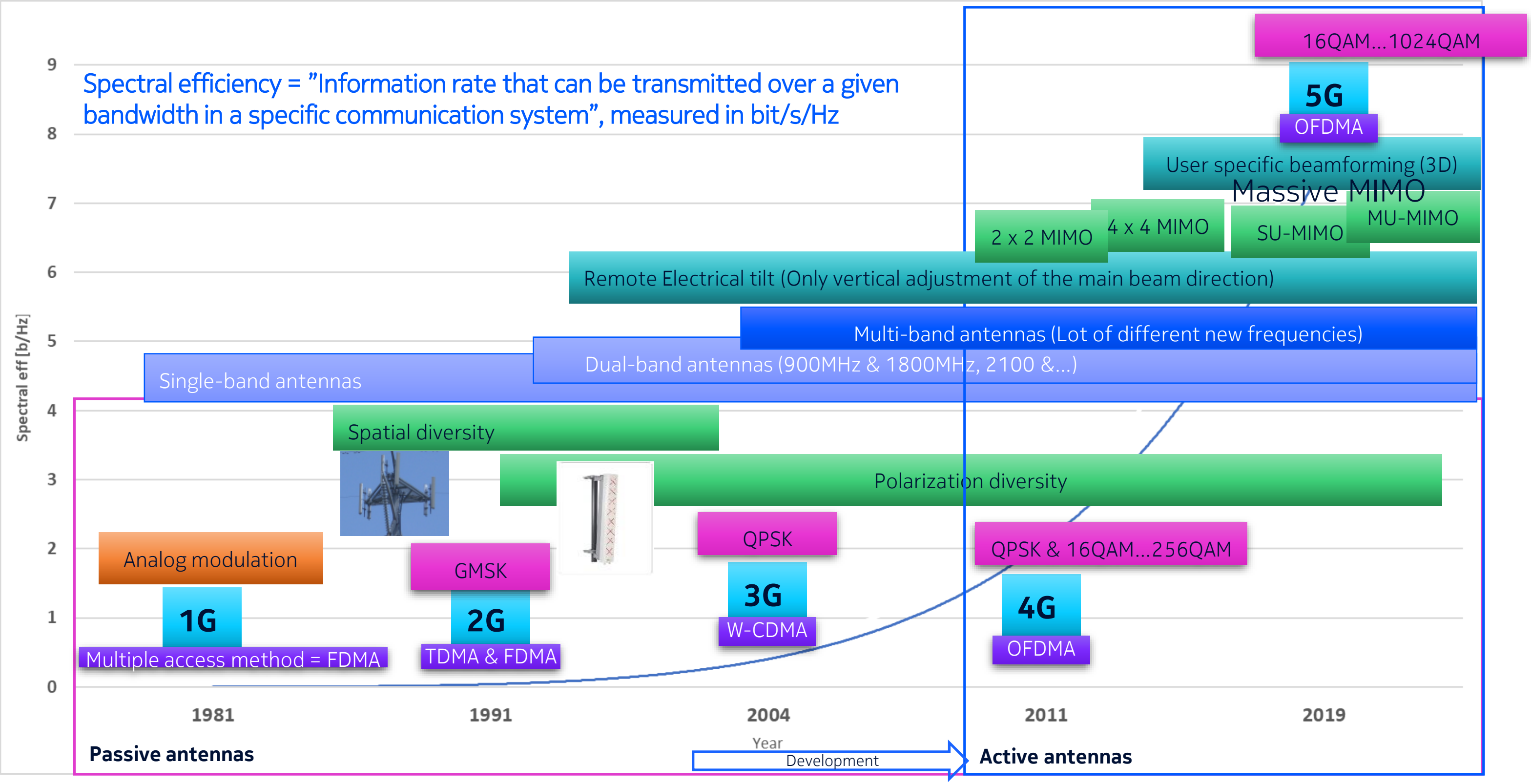




1. Evolution from 1G to 5G



Source: BTS and RF Basics Lecture 2022 by Kimmo Myllymäki (Nokia internal training)

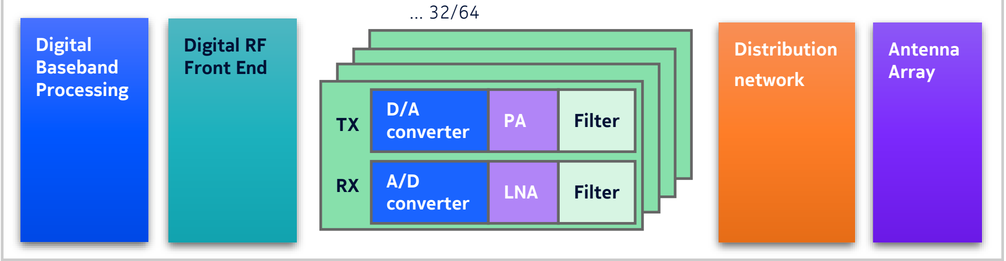
2. Beamforming/-Steering Methods

The phase shifts used to achieve beamforming can be applied either:

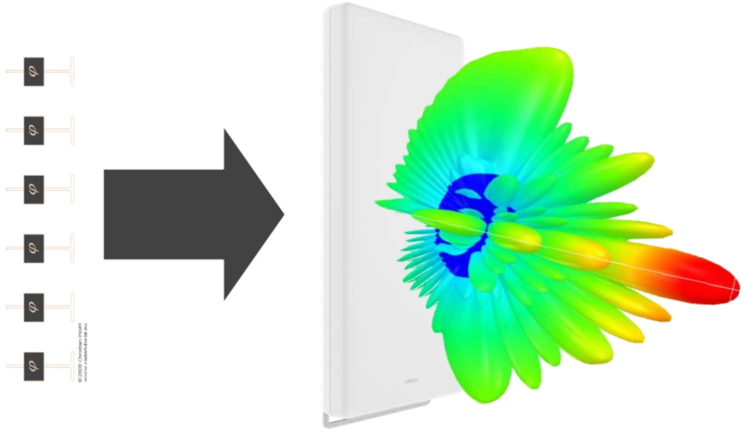
- at baseband (**Digital beamforming**)
- at RF (**Analogue beamforming**)
- combination of digital and analogue/electrical phase shift (**Hybrid beamforming**)

In 5G the beamforming is 3D beamforming => Beam is steered in both azimuth and elevation.

Hybrid BF used in order to reduce the number of TRXs



Active Antenna architecture with Digital Beam Forming

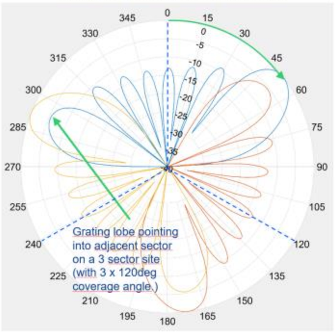


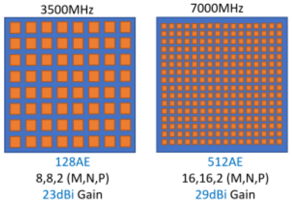
Sources: Beamforming_learning steps_1 basis.ppt / Amir Jiang / 09.2020
Beamforming and mMIMO basicsLecture 2021 by Kimmo Myllymäki (Nokia internal training)

3. Practical Design Challenges

1. **Grating lobes**
   - If radiator spacing is bigger than **0.5λ** , lobes emerge with large enough steering angle
   - Grating lobes cannot be tapered away
2. **Wideband problems with arrays and steering**
   - Balance between gain, BW, steering range (sidelobes & grating lobes) and isolation
3. **Coverage & array size & frequency**
   - Same cell size = same antenna area -> Path loss increases when frequency gets higher and that is why there needs to be more radiators.
   - Doubling the frequency requires 4x radiators. The antenna area is same, because the spacing is 0.5x in hor and ver
4. **Near and far coverage**
   - 2x1 or 3x1 vertical subgroups/array elements for gain&cost optimization ->Grating lobes
   - Grating lobes create disturbance (both uplink and downlink) and limit vertical steering range
5. **Calibration accuracy**
   - Phase and amplitude accuracy have significant effect on the sidelobe levels and null location & deepness -> Performance of the unit

Azimuth patterns of 3 sectors





4. Multi Discipline Design and Commercial Aspect

- **Optimized beam forming and radio performance requires combined expertize from different domains -> there is need for multi discipline knowhow**
  - Telecommunications
  - Radio architectures
  - Antenna & RF design
  - Digital design
  - Signal processing & algorithms
  - Software
  - ML/AI (Machine Learning / Artificial Intelligence)

- **Customer buying radios are interested also other things than just RF performance**
  - Product reliability
  - Usability: installation & size & weight
  - Energy consumption
  - Thermal performance
  - (Cost ☺)

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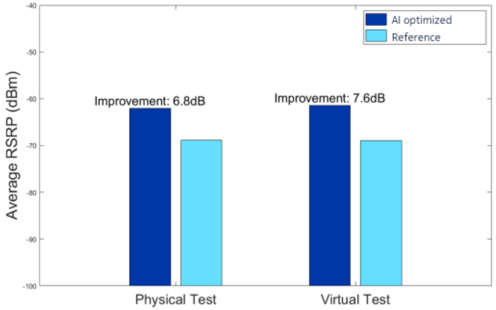
5. Design optimization and network performance

- Nokia is using the latest Virtual Design methods
- Multi-object optimization, ML & AI
- An example project of AI optimized antenna variant
  - ML/AI optimized antenna design (Multi-object optimization)
  - Virtual build and virtual testing compared to real prototype and field testing
    - Virtual design match extremely well with the prototype measurement results
    - Virtual drive test match well with the actual drive test with real prototype

Source: Pyry Salonpää & Tero Kangasvieri & Iikka Finning & Tomi Haapala /Nokia

Comparison of radios in the field test (Physical vs. Virtual)



Both virtual and physical field tests show that the AI optimized 5G mMIMO antenna improves average signal strength received by the UE at OuluZone environment.

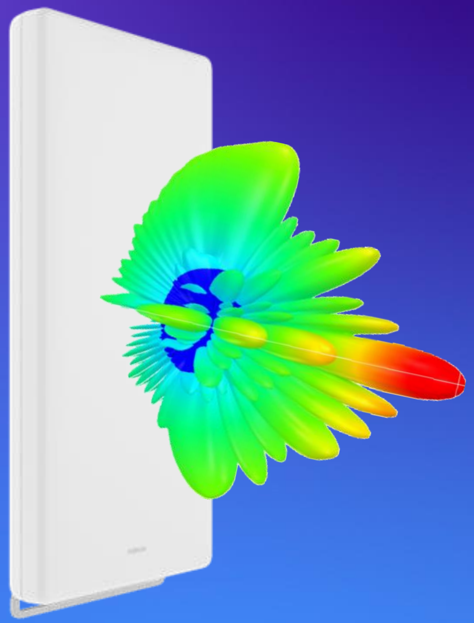
  | Public

Summary

- Using wide BW, high modulation scheme, MIMO, Beamforming and Massive MIMO enables high troughput and high capacity.
- 5G beamforming methods: Digital, Analog and Hybrid.
- Spacing, Gain, BW, Grating lobes, Steering range

  => Always a compromise (cannot optimize everything at the same time).
- Optimized beam forming and radio performance requires combined expertize from different domains -> there is need for multi discipline knowhow
- Customer buying radios are interested also other things than just RF performance
- Nokia is using the latest virtual design methods

  => Simulations and measurements correlate well



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