Project: IEEE P802.15 Working Group for Wireless Personal Area Networks (WPANs)

Submission Title: A first 300 GHz Phased Array Antenna
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Re: -

Abstract: A concept of a phased array operating at 300 GHz with horn elements and some simulation and measurement results are presented.

Purpose: Provide Information to the Interest Group

A first Phased Array Antenna with horn elements operating at 300 GHz

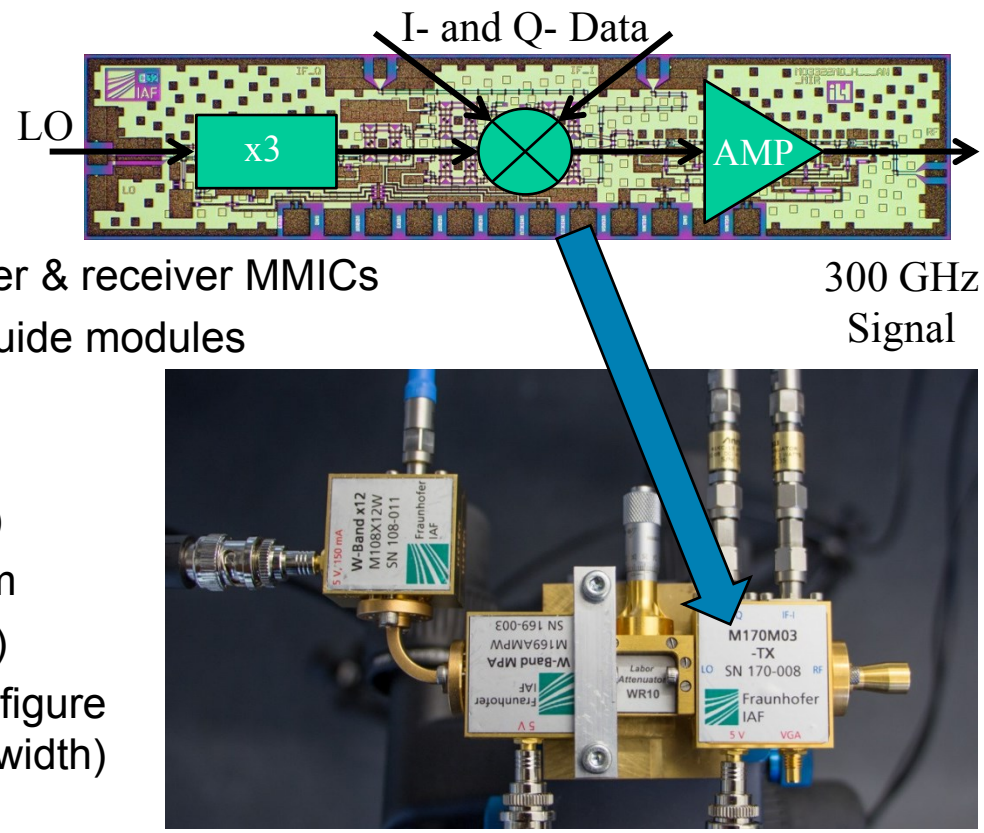
Outline

- **TERAPAN Framework**
- **Phased Array Antenna at 300 GHz**
- **Performance in Simulations**
- Measurement Results
- Summary

TERAPAN – SISO-Link

- Collaboration project (University of Stuttgart, Fraunhofer IAF, TU BS)
- 35nm GaAs mHEMT
- Fully integrated 300 GHz transmitter & receiver MMICs
- Compact high performance waveguide modules
- Link budget
  - -4.0 dBm transmit power
  - +24.2 dBi horn antenna gain (Tx)
  - -88.0 dB free space path loss 2 m
  - +24.2 dBi horn antenna gain (Rx)
  - -(-59.2 dB) receiver noise (noise figure 6.7 dB, 64 GHz bandwidth)

  = 15.6 dB SNR

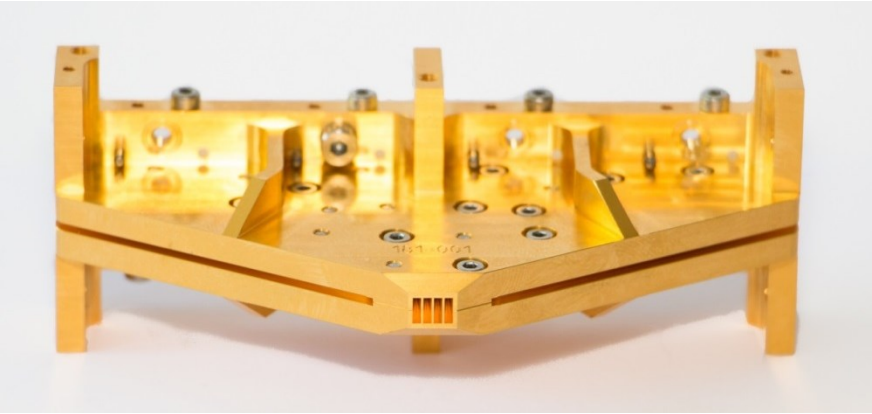


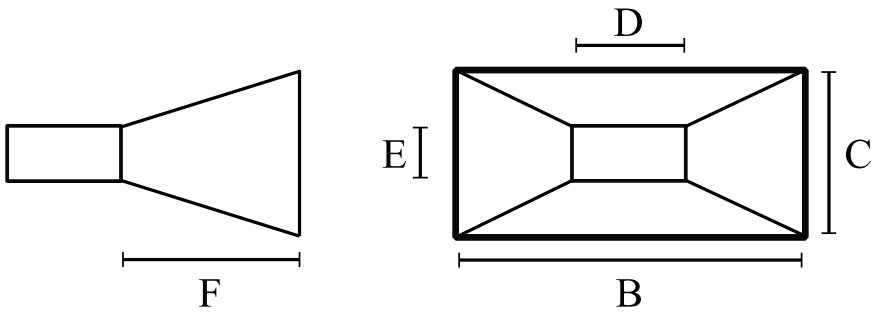
- Successfully demonstrated 64 Gbit/s data transmission with QPSK (limited by measurement equipment and linearity)

Constraints and Targets for the Design

- Max. **4 channels**
  - Max. number of available AWG channels
  - Enough for beam steering demonstration
- Standard **WR-3 wave guide flange** for each element
  - Easier characterization of components
  - Practical reasons (easy exchange in case of defect, etc)
  - Flexibility
- Operational frequency range 275 to 325 GHz
- At least a **gain of 20 dBi** (whole array), 14 dBi single element
  - SISO-link used 24.2 dBi horn antenna
  - Transmitter: 20 dBi (array gain) + 6 dB (4 channels with the same power)
- Linear array in one dimension
  - Narrower main lobe
  - Better steering capabilities than 2x2
- Manufacturability

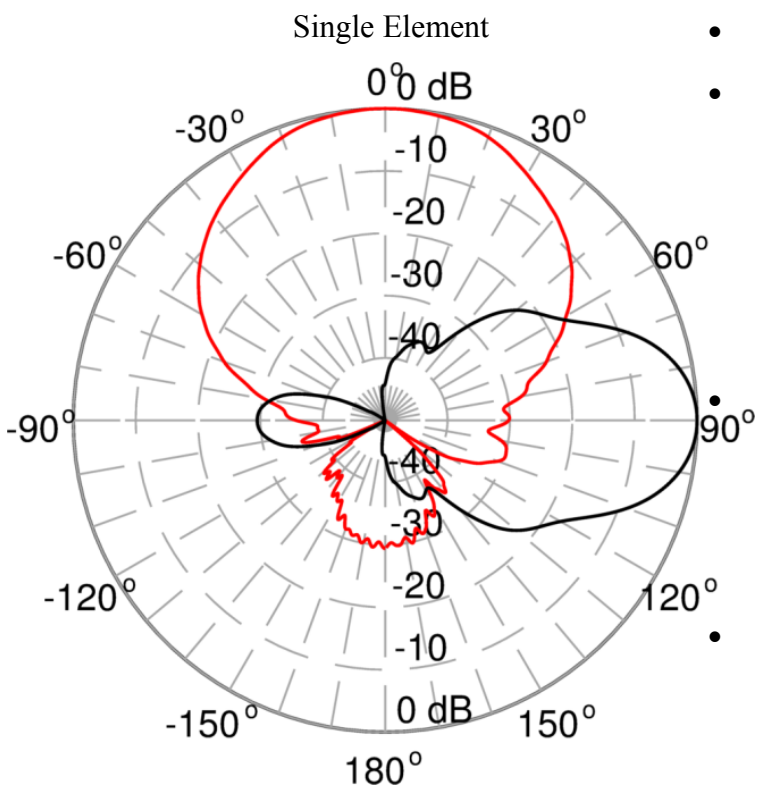
Proposed Antenna





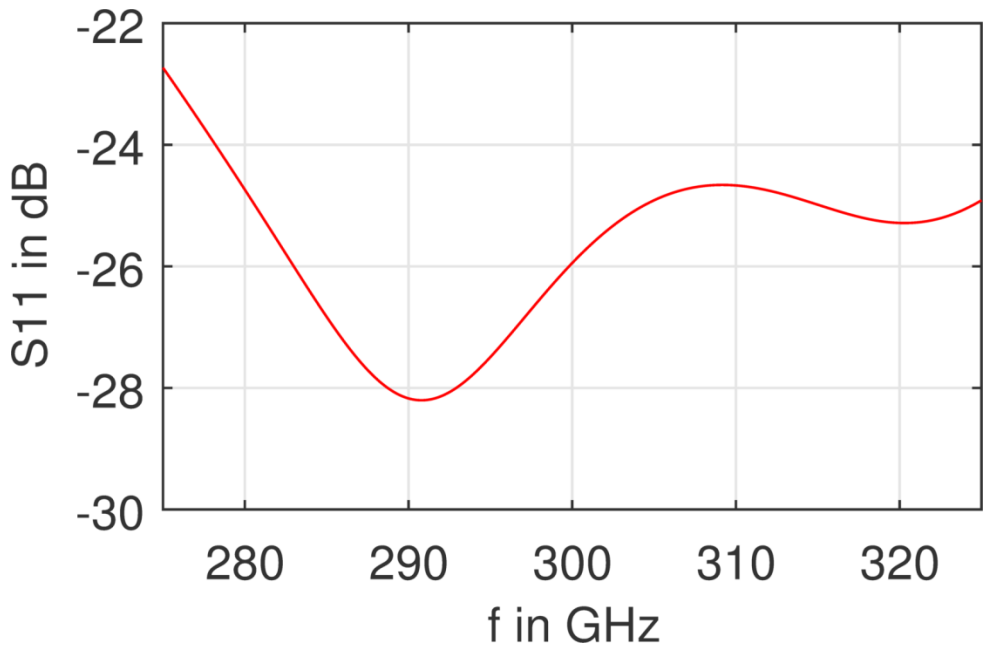
Parameter	Size
B	3.0 mm (horn width)
C	1.0 mm (horn height)
D	0.8640 mm (WR3)
E	0.4320 mm (WR3)
F (flare)	3.577 mm
spacing	1.25 mm= C + 0.25 mm

Simulation Results – Single Element



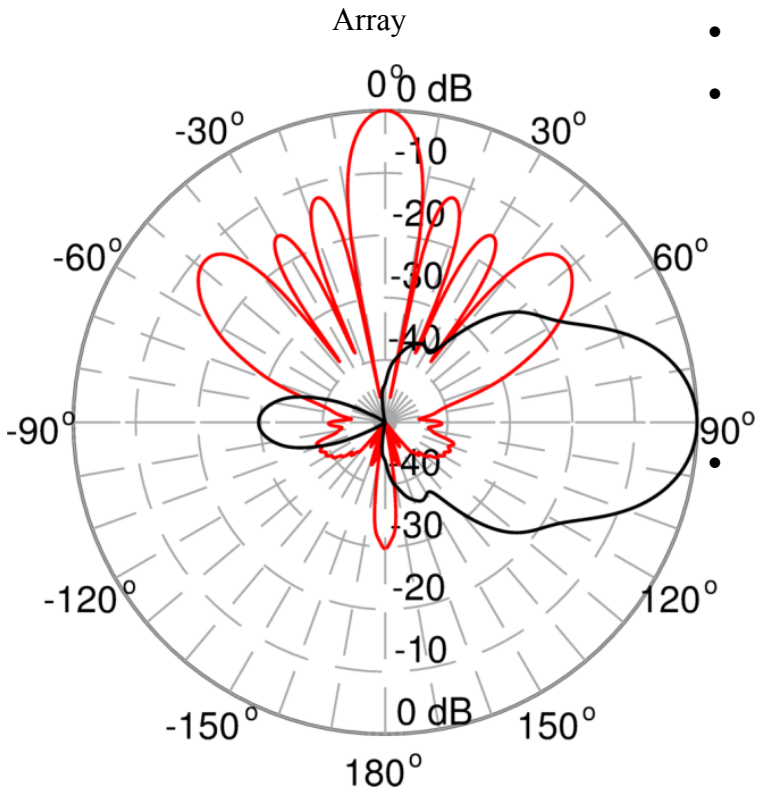
- 300 GHz Pattern
- Single (inner) horn
  - **14.8 dBi gain**
  - 50.0° horizontal HPBW (along width)
  - 23.6° vertical HPBW (along height)
- Outer elements
  - -0.2 dB less gain; Horizontal HPBW approx. 2° wider
- Average S11 of -25.7 dB; max. -22.7 dB

Simulated Impedance Matching



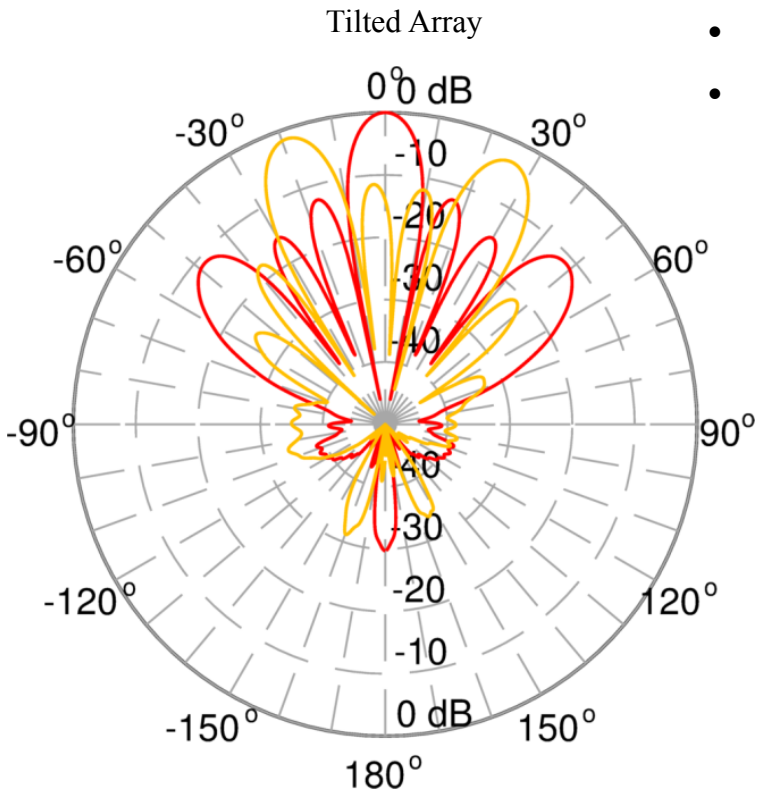
- Average S11 of -25.7 dB; max. -22.7 dB

Simulation Results – Array



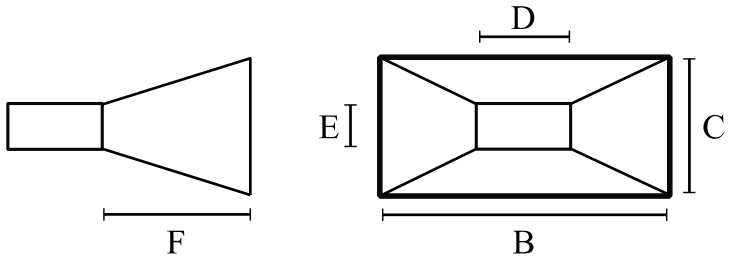
- 300 GHz Pattern
- Array
  - **20.7 dBi gain**
  - 10.3° horizontal HPBW (along width)
  - 23.6° vertical HPBW (along height)
  - Grating lobes
- All values for 300 GHz with Time Domain Solver of CST Microwave Studio
  - For 275 GHz 19.9 dBi, 11.3°, 24.9°
  - For 325 GHz: 21.4 dBi, 9.5°, 22.3°

Simulation Results – Grating Lobes



- 300 GHz Pattern
- Array
  - Grating lobes
  - Spacing bigger than half of the wavelength

Parameter	Size
B	3.0 mm (horn width)
C	1.0 mm (horn height)
spacing	1.25 mm= C + 0.25 mm



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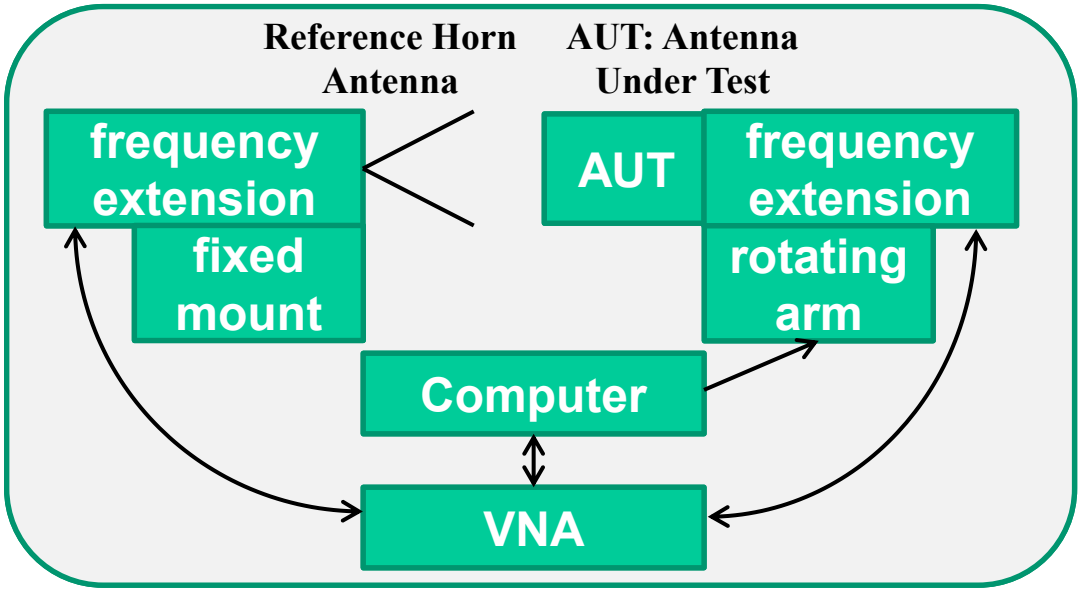
- **Measurement Results**
- **Summary**

Antenna Scanner Setup

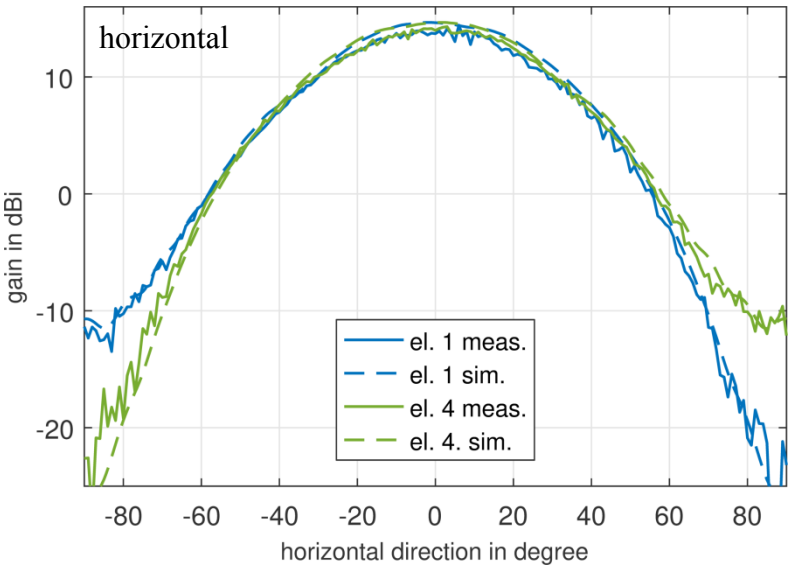


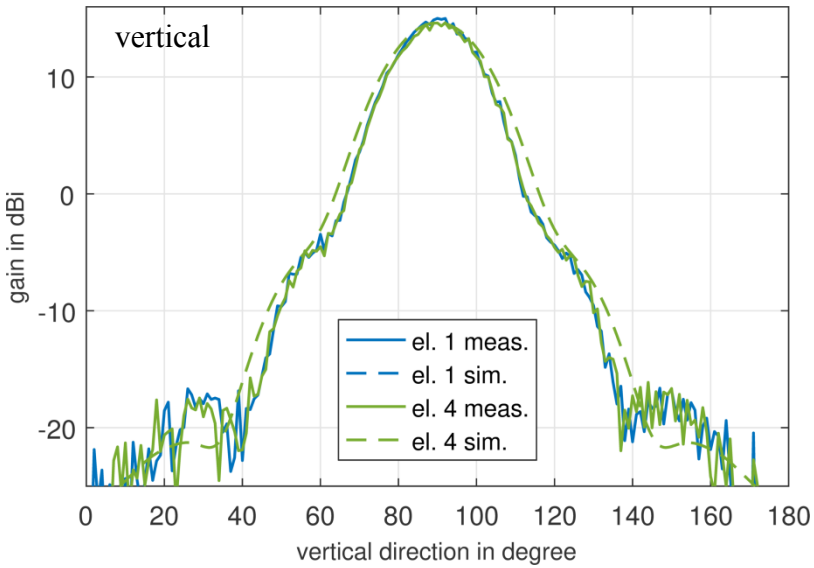
- inhouse made antenna scanner in a semi-anechoic chamber at PTB in Braunschweig
- Vector network analyzer Rohde & Schwarz ZVA 50 with frequency extensions ZV-Z325
- S12 is recorded and analyzed
- Known reference horn on port 1, single element of the phased array at port 2
- Measurement bandwidth 10 Hz, 220 – 325 GHz in 5 GHz steps, angular range +/- 90 degree

Measurements of the array as a whole:

- No 5 port VNA at 300 GHz available
- with TERAPAN 4 Channel Rx/Tx-Modules

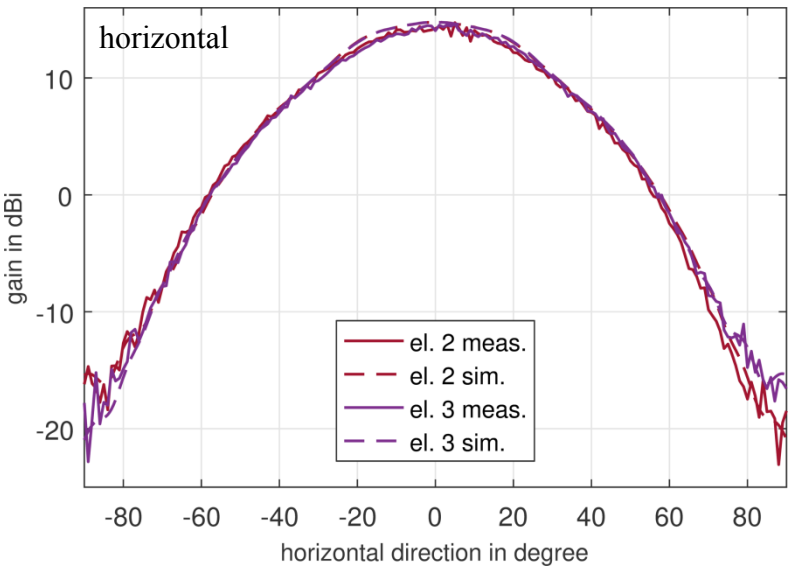
Antenna Patterns – Outer Elements

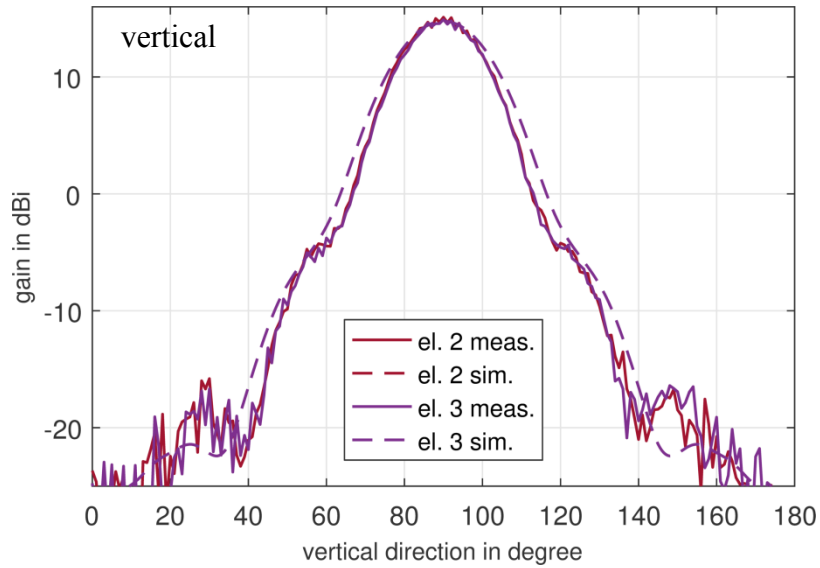




- Measurements match the simulation very well
  - Less than 0.6 dB mean error for horizontal patterns, standard deviation <1.35 dB
  - Less than 1.2 dB mean error for vertical patterns, standard deviation < 3.3dB
- Restricted to -45…45 deg. (horizontal)/45...135 deg. (vertical)
  - Mean error below 0.75 dB/1.6 dB with a standard deviation <0.4 dB/1.3 dB

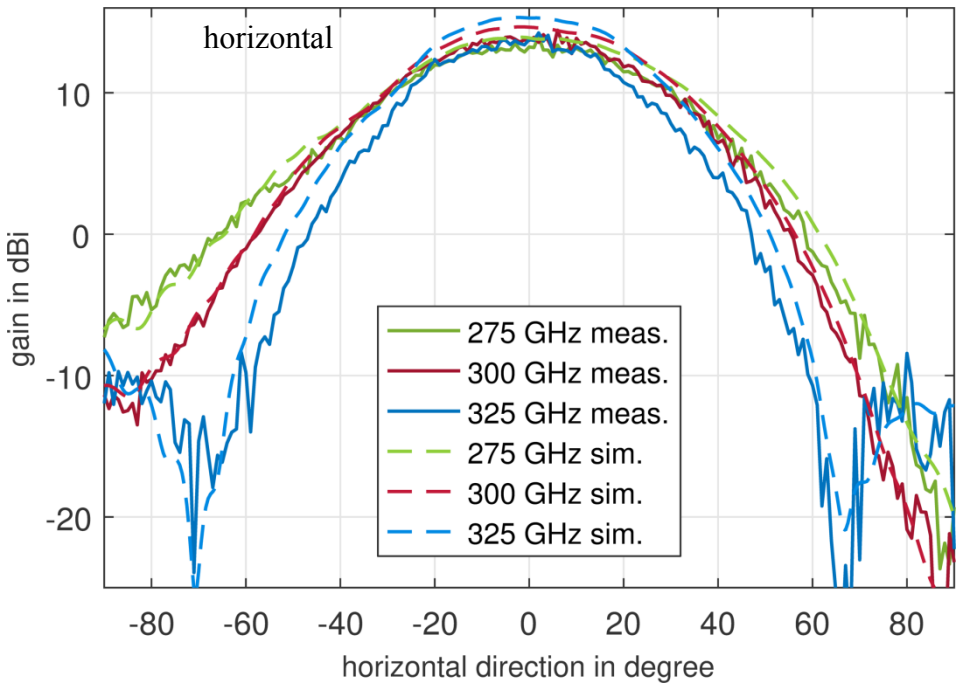
Antenna Patterns – Inner Elements





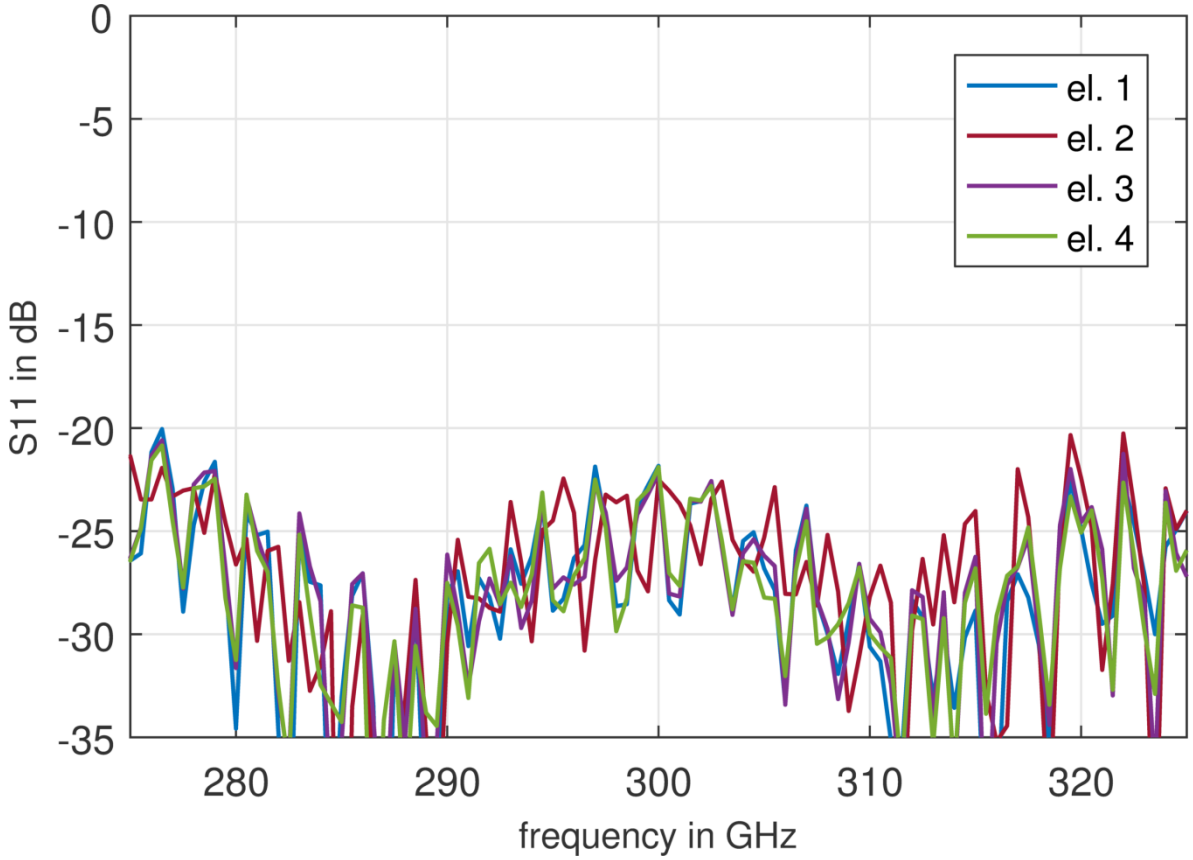
- Measurements match the simulation very well
  - Less than 0.3 dB mean error for horizontal patterns, standard deviation <0.82 dB
  - Less than 1.1 dB mean error for vertical patterns, standard deviation < 3.5dB
- Restricted to -45…45 deg. (horizontal)/45...135 deg. (vertical)
  - Mean error below 0.4 dB/1.6 dB with a standard deviation <0.3 dB/1.2 dB

Antenna Patterns – Frequency



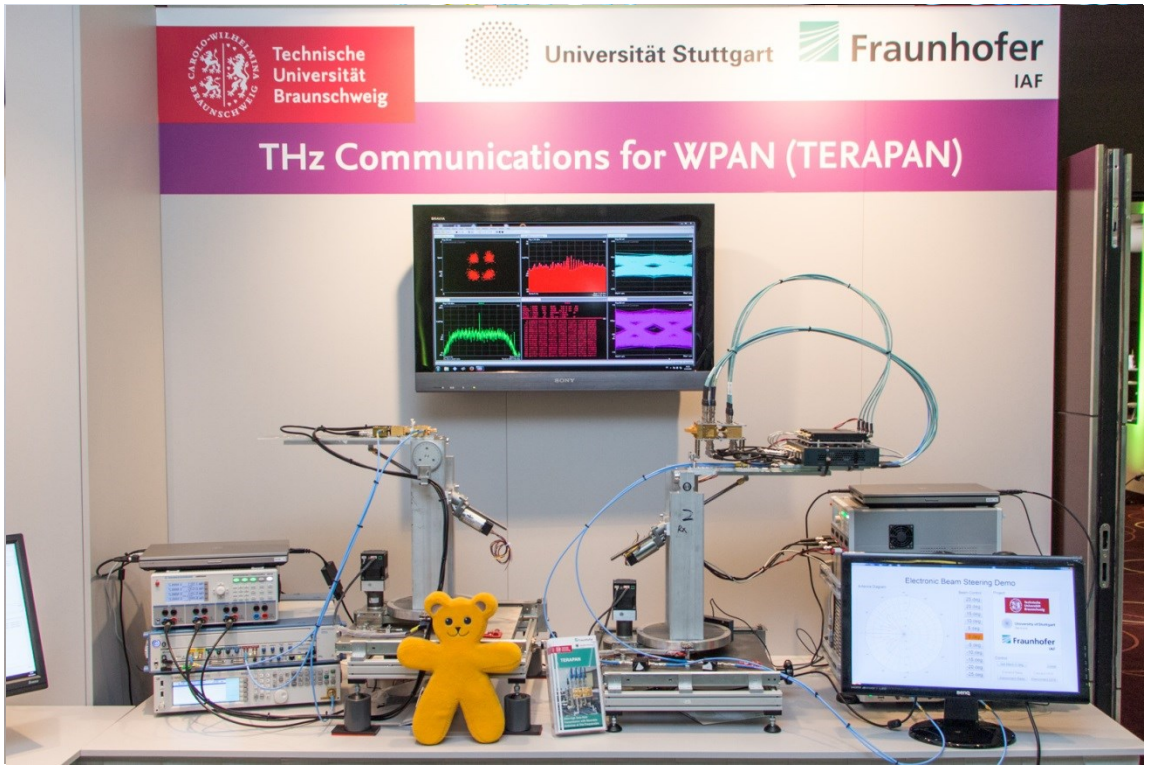
- Measurements match the simulation very well
  - Increasing directivity with frequency
  - (Increasing gain with frequency)

Antenna Matching



- Setup
  - Single Element is aligned to the direct path (0°).
  - VNA Sweep in 5 GHz steps
- S11 is below -20 dB for each antenna element: excellent matching

Demonstration of Beam Steering at NGMN IC&E 2016



Demo at NGMN IC&E 2016

- 60 cm distance
- single transmitter
- 4 channel receiver with phased array antenna
- electronic beam steering shown and verified by mechanical rotation
- QPSK modulation
- data rate of 12 Gbit/s (to see data transmission even within a side lobe)
- Local oscillator generated by DDS modules

Summary

- Requirements for 300 GHz antennas have been briefly reviewed
- A phased array with horn elements has been introduced
- Simulation and measurement results have been shown

- References:

  - S. Rey, T. Merkle, A. Tessmann, and T. Kürner, “A phased array antenna with horn elements for 300 GHz communications,” *in Proceedings International Symposium on Antennas and Propagation (ISAP)*, pp. 122–123, 2016.
  - S. Rey, D. Ulm, T. Kleine-Ostmann, and T. Kürner, “Performance evaluation of a first phased array operating at 300 GHz with horn elements,” *in Proceedings of the 11th European Conference on Antennas and Propagation (EUCAP)*, pp. 1629–1633, 2017.

Vielen Dank für Ihre Aufmerksamkeit.

Thank you for paying attention!