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Verkotan

100GHz 3D Antenna testing

RF Summit 19.3.2025

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100GHz antenna testing

Verkotan Anechoic chamber

Three antenna calibration method & results

Results AntView®

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Introduction

- Verkotan participated in the CELTIC NEXT project ENTRY100GHZ during the years 2021-2024
- The project consortium consisted of 18 members from three countries
- Verkotan's main objective was to develop and trial 100GHz 3D antenna pattern measurements
- The work was done in collaboration with Aalto University, Chalmers University of Technology and the University of Oulu
- In this presentation we show some of the results from this work
- The Finnish consortium was funded by Business Finland
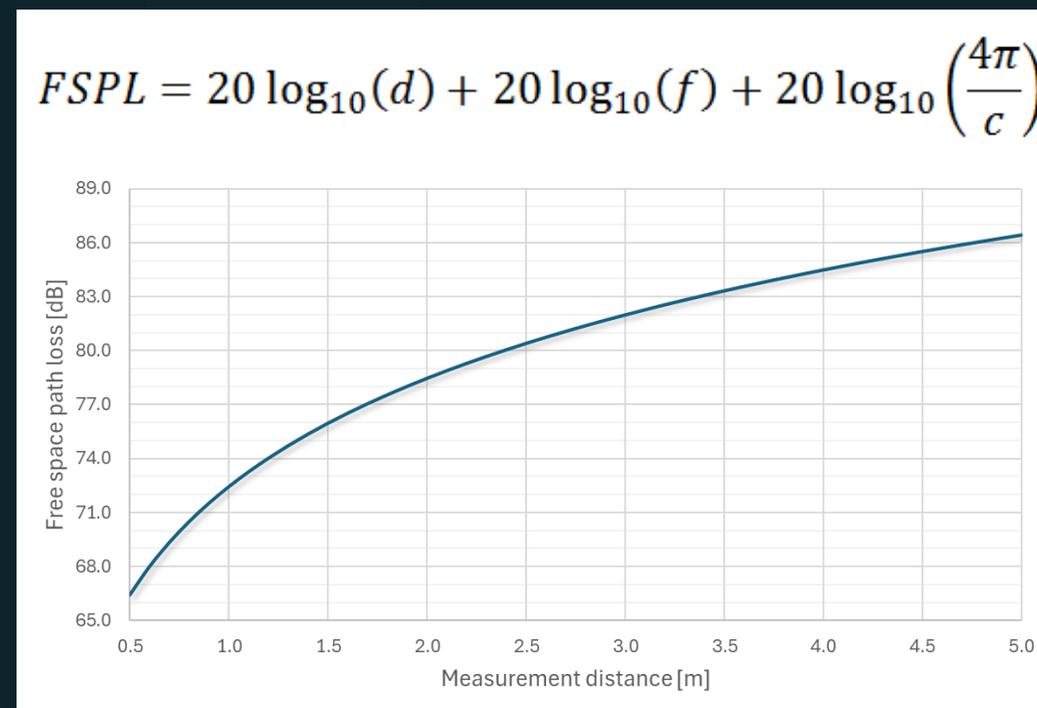
100GHz antenna testing test setup

- Verkotan 6.2x7.4x6.5 meter anechoic chamber
- KUKAs 6-axis 6 meter industrial robot with pose repeatability of ± 0.05 mm max 210kg
- Absorbers EMC-24PCL (60cm) rated up to 40GHz

DUT

4000mm
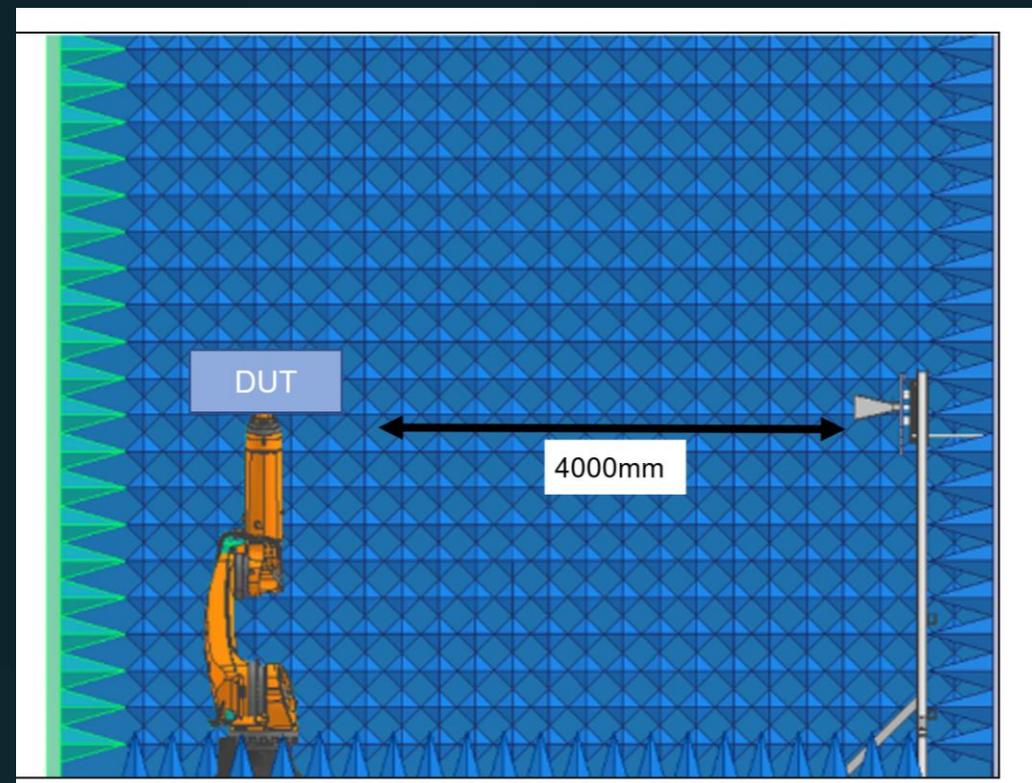
100GHz antenna testing dynamic range

Main challenge at 100GHz testing is to archive sufficient dynamic range

- Limited amplifier power output

- Noise figure of amplifiers are high
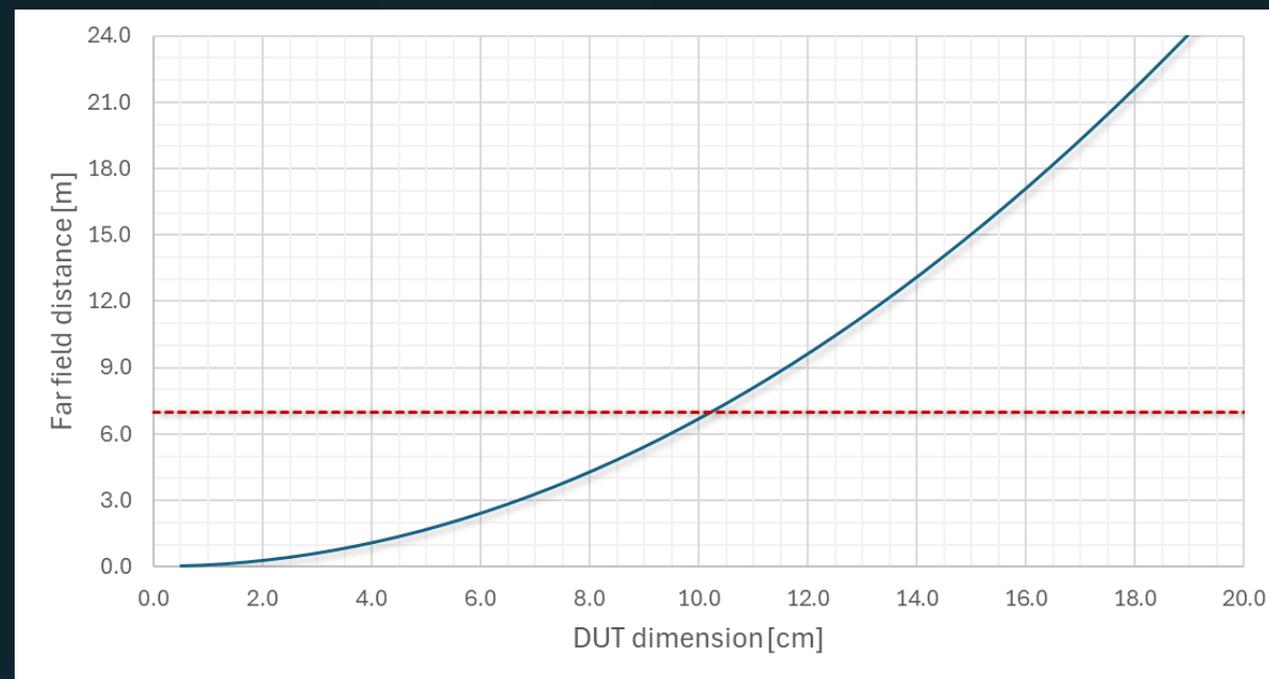
- RF cable losses are high

- Free space loss

$$FSPL = 20 \log_{10}(d) + 20 \log_{10}(f) + 20 \log_{10}\left(\frac{4\pi}{c}\right)$$

Free space loss for 100GHz

100GHz antenna testing far field

To get far field antenna pattern measurement distance has to be greater than Fresnel region:
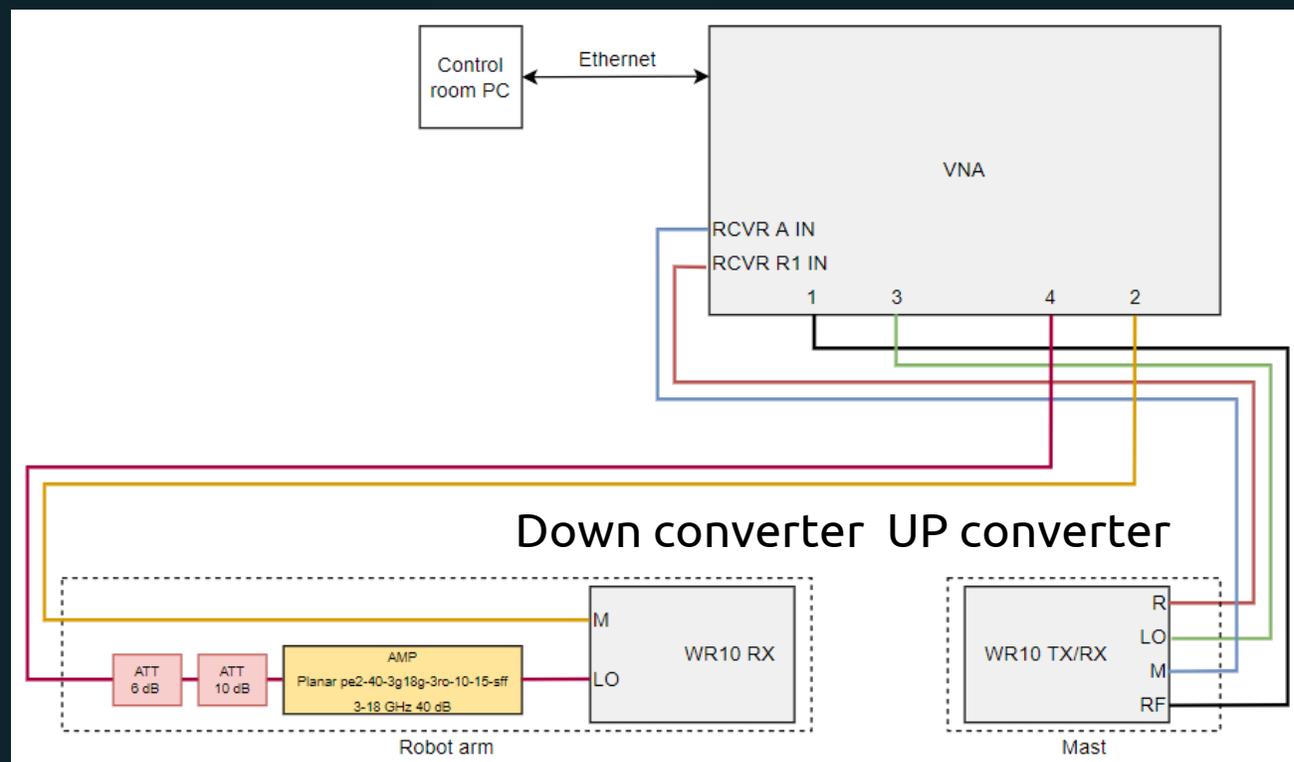
$$\text{Far Field} \geq \frac{2D^2}{\lambda}$$

Verkotan has anechoic chamber

with measurement distances up to 7meter enabling testing antennas up to 10.5cm.
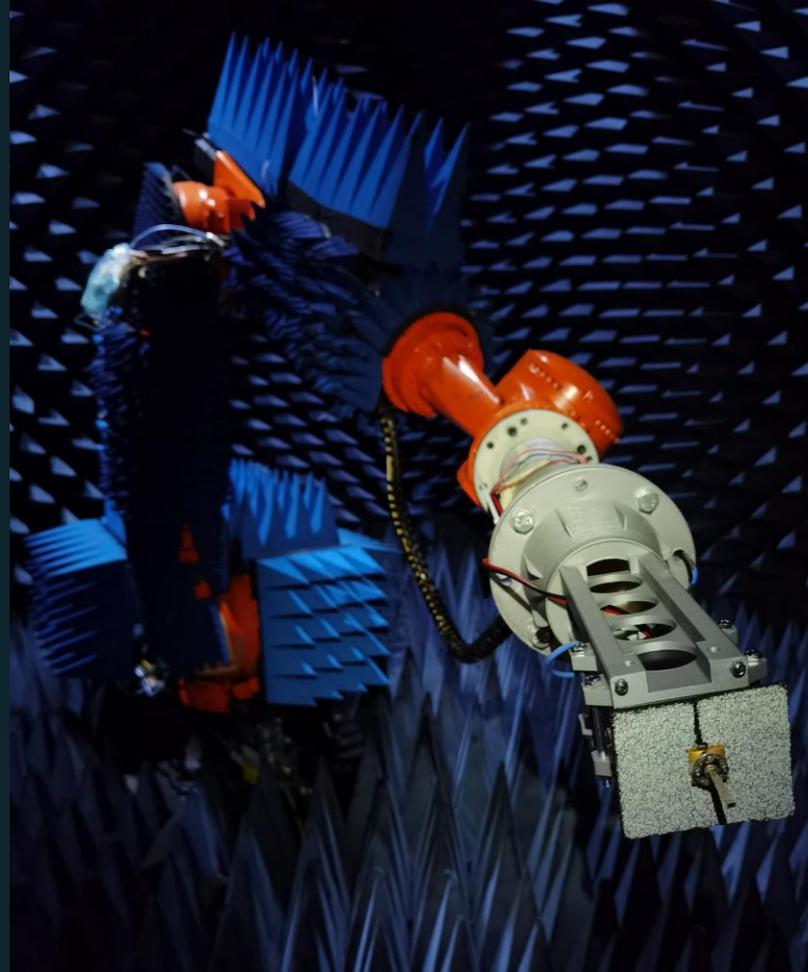
100GHz antenna testing schematic

- VNA used in testing Keysight PNA-X Network Analyzer N5242B
- VNA generates local signal for the up- and downconverters (~10-14GHz)
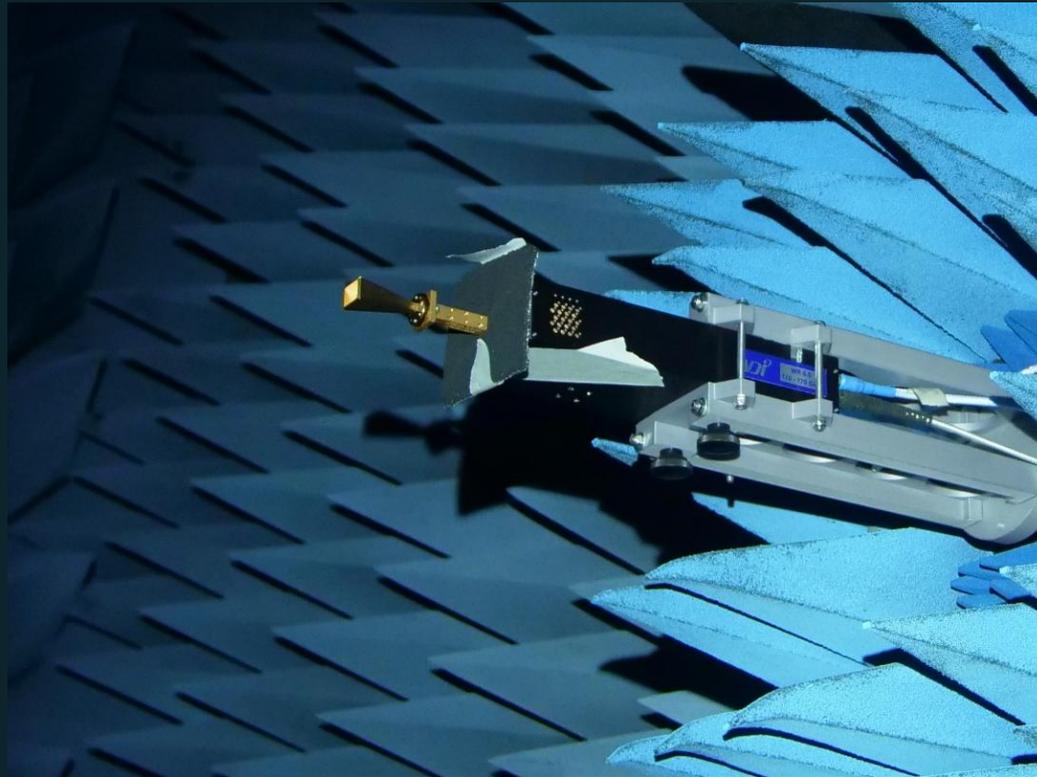- Down converted RF frequency was fixed 279MHz

100GHz antenna testing test setup

- Down converter WR-10 RX and antenna installed to the robot

100GHz antenna testing test setup

- Down converter WR-10 RX/TX and testing antenna installed to the polarization turntable

100GHz three antenna calibration

- Three antenna calibration method convert revert antenna gains from measurement distance
- Free space loss is assumed in the calibration. Accuracy of this free space loss assumption can be using extrapolation technique*
- Antenna distance is not precisely defined for a unknown antenna. This introduces error to calibration accuracy
- Three antennas can produce three pairs of antenna where three unknown antenna gains can be solved

* NEWELL, A.C., BAIRD, R.C. and WACKER, P.F, "Accurate measurement of antenna gain and polarisation at reduced distances by an extrapolation technique", IEEE Transactions on Antennas and Propagation, Volume: 21, Issue: 4, pp. 418 – 431, July 1973.

100GHz three antenna calibration

- Varying distance between antennas on can diminish error introduced by reflections inside the anechoic chamber and mutual reflections between antennas
- 25 Distances between 2530-3700mm were measured
- Plan was to use four antennas to study accuracy of calibration. Unfortunately one of the antennas was not well suitable for calibration as it did have too low gain at boresight at certain frequencies.

100GHz three antenna calibration antennas

AeroWave Horn antenna with nominal 20 dB gain

100GHz three antenna calibration antennas
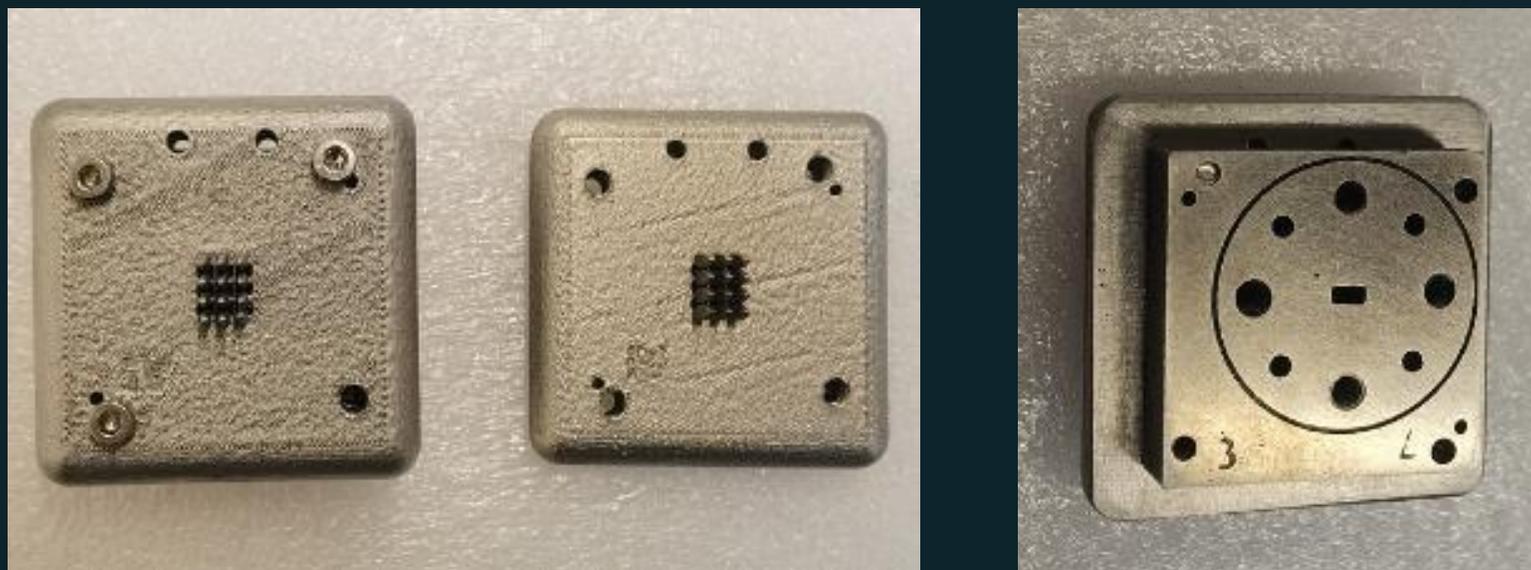

Probe antenna
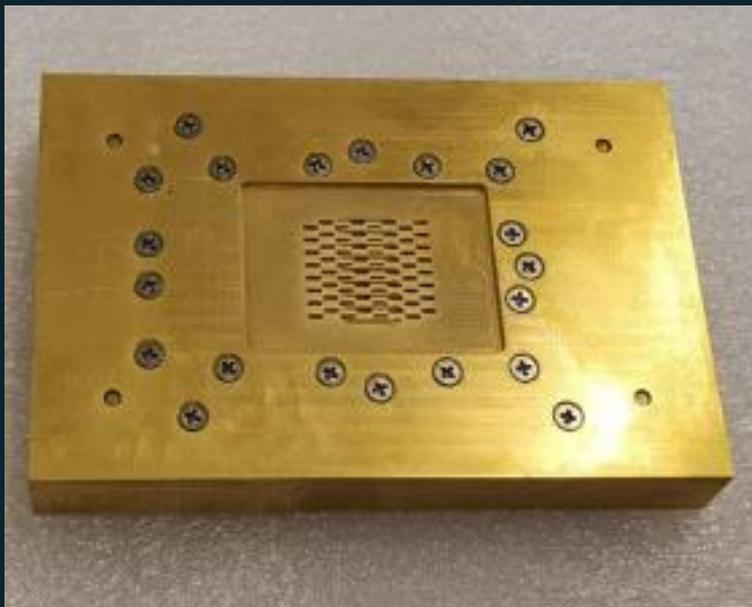
Chalmers Slotted Array Antenna

100GHz three antenna calibration antennas

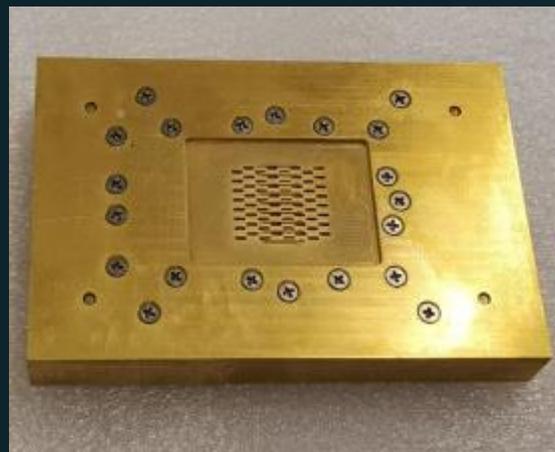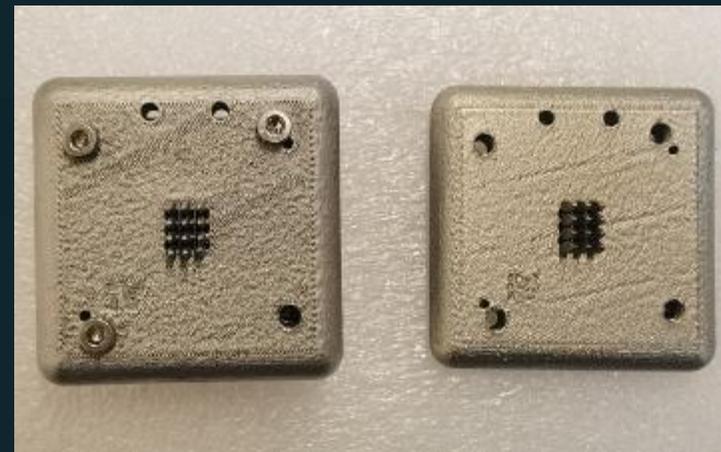Aalto Vivaldi Array Antenna 1 and 2

100GHz three antenna calibration

A   B   C   D   E

- Five antennas used in the three antenna calibration
- A-B-C, B-C-D and B-C-E combinations were measured

100GHz three antenna calibration equation

$$Gain_A + Gain_B - FreeSpace_{loss} = Result_{AB}$$
$$Gain_A + Gain_C - FreeSpace_{loss} = Result_{AC}$$
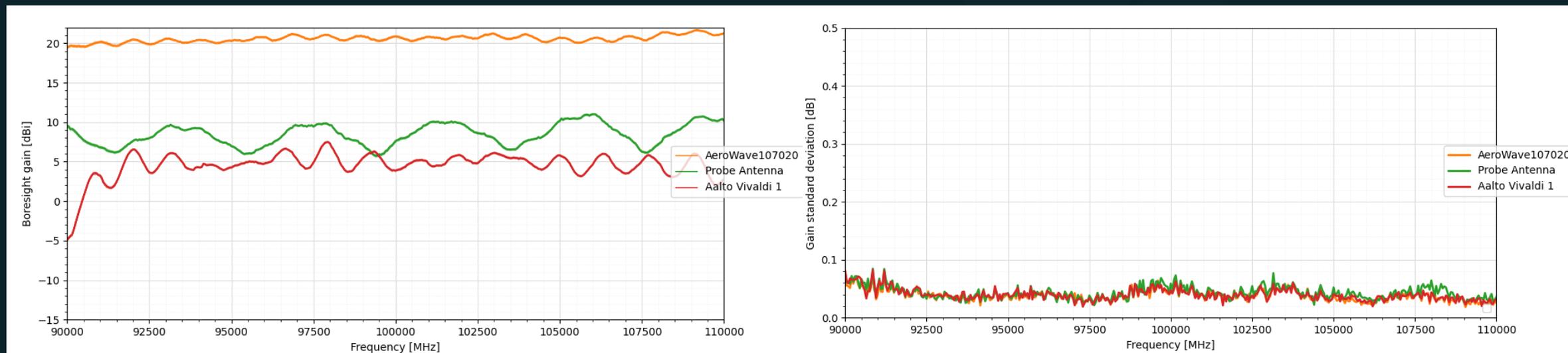$$Gain_B + Gain_C - FreeSpace_{loss} = Result_{BC}$$

- From these three equations unknown Gains can be solved

$$Gain_A = \frac{Result_{AB} + Result_{AC} - Result_{BC} + FreeSpace_{loss}}{2}$$
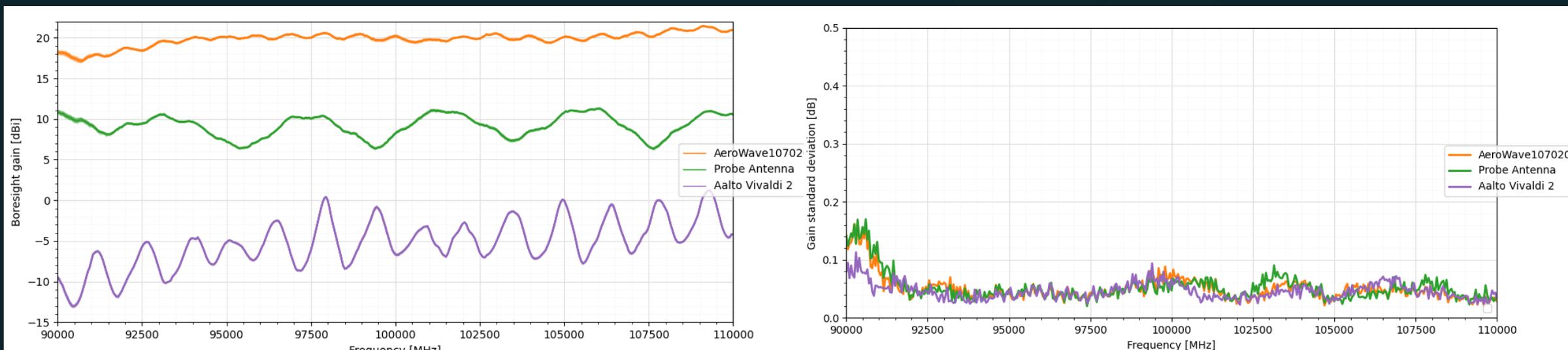$$Gain_B = Result_{AB} + FreeSpace_{loss} - Gain_A$$
$$Gain_C = Result_{BC} + FreeSpace_{loss} - Gain_A$$
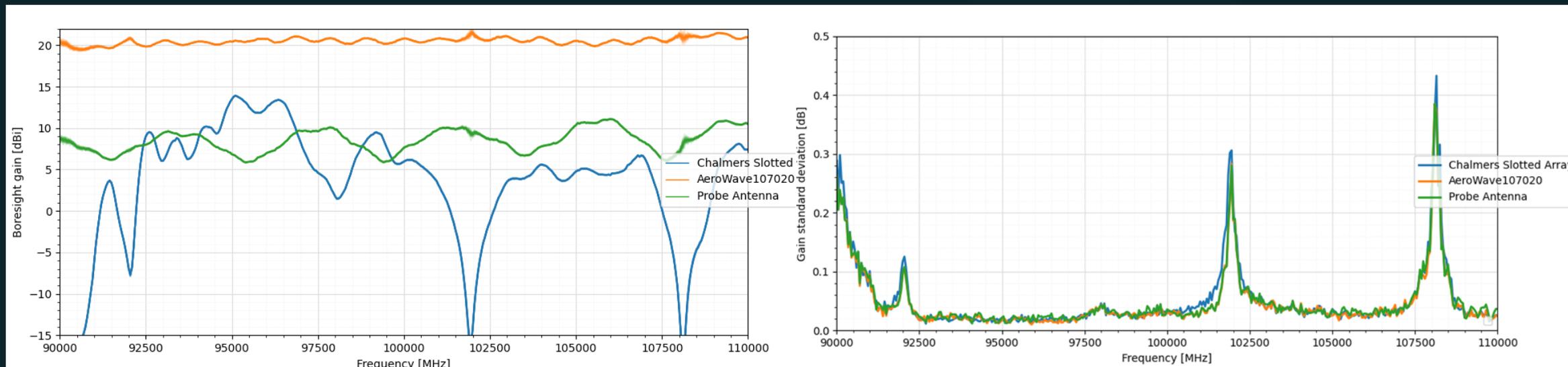
100GHz three antenna calibration results

- B-C-D pair results
- Standard deviation of the calibration values for different distances <0.1dB
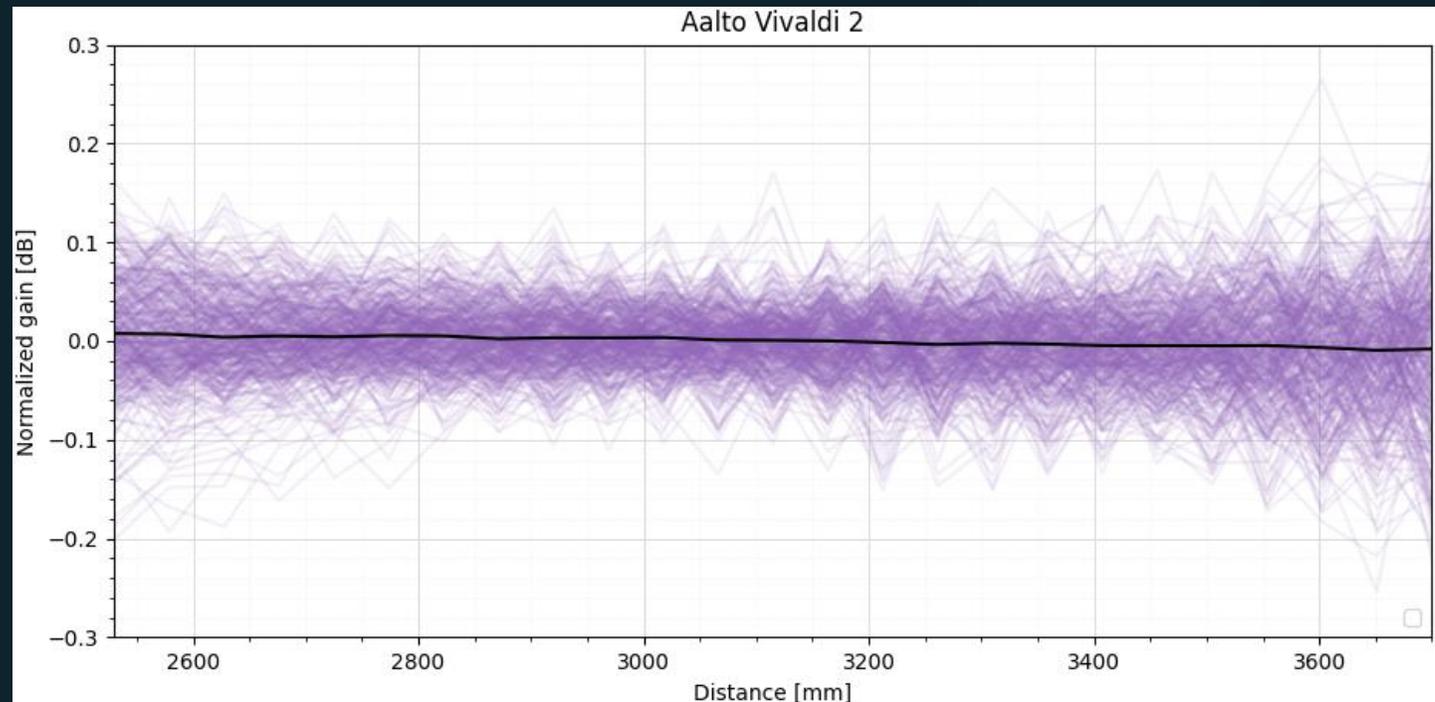
100GHz three antenna calibration results

- B-C-E pair results
- Standard deviation of the calibration values for different distances mostly <0.1dB

100GHz three antenna calibration results

- A-B-C pair results
- Standard deviation of the calibration values for different distances mostly <0.1dB except frequencies where C-antenna gain was bellow -5dB

100GHz three antenna calibration results

- Calibration distance stability for different frequencies
- Free space loss seems to be very good estimation, +-0.01dB on average

100GHz three antenna calibration conclusions

Pros
- Three antenna calibration procedure is one of the most accurate way to calibrate antennas
- Varying distance increase accuracy
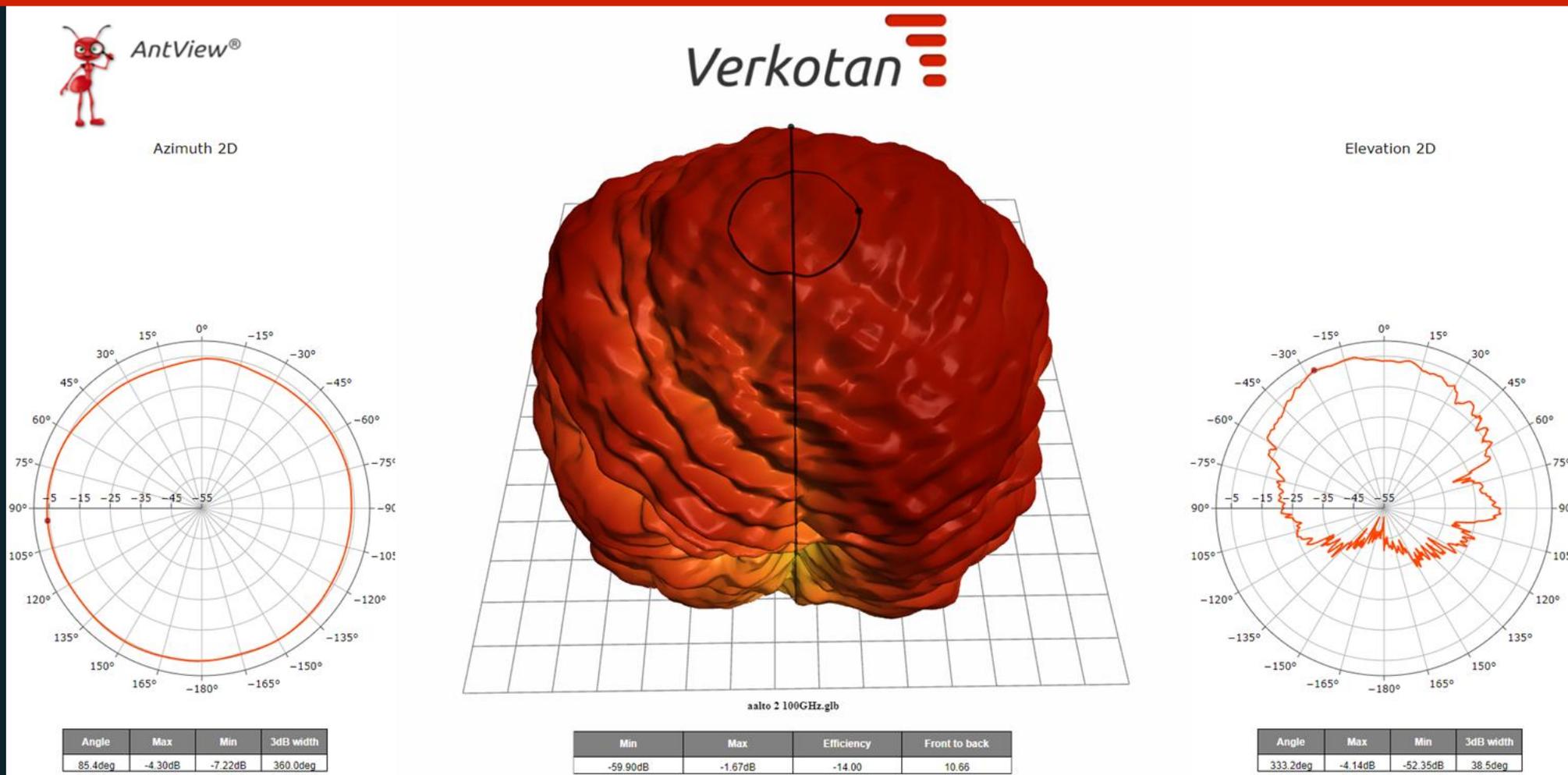- Using more than 3 antennas accuracy can be further increased

Cons
- Three or more antenna pairs need to be measured
- Switching antennas is manual labor and needs to be done precisely
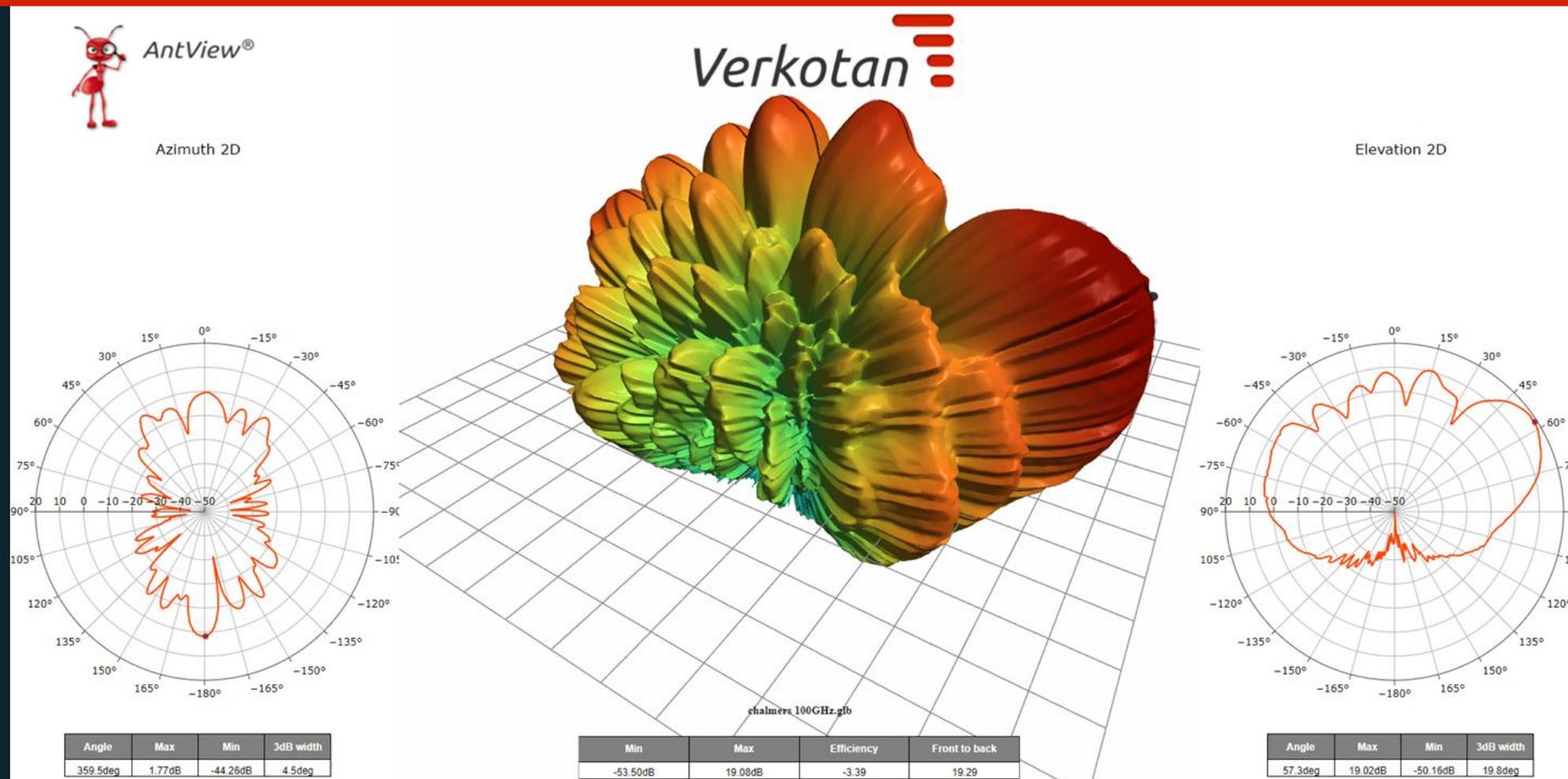- Low gain antennas might reduce accuracy
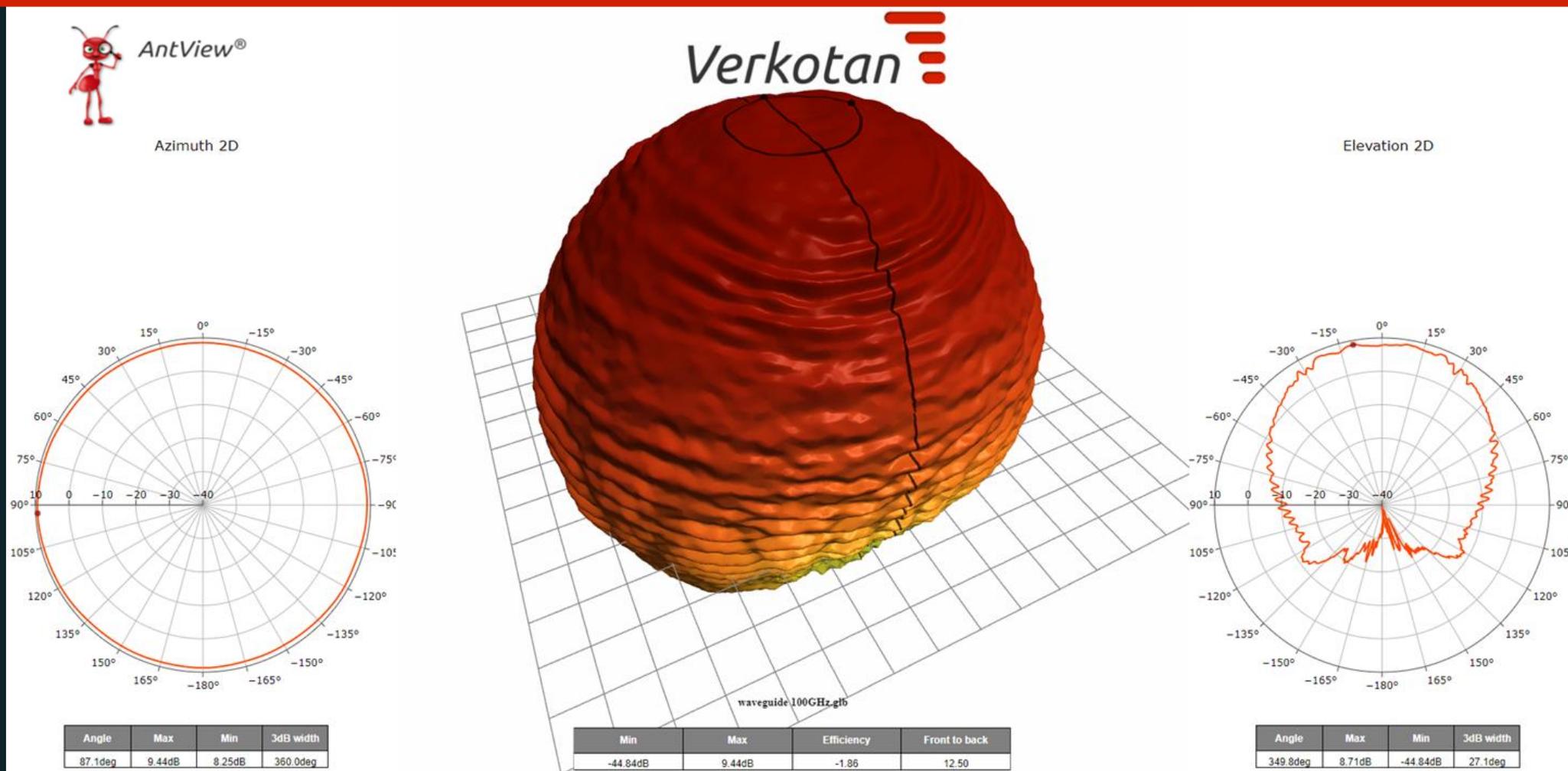
100GHz three antenna examples
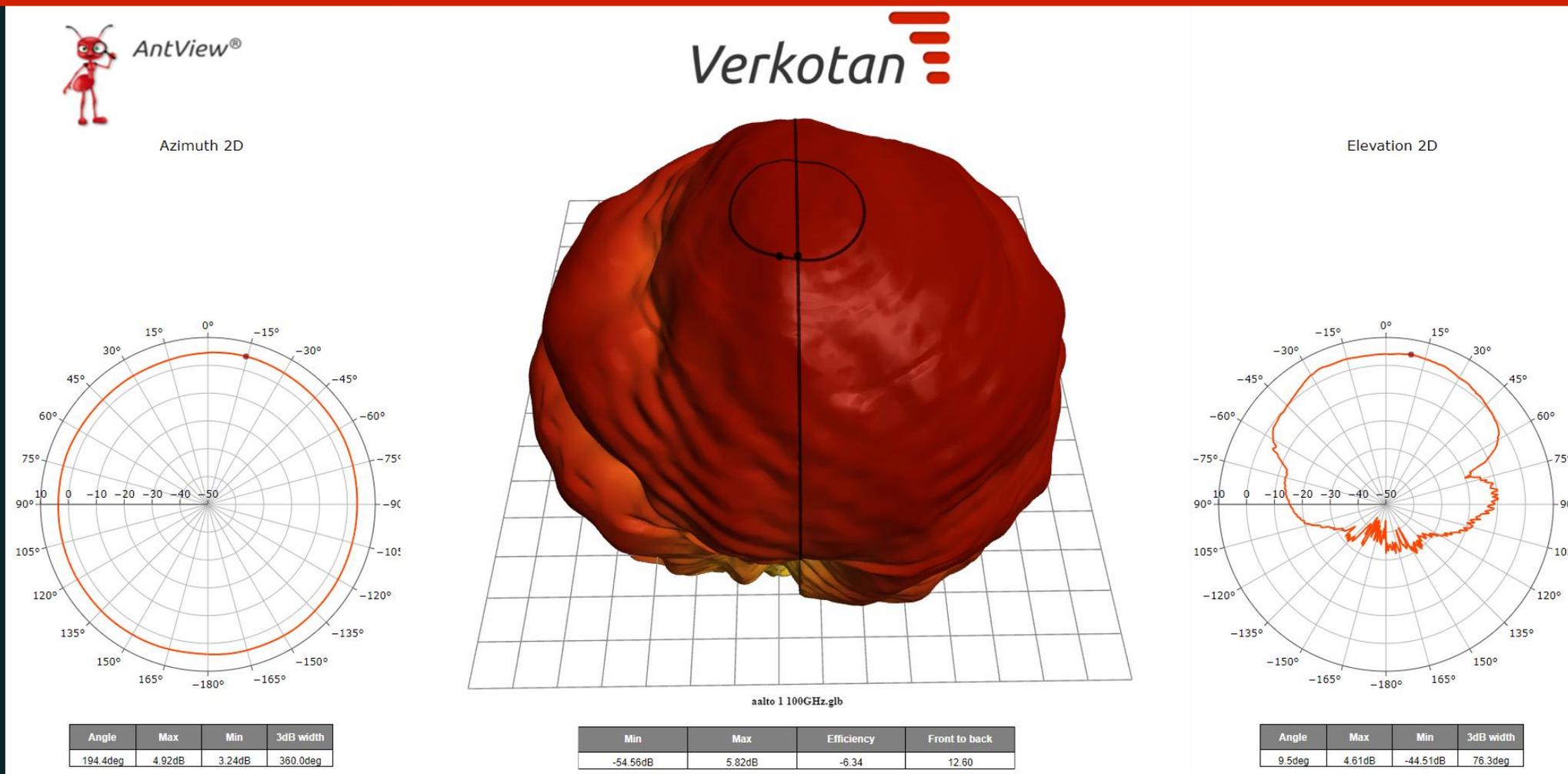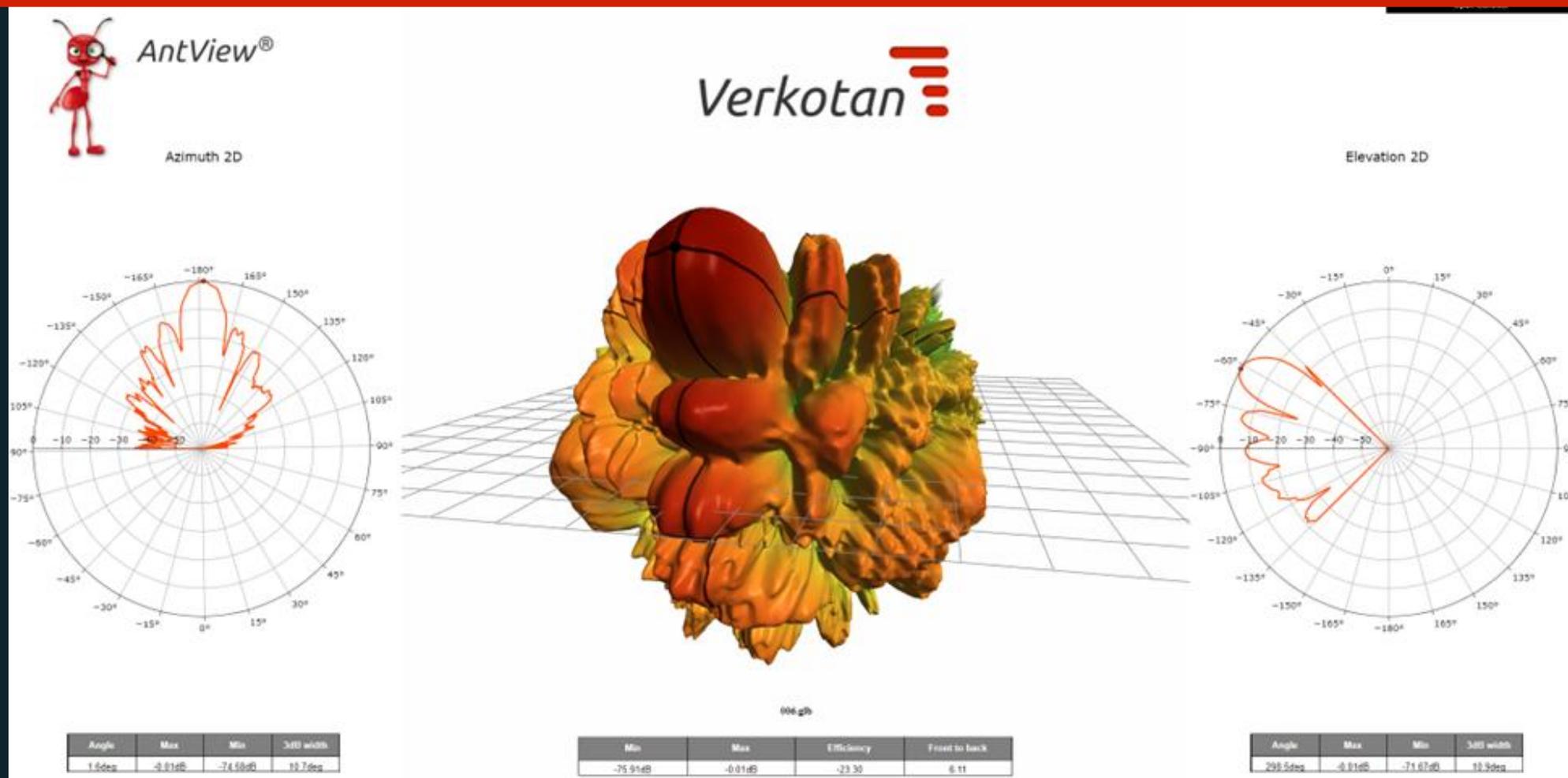
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