SIEMENS

Bogie Sensors
AUT Report
Version 0.1

Distribution list:

Name (alphab.)	Departement	Location
Demmer, Andreas	T ICE ELC-AT	VIE SIE
Derler, Jürgen	SMO RS CP BG&P EN BMD EE	GRZ EGGEN
Dr. Mayer, Lukas Walter	T ICE	VIE SIE
Dr. Kail, Georg	T ICE ELC-AT	VIE SIE

Author:
Name: A. Demmer
Dept.: T ICE ELC-AT
Tel.: +43 664 850 4475

Inspector:
Name: L.W. Mayer
Dept.: T ICE
Tel.: +43 51707-36951

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Contents

1 Introduction

1.1 Purpose of the document

This document describes the antenna measurements of the hardware revision v4 of the bogie sensors.

The EUT is equipped with four antennas. Antenna switches are used to switch between the antennas. Only one antenna can be connected to the transceiver IC. Simultaneous operation of more than one antenna is not possible.

1.2 Information of antenna and measurement

Name of test personnel	Andreas Demmer, MSc
Antenna type	Planar inverted F
Test date	2023-03-07

Figure 1: Layout data of layer 2 and 3 the structure of one antenna.

2 Modifications for measurement

2.1 HW-Modifications

- Re-placement of the serial capacitor on the RF trace, to connect the common input of the antenna switch to the UF.L socket.
- Bridge resistors to enable communication via the USB to UART TTL 3.3 V adapter

2.2 SW-modifications

- Disable the RF output of the chip to avoid interference with the measurements.
- Adapt the software to enable remote control of the antenna switch.

Remark:
The peak gain is referenced as “untreated” because further measurements were made to check for the influence of the EUT to environmental conditions. The untreated EUT shows the highest gain.

3 Preparations for the measurements

The measurements were done with the sensor and power supply module installed inside the housing which is shown on Figure 2.

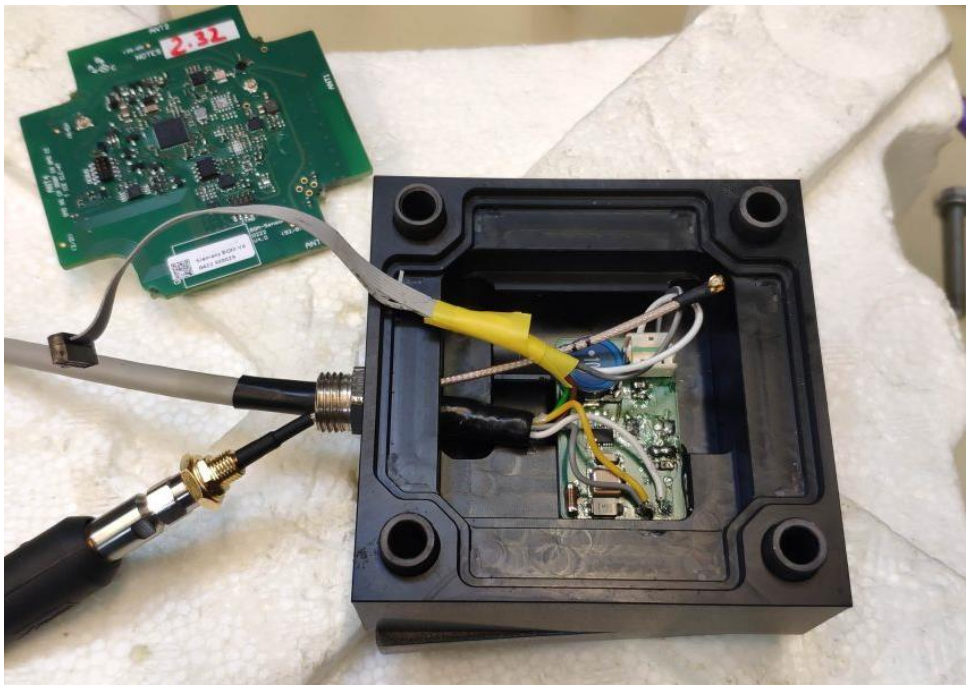


Figure 2: Supply module inside the housing

Underneath the housing there is the mounting plate. The sensor module must have tight contact to the housing and top lid. For the measurements the tight connection is realised by stacking a foam tape (VHB, 3M) between the washers and the top lid. See Figure 3.

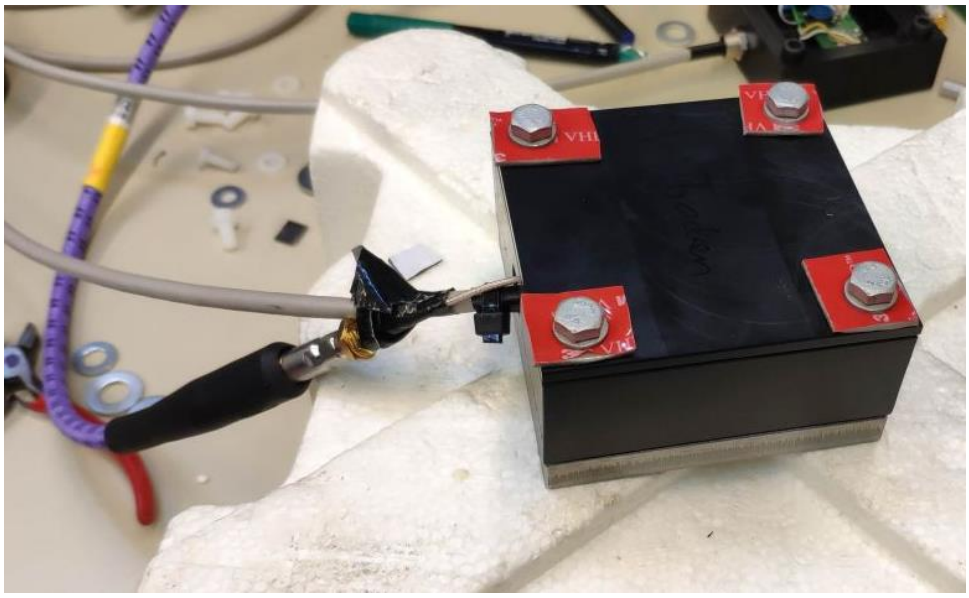


Figure 3: Test setup for measuring antenna matching

The tight connection for the final product is realised by gluing the three parts together. Tight pressure must be applied during the curing phase.

4 Antenna measurements

4.1 Matching

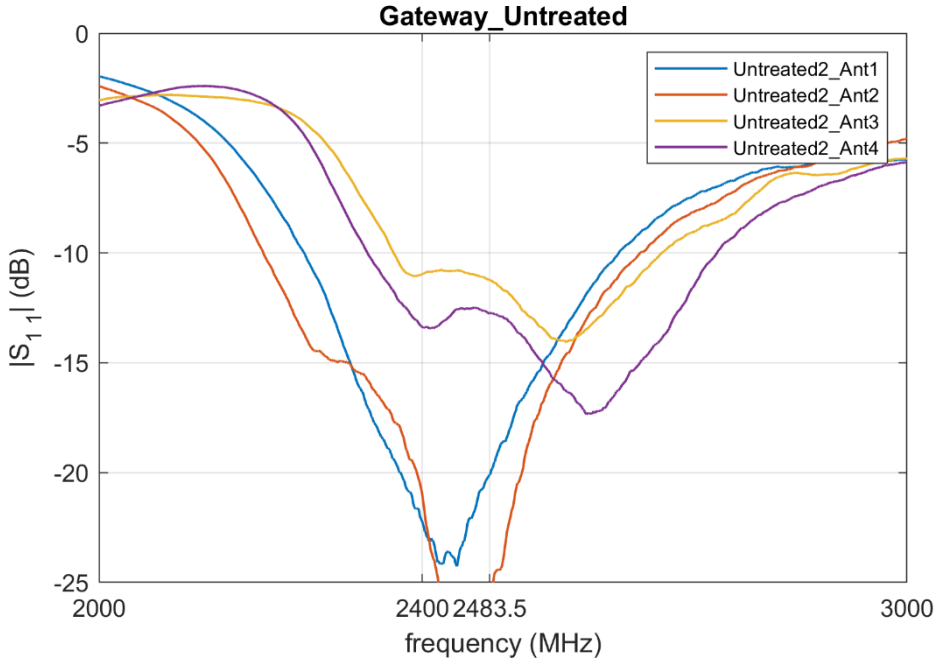


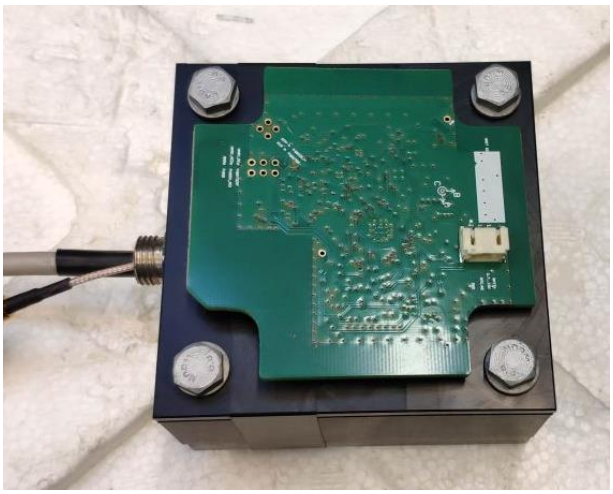
Figure 4: S_{11} of each antenna

Conclusions:

- Antenna 1 and 2 are macheted perfectly ($|S_{11}| < -20$ dB)
- Antenna 3 and 4 show sufficient matching ($|S_{11}| < -10$ dB)
- This is caused by the proximity of the RFID antenna (passive tag).

ANT 1: Rear

ANT 3: Right



ANT 2: Left

Figure 5: Antenna positions

ANT 4: Front

4.2 Radiation pattern

4.2.1 Coordinate system for antenna gain measurement

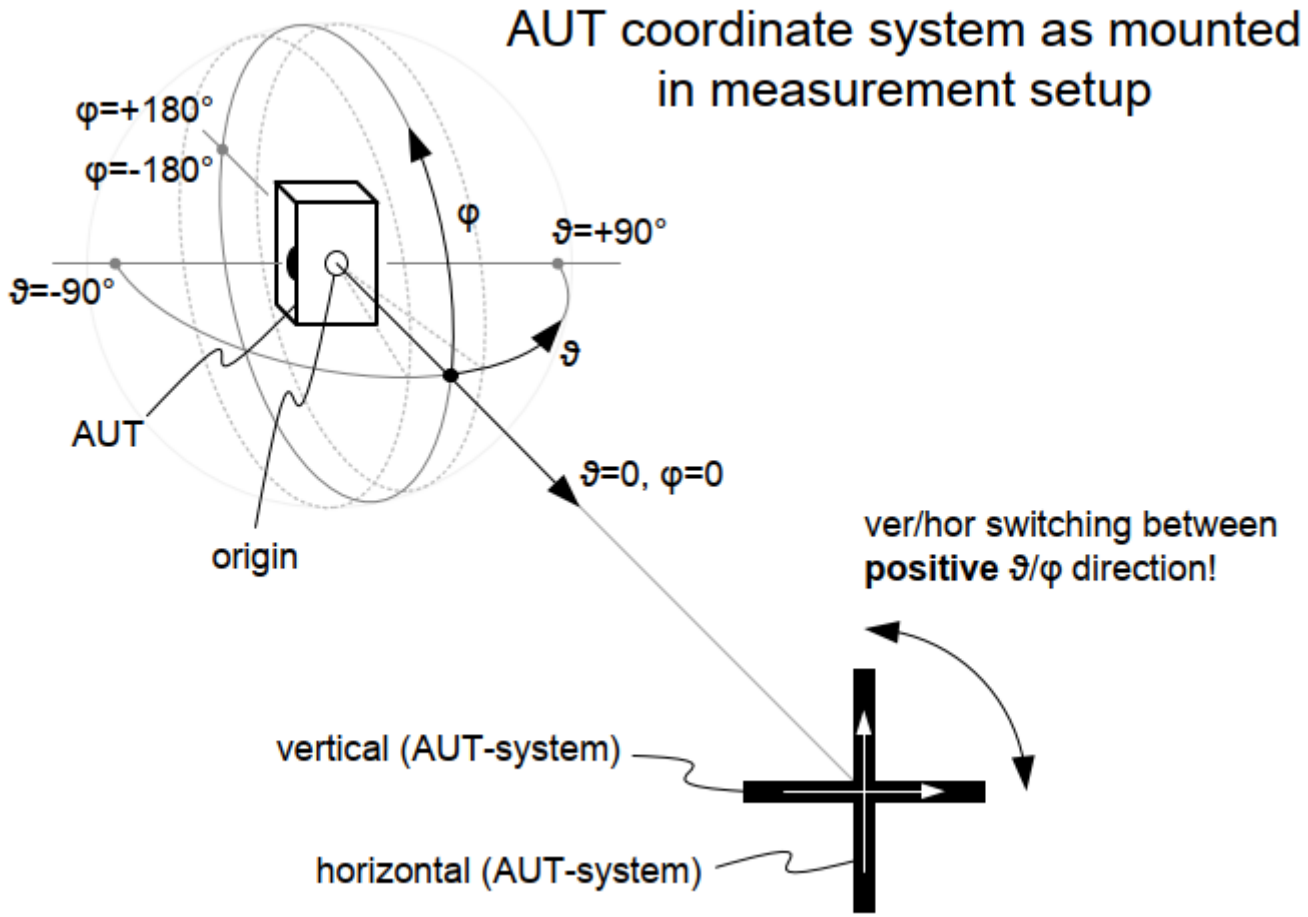


Figure 6: Coordinate system for antenna gain measurement

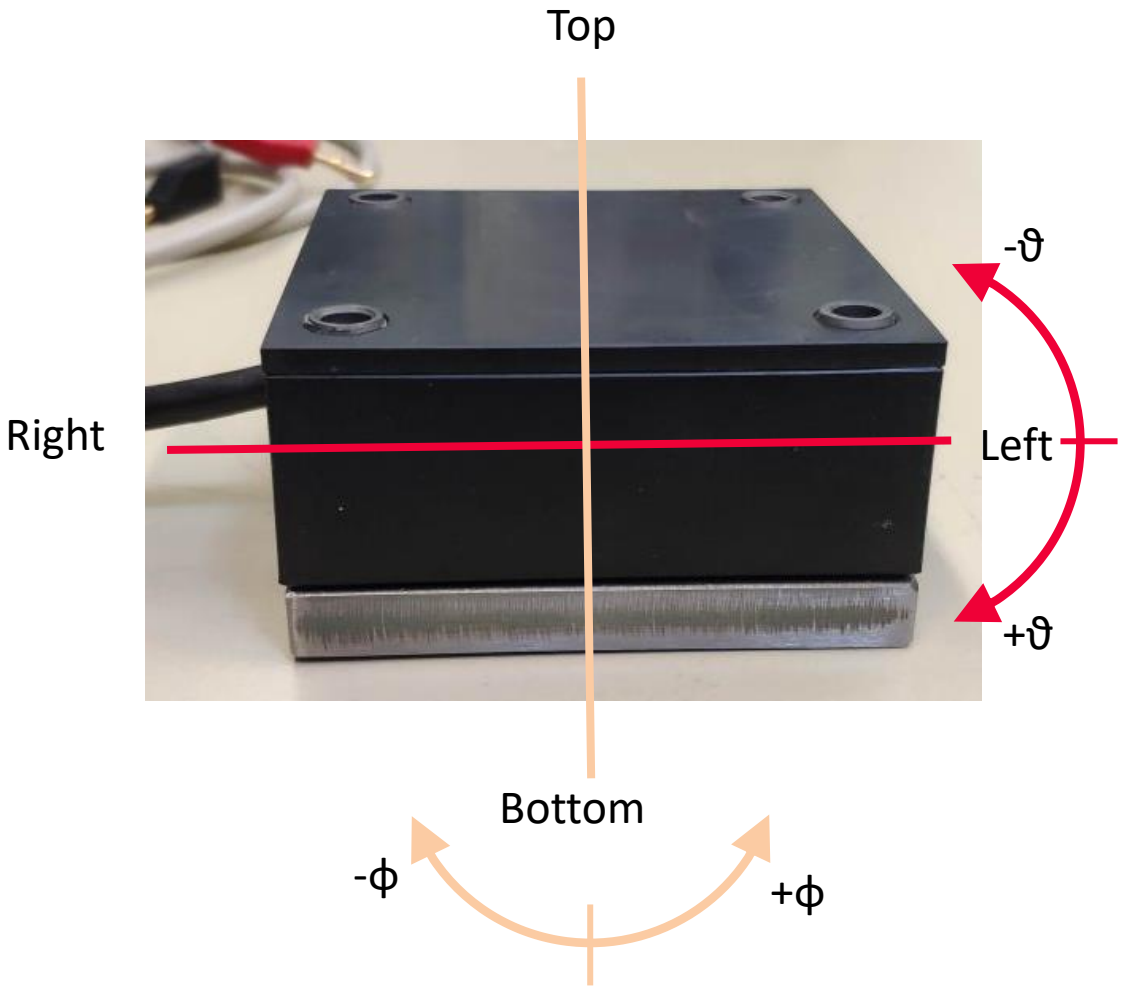


Figure 8: Coordinate system for ETU

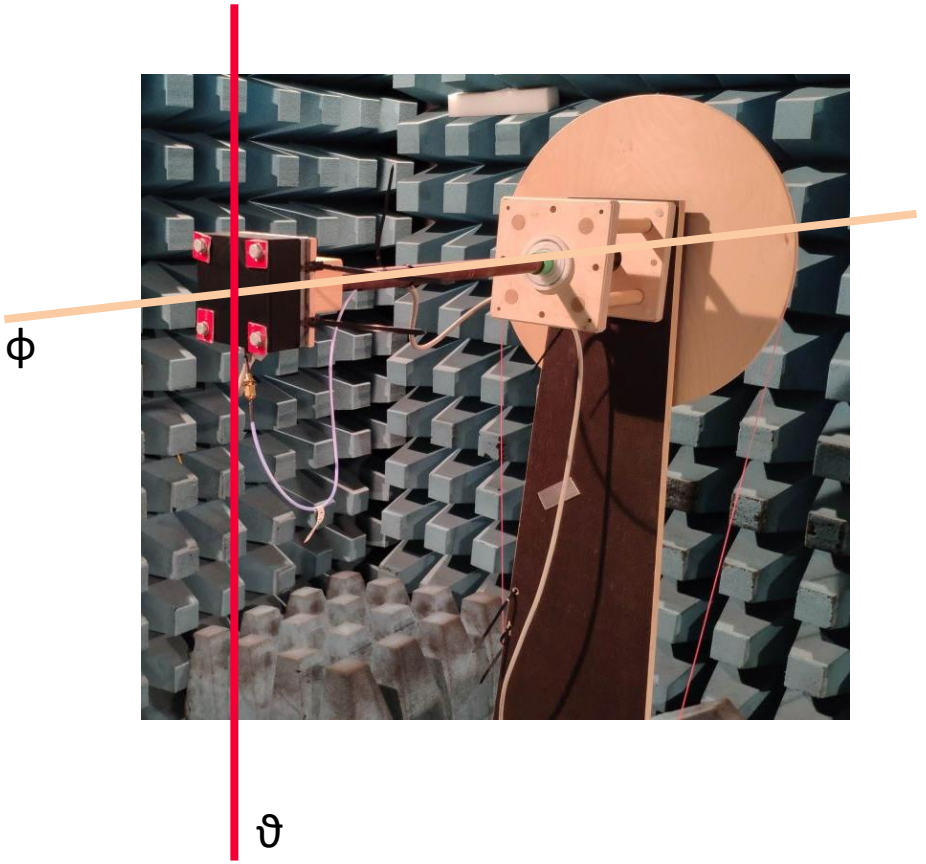


Figure 7: Coordinate system for ETU on turntable

The radiation patterns for all antennas at 2450 MHz are shown on the following figures.

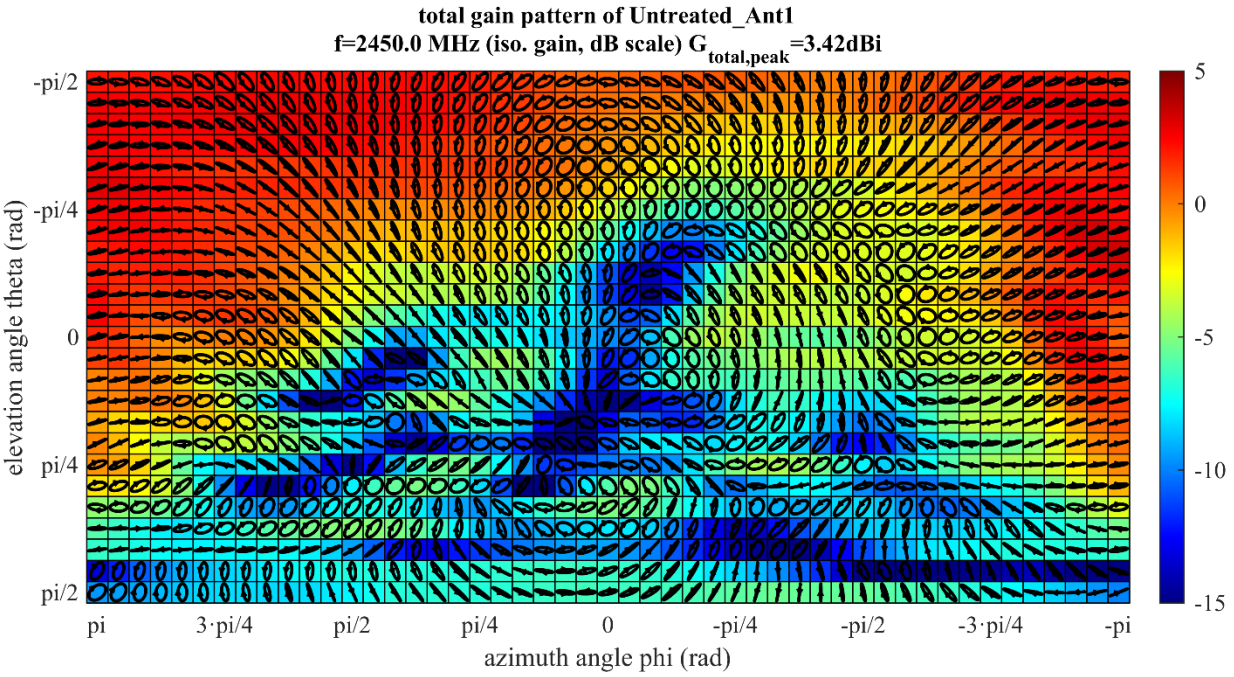


Figure 9: Antenna 1

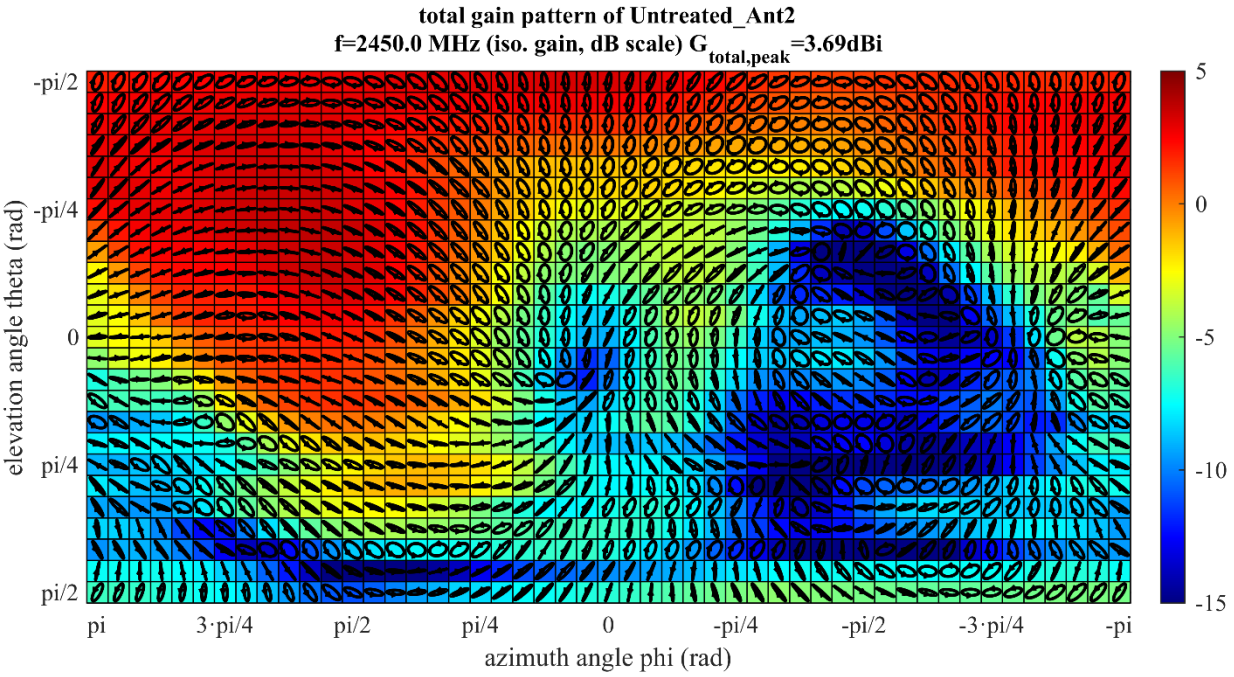


Figure 10: Antenna 2

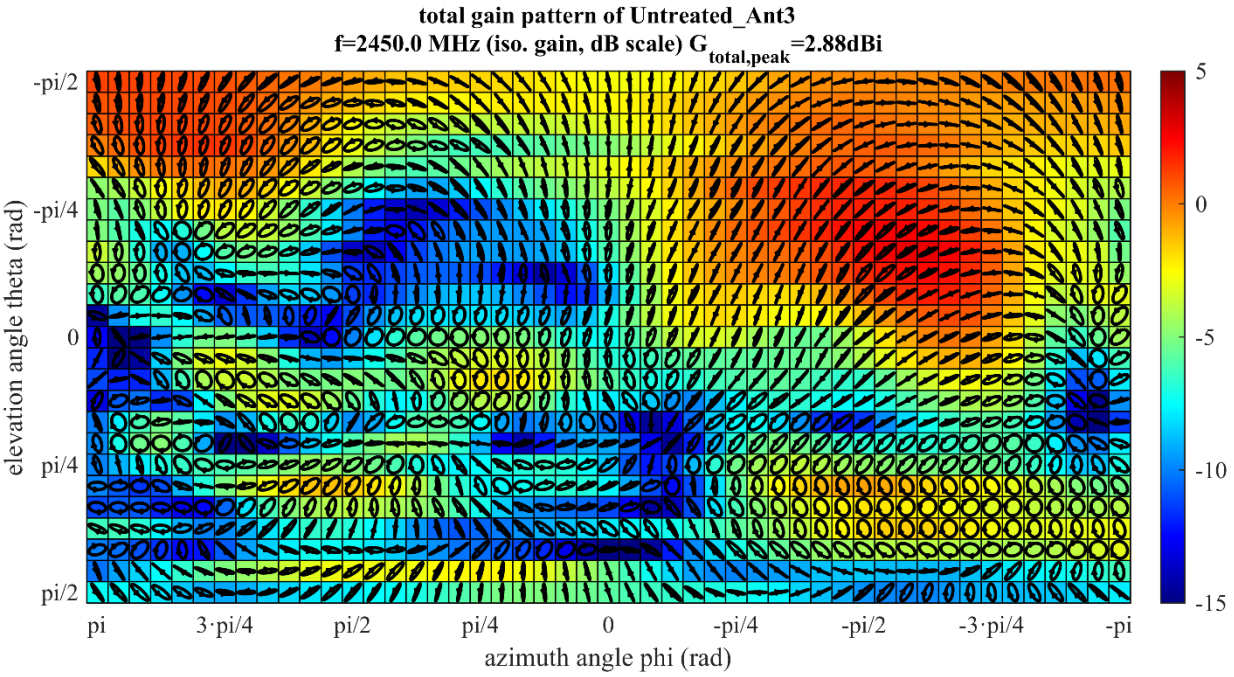


Figure 11: Antenna 3

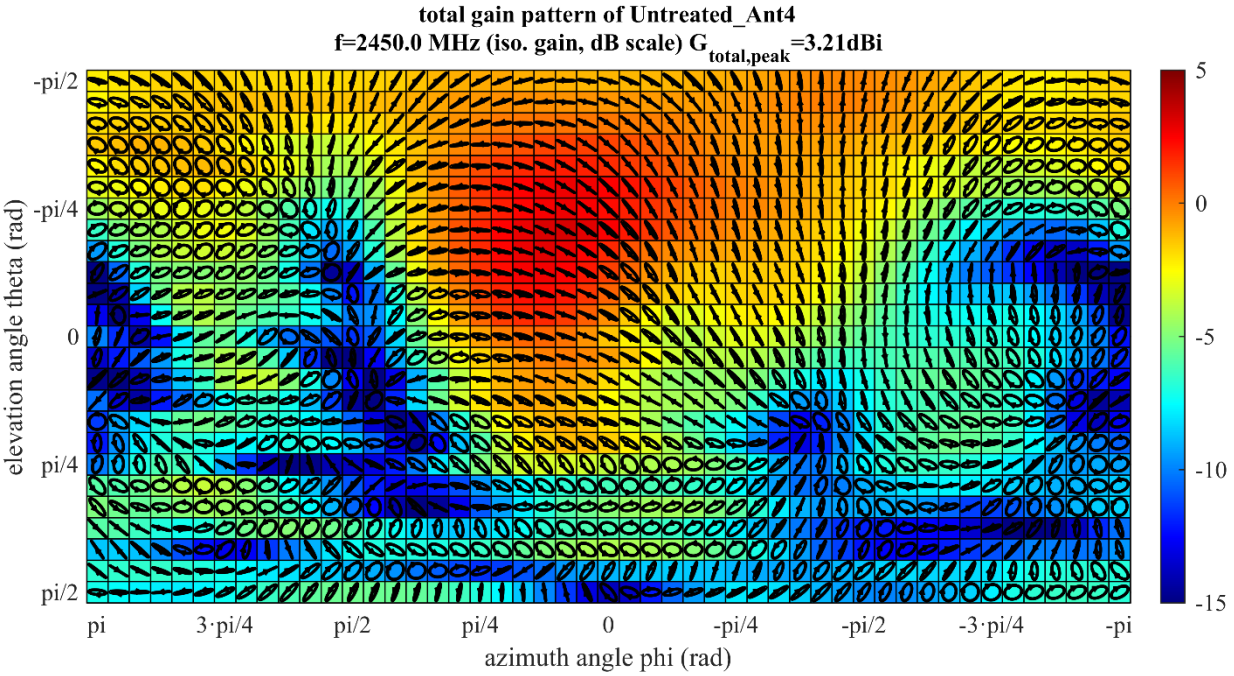


Figure 12: Antenna 4

Conclusion:
The radiation patterns correlate with the direction of the antennas.

Ant 1	Rear
Ant 2	Left
Ant 3	Right
Ant 4	Front

4.2.2 Peak Gain

Antenna	Direction	Peak gain at 2450 MHz
1	Rear	3.42 dBi
2	Left	3.69 dBi
3	Right	2.88 dBi
4	Front	3.21 dBi

5 Antenna measurement system

The measurement system consists of the following parts.

- Stepper motor control turning
  - AUT on turntable (Rotating Theta and Phi axis) and
  - Reference antenna (Rotating Psi axis)
- Vector network analyser (Measuring magnitude and phase)
- Coaxial cabling
- Amplifier

These parts are placed inside an anechoic chamber.
The walls of the camber are covered with ferrite tiles and foam absorbers.

The stepper motor control and the vector network analyser (VNA) are controlled form outside the anechoic chamber by a notebook running MathWorks MATLAB.

Calibration of the test setup
Before the gain measurement, the ends of the cables for the AUT and the reference antenna are connected with an SMA(F) calibration standard followed by a trough calibration on the VNA. This eliminates the influence of the cables and the amplifier.

Measurement
The AUT and the reference antenna are rotated to each coordinate and polarization of interest. On all coordinates the S21 between the antennas are measured over the frequency range of interest.

Calculation of the AUT gain
Using the known gain of the refence antenna and the distance between the antennas, the gain of the AUT for each polarization and direction can be calculated.

$$G(thata, phi, pol, f) = \frac{abs(S_{21}(thata, phi, pol, f)) \left(\frac{4\pi f}{c_0}\right)^2}{g_{Reff(f)}}$$

The gain for perfectly matched polarization can be calculated by summarizing the components of G(hor) and G(ver) on each direction.

$$G_{total}(thata, phi, f) = G_{hor}(thata, phi, f) + G_{ver}(thata, phi, f)$$

The peak gain can be found by searching the peak value over theta and phi.

$$G_{total,peak}(f) = \max\left(G_{total}(thata, phi, f)\right)$$

The result can be written in logarithmic scale (dBi)

$$G_{total,peak}(f) = 10\, log_{10}\left(G_{total,peak}(f)\right) \quad (dBi)$$

6 Measurement equipment

Device	Manufacturer	Model	Serial Number	Remark
VNA	Rohde & Schwarz	ZVB8 1145.1010.08	100110	Last manufacturer calibration: 2022-05-30 Calibrated with through standard: 2023-03-01
Reference Antenna	ETS-Lindgren	Dual polarised horn 3164-03	62966	Calibrated using three antenna method: 2022-05-10