YUNEX TRAFFIC

AUT-Report

Project: OBU2X-US

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Document Management

History of changes

Version	Status	Date	Person resp.	Reason for Change
0.0.1	work	2024-03-19	A. Demmer	Creation
0.0.2	review	2024-02-20	T. Jatschka	Review
0.1.0	Not valid	2024-02-20	T. Leitgeb	Release
0.1.1	work	2024-03-22	A. Demmer	Addition of external antenna, more detailed phots of 2.4 GHz and cellular antenna, added radiation pattern of cellular bands, corrections
0.1.2	Review	2024-03-22	T. Jatschka	Review
0.2.0	valid	2024-03-22	A. Demmer	Release

Document status: work, review, valid, approved

Persons authorized to make changes:

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Thomas Leitgeb	Vienna, Austria
Andreas Demmer	Vienna, Austria

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1 Introduction

1.1 Purpose of the document

The purpose of this document is to describe the antennas of the OBU2X-US product. The target user group of this document is persons involved in FCC certification.

This antenna under test (AUT) report describes the antenna measurements of the OBU2x-US (EUT).
The EUT is equipped with three antennas for V2X, cellular and 2.4 GHz.

1.2 Test site and test personnel

Name of test personnel	Demmer, Andreas Dr. Mayer, Lukas W.
Test site	Room 12.1004 Siemensstrasse 90 1210 Wien Austria
Date of measurements	Between: 2024-03-12 and 2024-03-13

Table 1-1: Test site and test personnel

1.3 References

1	Datasheet for external V2X antenna Mobilemark MULTIBAND SURFACE MOUNT ANTENNA SMWG-313
2	Datasheet Taoglas 5.9GHz DSRC Circular Polarized Embedded SMD 12*12*4mm Patch Antenna Part No: SDCP.5900.12.4.A.40

Table 1-2: References

1.4 Equipment under test (EUT)

This section contains pictures of the EUT and its antennas.

Figure 1: EUT front view

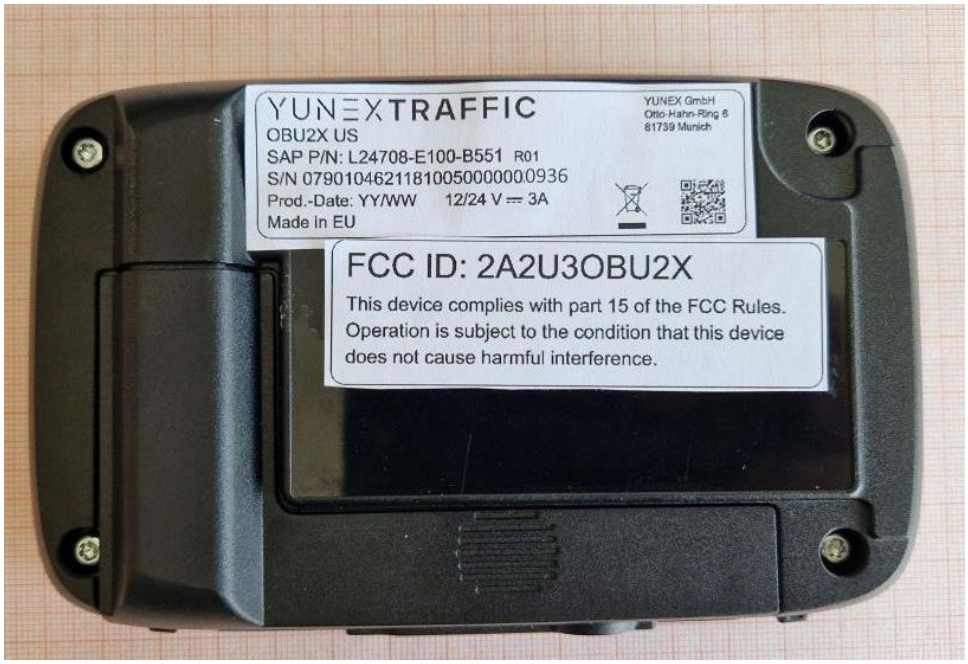

Figure 2: EUT rear view

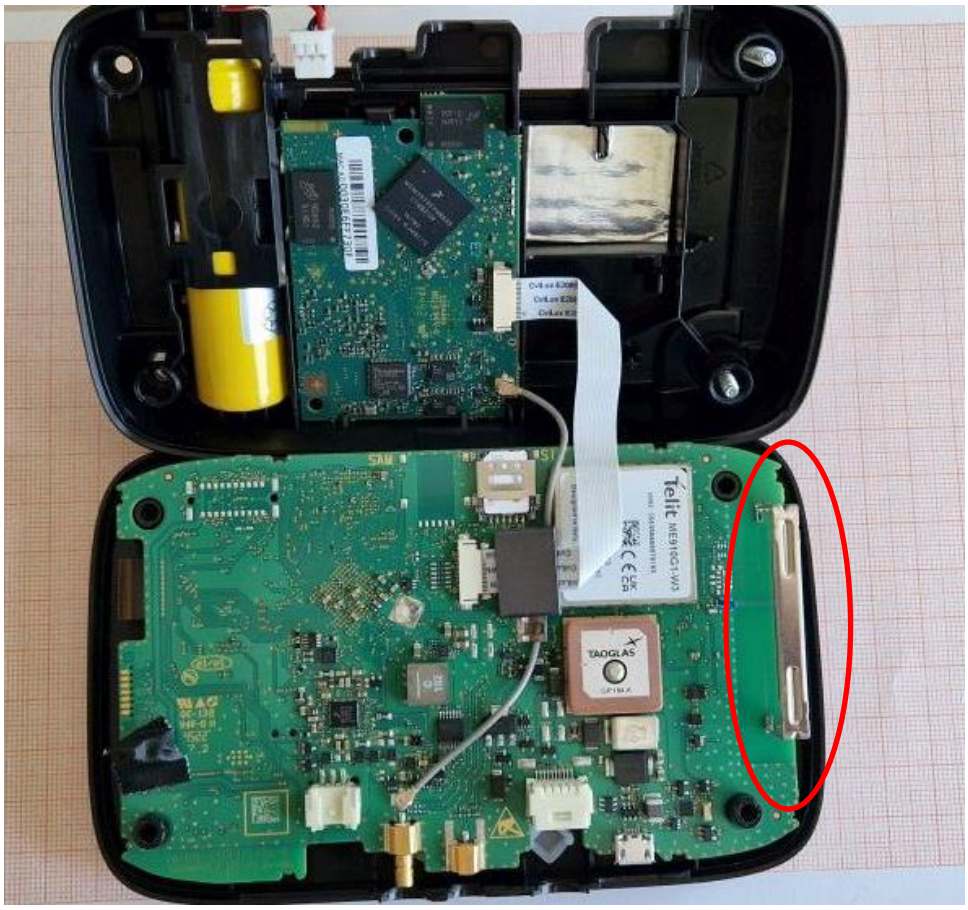

Figure 3: EUT internals, showing main board (side 1) with cellular antenna and V2X board

Figure 4: Close up of cellular antenna (side 1).

Figure 5: Close up of cellular antenna (side 2).

Figure 6: V2X board, with ceramic antenna

Figure 7: rear view of main board (side 2) showing 2.4 GHz antenna.

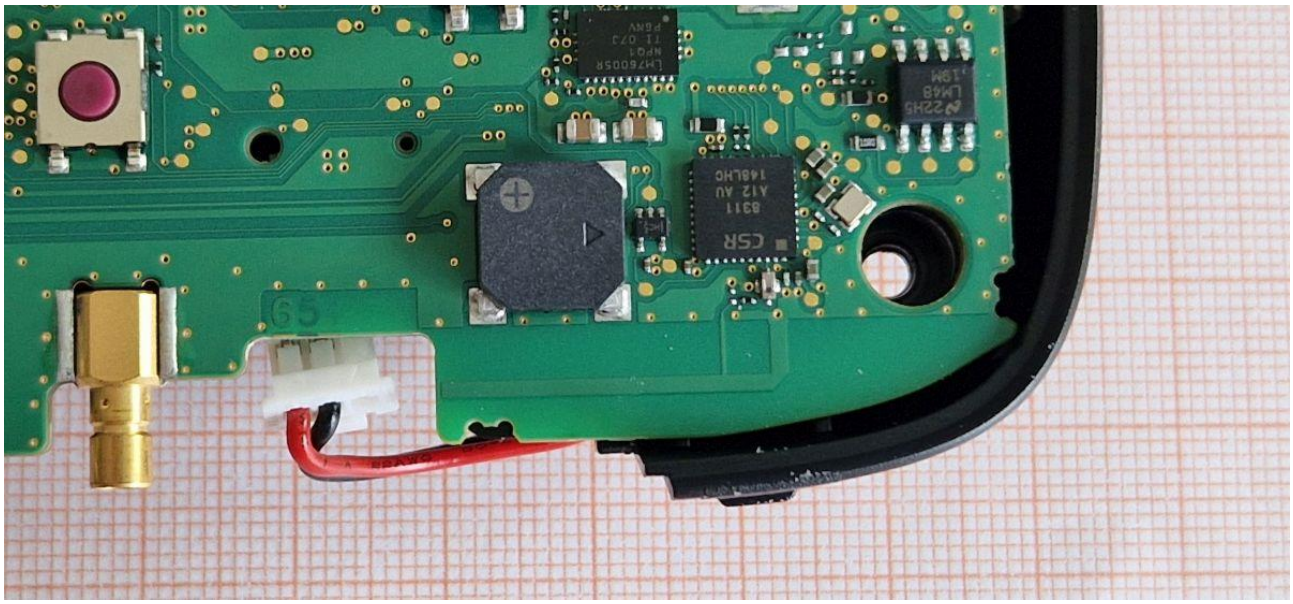

Figure 8: Close up of 2.4 GHz antenna (side 2)

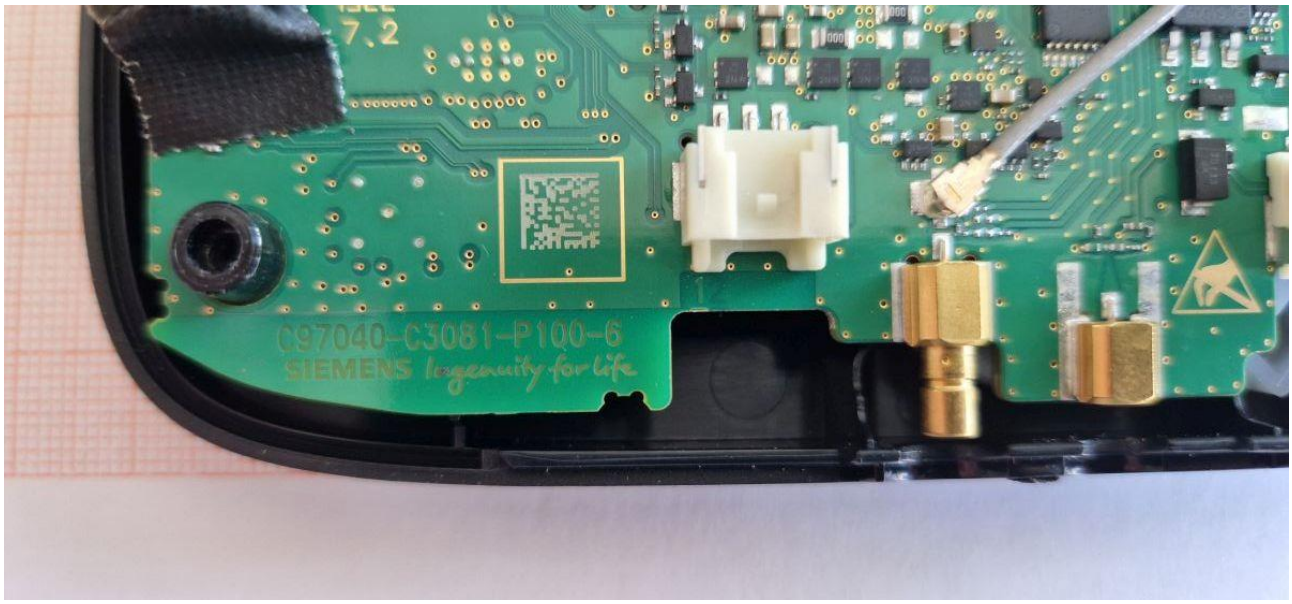

Figure 9: Close up of 2.4 GHz antenna (side 1)

2 External V2X antenna of the EUT

Radio interface	**V2X external**
Proprietary antenna	no
Manufacturer	Mobilemark
Type	SMWG-313
Frequency range	5.8 – 6 GHz
Peak antenna gain	5 dBi (see [1] antenna manufacturer datasheet)
Cable type	RF-195
Cable length	10 ft
Cable loss for 10 ft.	3 dB

3 Internal antennas of the EUT

Radio interface	**V2X internal**	**Cellular**	**2.4 GHz communication (BLE)**
Proprietary antenna	no	yes	yes
Antenna type	Ceramic patch	Bent sheet metal part	Planar inverted-F antenna (PIFA)
Manufacturer	Taoglas	-	-
Type	SDCP.5900.12.4.A.40	-	-
Frequency ranges (Tx)	5.850–5.925 GHz	698-960 MHz, B12 & B85 699 – 716 MHz, B12 777 - 787 MHz, B13 788 – 798 MHz, B14 814 - 849 MHz, B5 & B26 897.5 – 900.5, B8 (39d) 1710 - 1755 MHz, B4 1710 – 1780 MHz, B66 1850 - 1915 MHz, B2 & B25	2400 – 2483.5 MHz
Polarization	RHCP	linear	horizontal
Peak antenna gain	4.64 dBi (see [2] antenna manufacturer datasheet)	-5.45 dBi …. 2.84 dBi	1.31 dBi
Matching components	no	yes	no

Table 3-1: Antennas in the EUT

The data of the proprietary antennas measured and given in the following chapters.

4 Cellular antenna

4.1 Peak gain for each cellular band

E-UTRA Band	Uplink Frequency (MHz)	Band center (MHz)	measured@ (MHz)	Peak gain (dBi)
12 & 85	698 – 716	707	708.4	-5.45
13	777 - 787	782	782.2	0.76
14	788 - 798	793	793.2	1.15
5 & 26 (850)	814 - 849	831.5	830.1	2.84
8 (39d)	897.5 – 900.5	899	900.2	0.29
4	1710 - 1755	1732.5	1733.6	1.18
66	1710 – 1780	1745	1744.6	1.51
2 & 25 (1900)	1850 - 1915	1880	1881.1	0.67

4.2 Radiation pattern

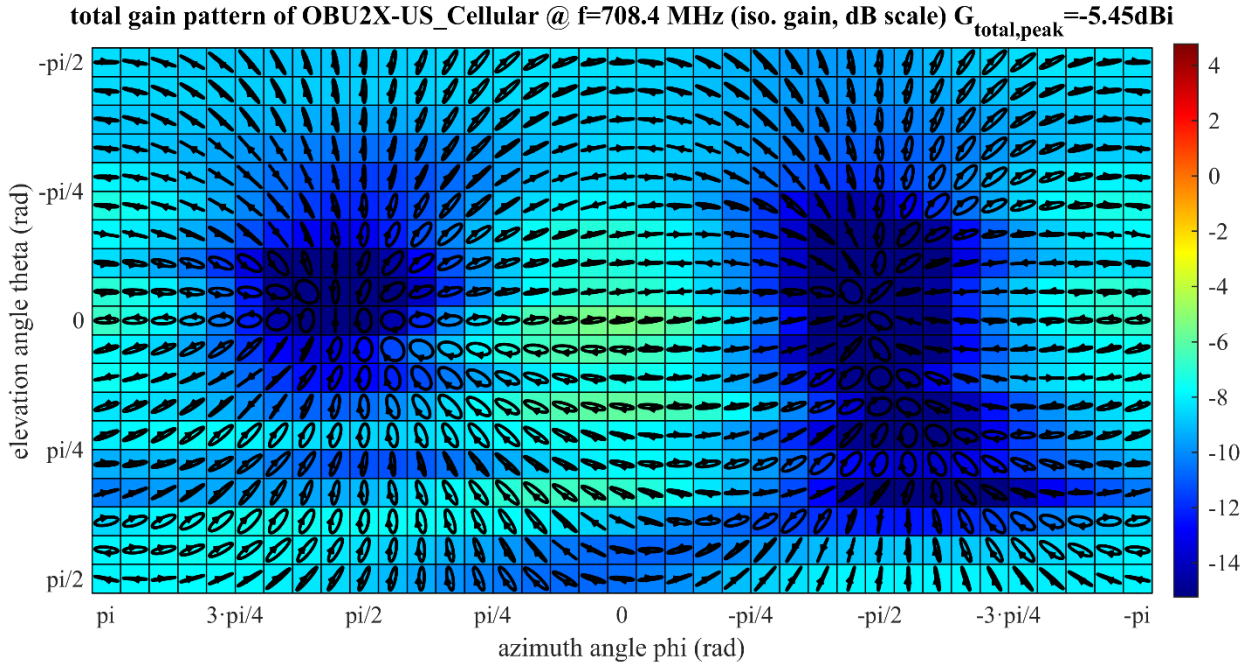

Figure 10: Radiation pattern for center of band 12 & 85

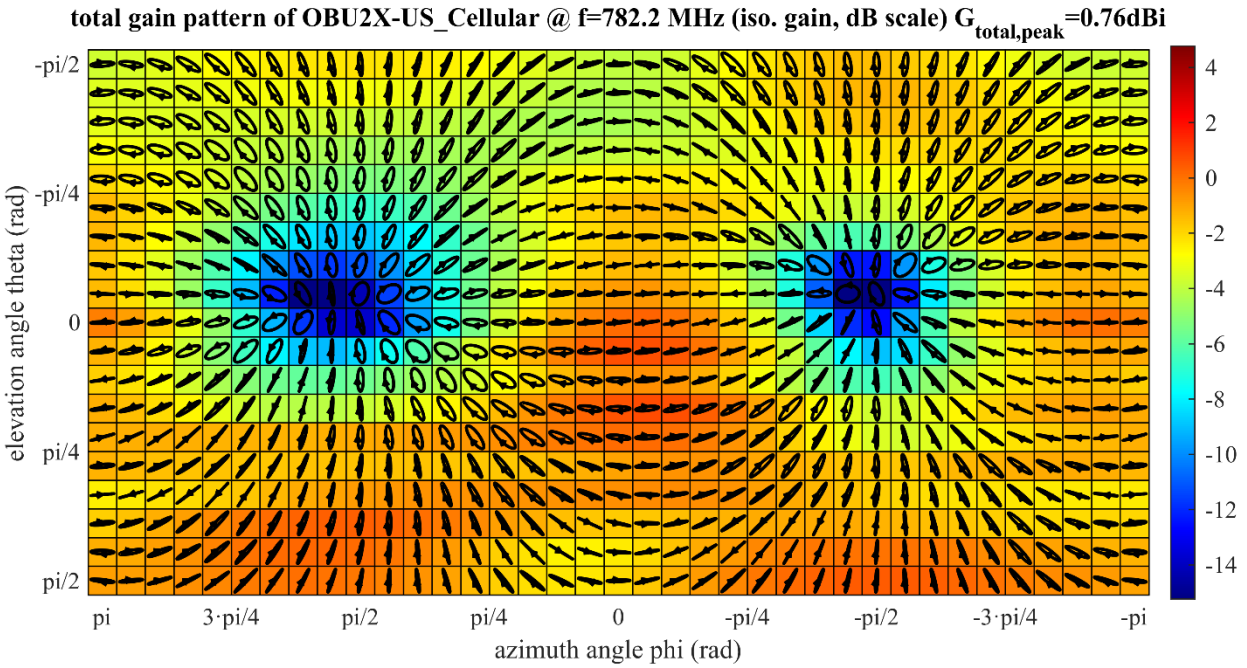

Figure 11: Radiation pattern for center of band 13

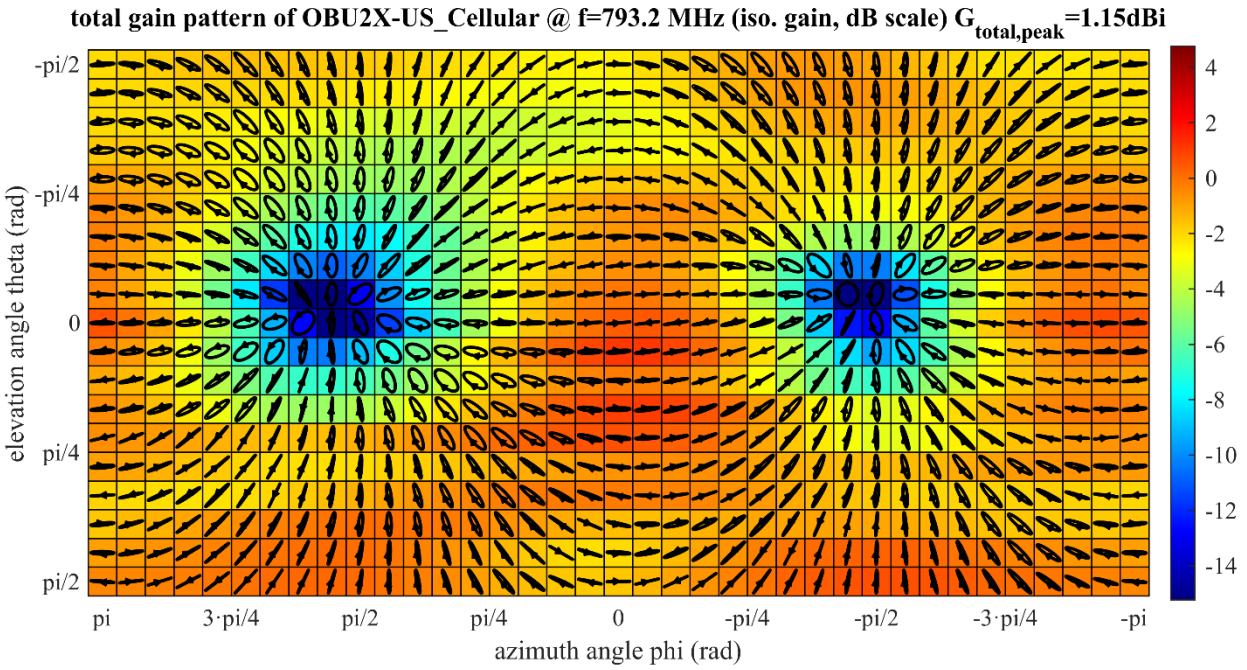

Figure 12: Radiation pattern for center of band 14

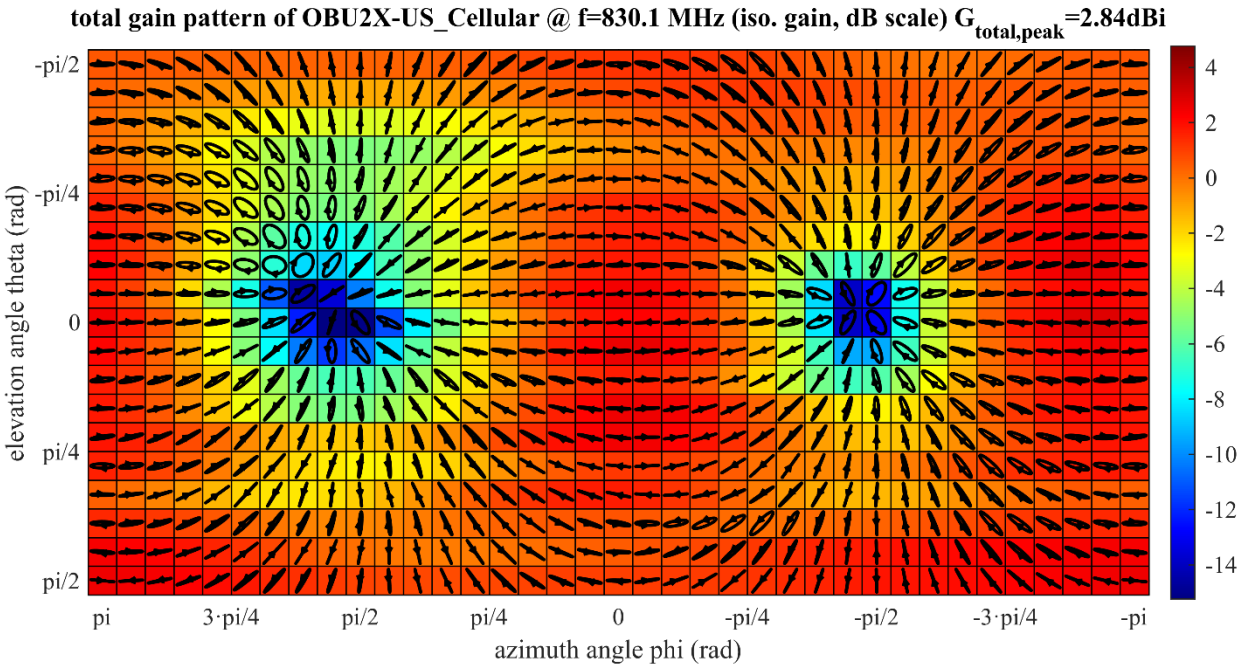

Figure 13: Radiation pattern for center of band 5 & 26

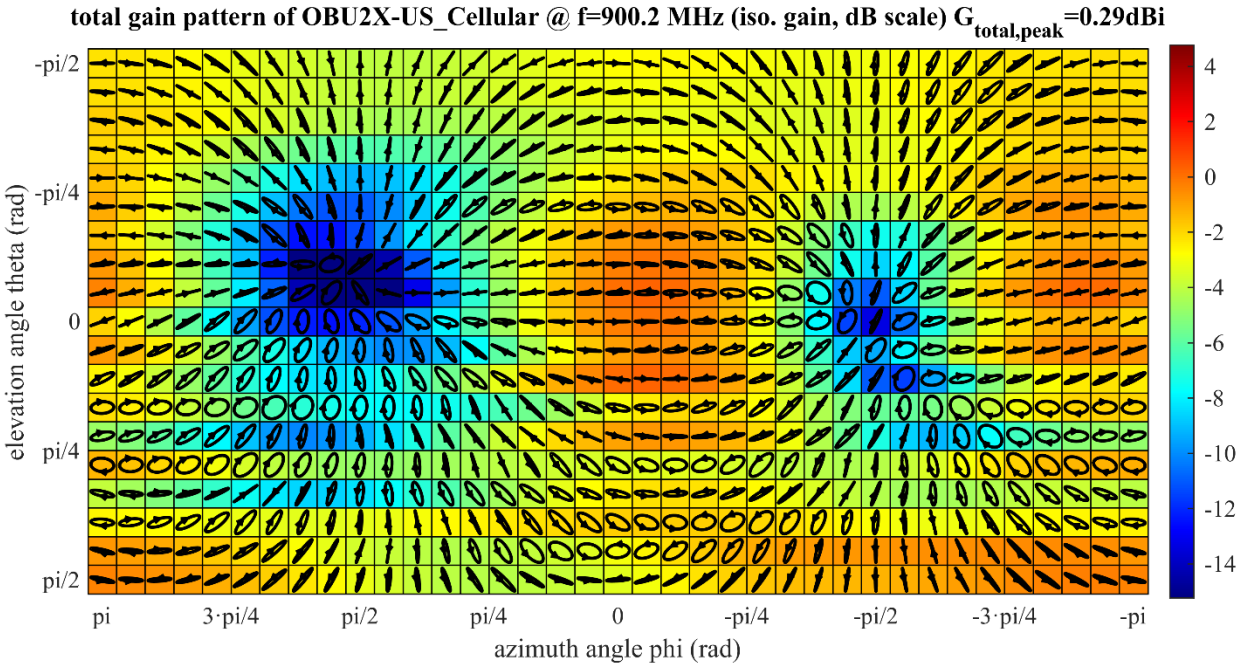

Figure 14: Radiation pattern for center of band 8

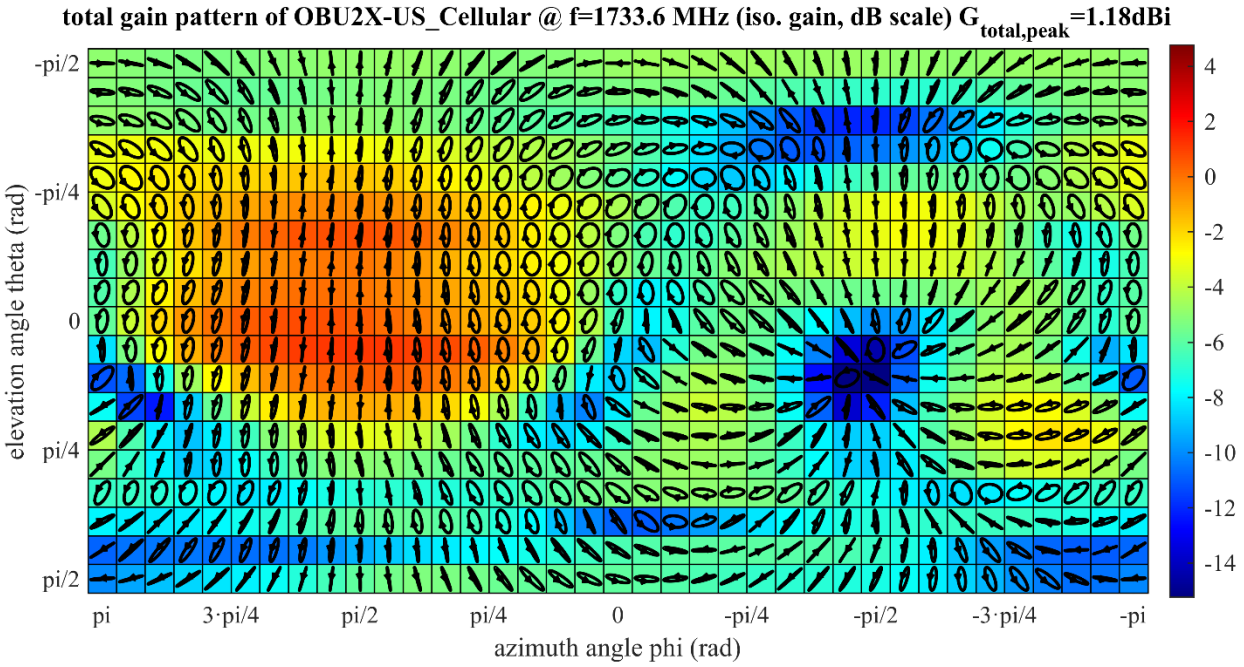

Figure 15: Radiation pattern for center of band 4

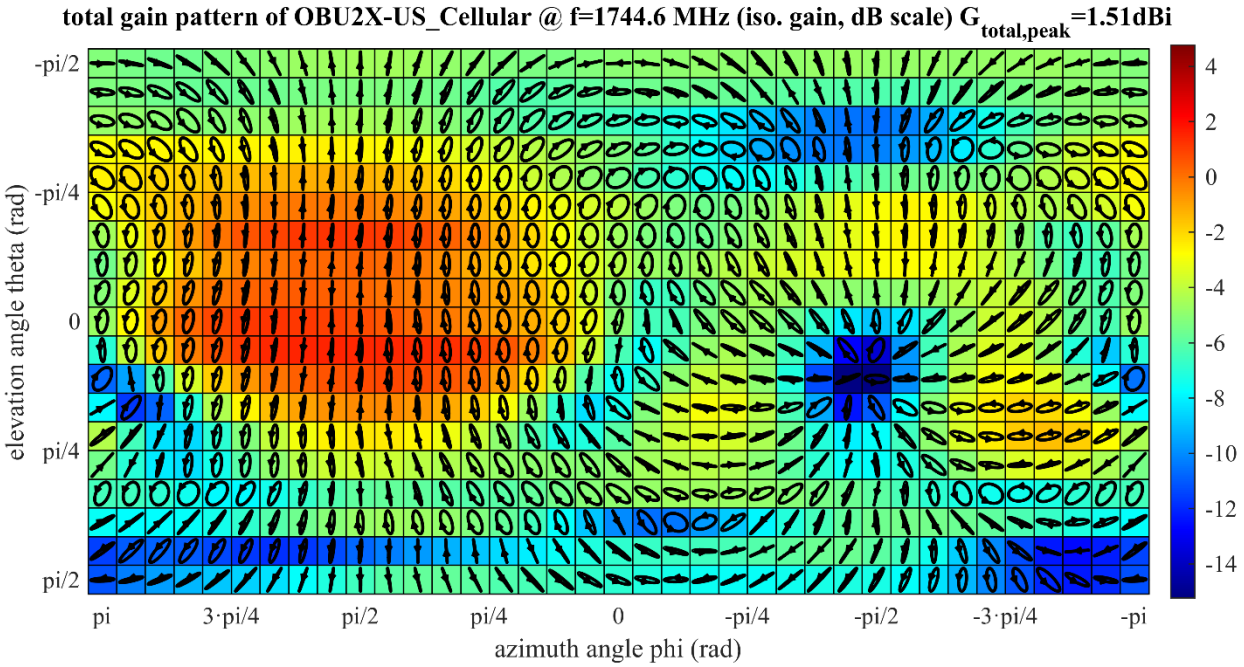

Figure 16: Radiation pattern for center of band 66

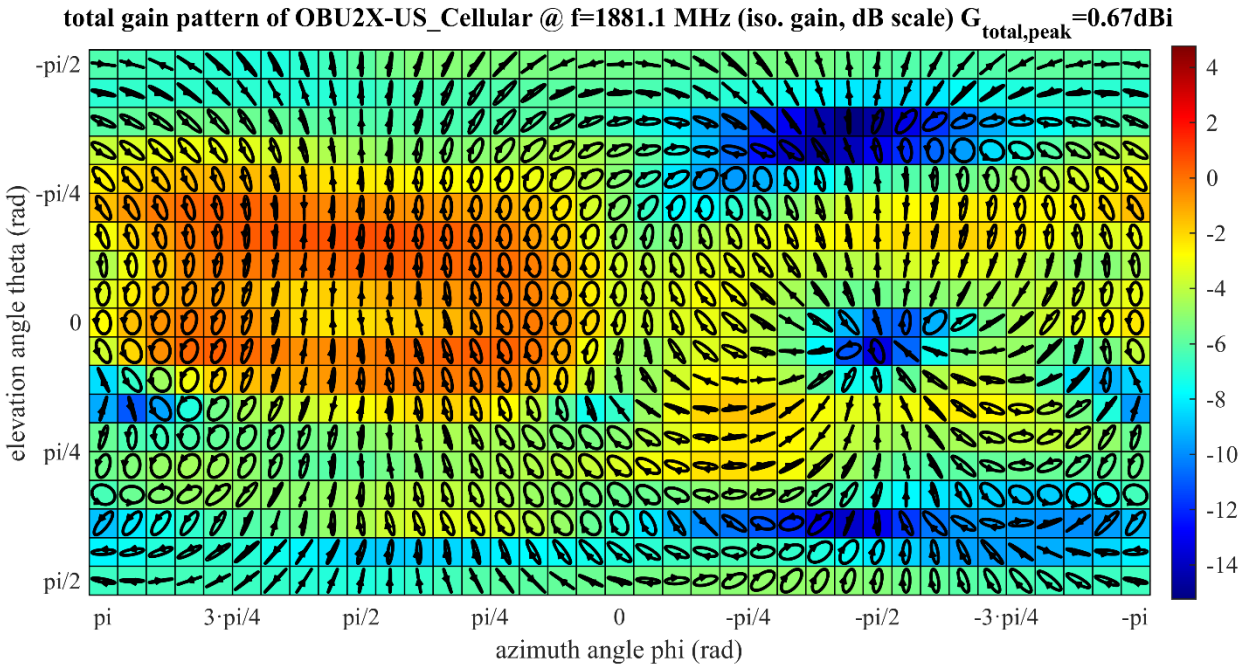

Figure 17: Radiation pattern for center of band 2

5 2.4 GHz Antenna

5.1 Peak gain

Frequency band (MHz)	Band center (MHz)	measured@ (MHz)	Peak gain (dBi)
2400 – 2483.5	2441.75	2442.6	1.31

5.2 Radiation pattern

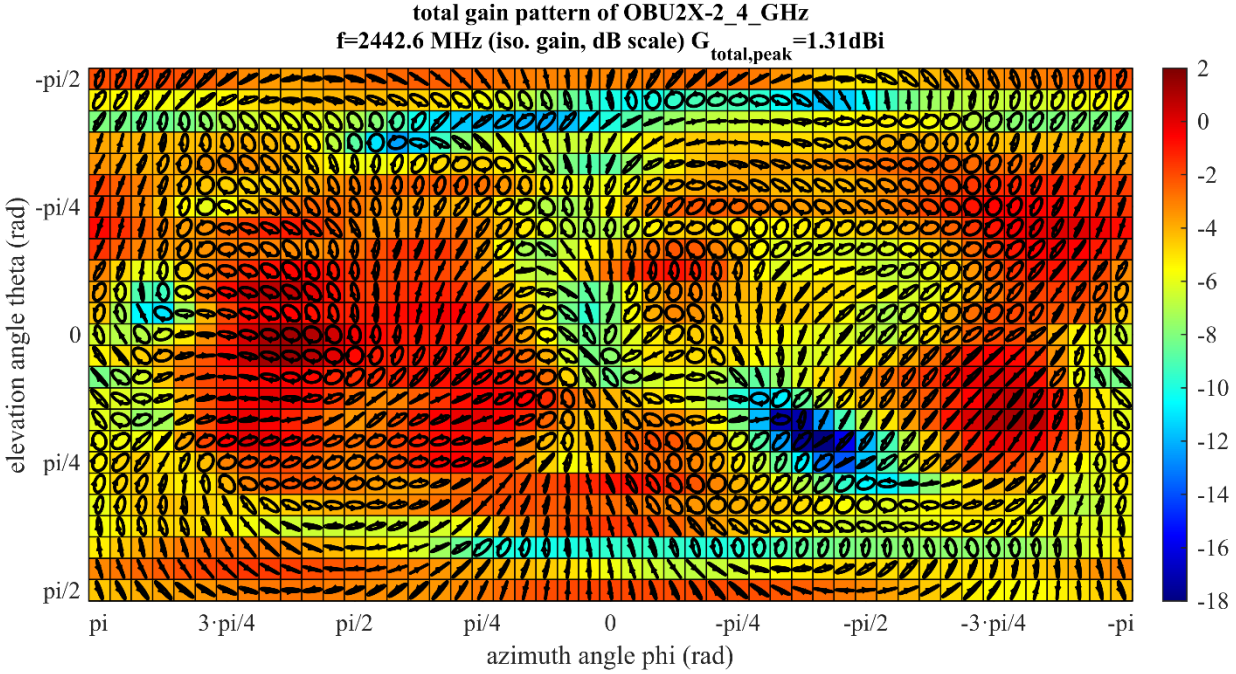

Figure 18: Radiation pattern for center of 2.4 GHz band

6 Antenna coordinate system for radiation patterns

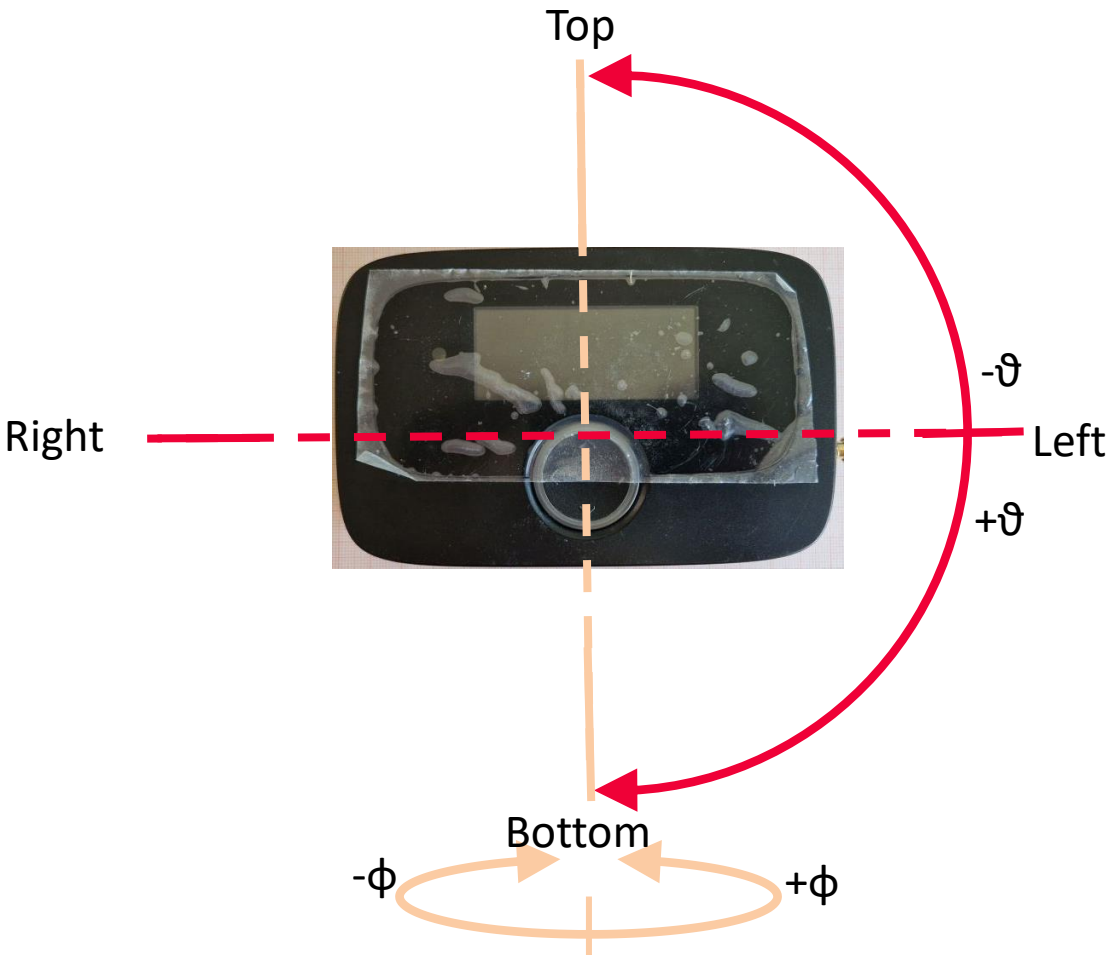

Figure 20: Coordinate system for EUT

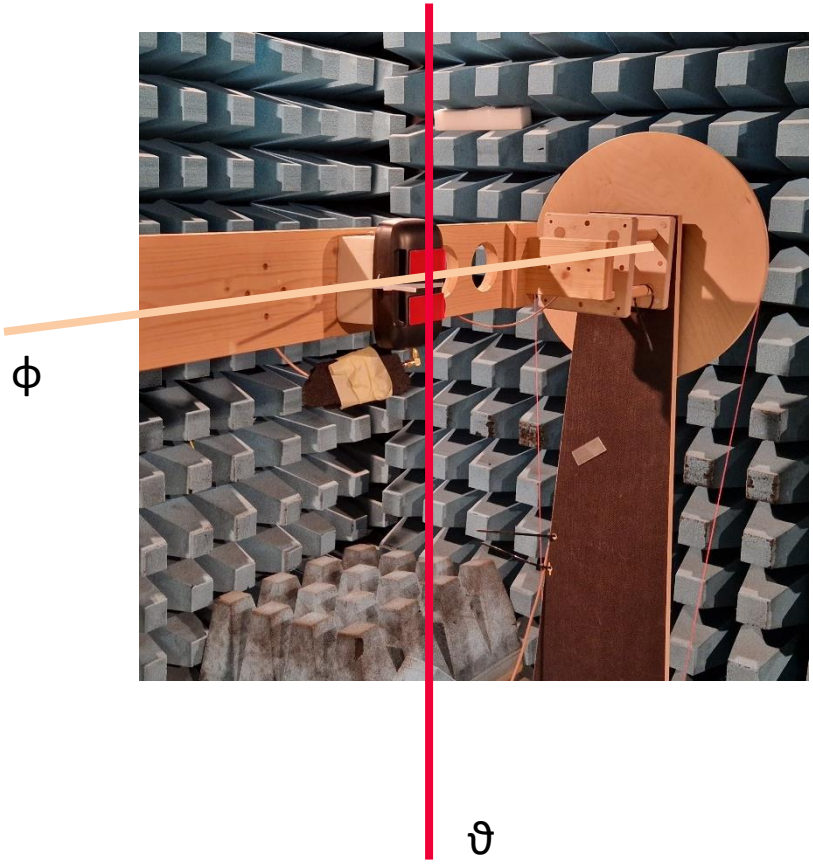

Figure 19: Coordinate system for EUT on turntable

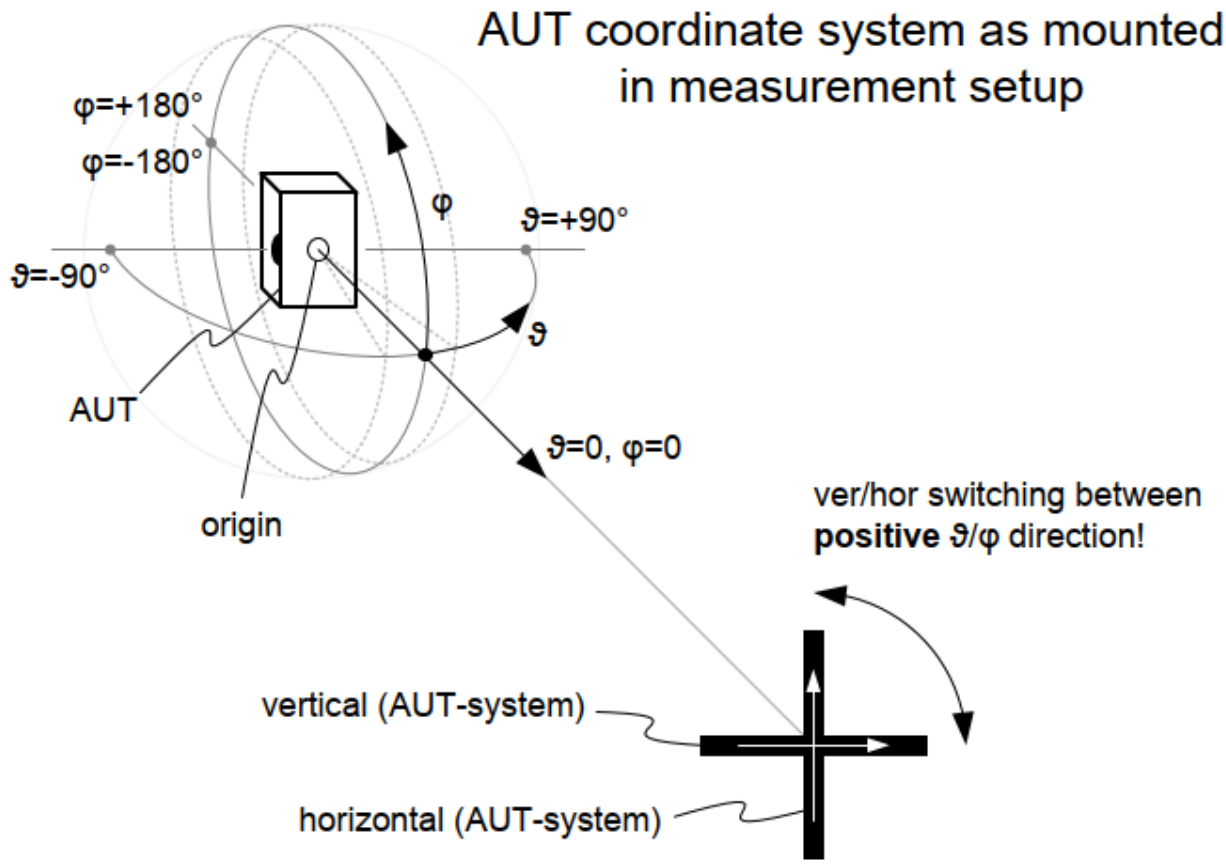

Figure 21: Coordinate system for antenna gain measurement.

7 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 for horizontal and vertical polarization)
- Vector network analyzer (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 analyzer (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 power gain of the AUT over isotropic radiation for each polarization and direction can be calculated by

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

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

$$G_{total}(theta, phi, f) = G(theta, phi, \text{"horizontal"}, f) + G(theta, phi, \text{"vertical"}, f)$$

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

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

The result can be written in logarithmic scale (dBi).

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

8 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