ANTENNA MEASUREMENT REPORT

8000-6240589-240829-01

Characterisation of

One WLan Antenna

Ordered by

Robert Bosch GmbH
Robert-Bosch-Str. 200
D-31132 Hildesheim
GERMANY

Performed at

IMST GmbH
Test Centre Antennas
Carl-Friedrich-Gauss-Str. 2-4
D-47475Kamp-Lintfort
GERMANY

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4 General Information

4.1 Administrative Information

Customer :	Robert Bosch GmbH Bernd Meyer Robert-Bosch-Str. 200 31139 Hildesheim GERMANY
Devices under test (DUTs):	One embedded 2.5GHz WLan-Antenna. DUT: CTU-Pro
Subject:	Antenna performance measurement according to chapter 4.5
Date of measurement:	28. August 2024
Performed:	Stefan Weitz
IMST-Quotation-No.:	5240242-A
Customers-Order-No.:	4503850706
IMST-Project-No.:	8000_6240589
Department:	Antennas & EM Modelling
Responsible:	Aline Friedrich +49-2842-981-337

Performed:..... Reviewed:.....

Stefan Weitz — Test engineer

Aline Friedrich — Head of laboratory

4.2 Abbreviations, Term and Definitions

Abbreviation / Term	Definition
@	at
dB	Decibel
dBi	Decibel related to an isotropic radiator
DUT	Device Under Test
MHz	Mega hertz
n/a	Not applicable
nan	Not a number
GHz	Giga hertz
VSWR	Voltage Standing Wave Ratio (Matching)
VNA	Vector network analyzer
WLan	Wireless local area network

Table 4-1: Abbreviations, term and definitions

4.3 Applicable and referenced documents

-/-

4.4 DUT Description

The DUT is a device with an embedded WLan antenna for the 2.4 GHz band. The following figures show different views of the DUT.

Figure 4-1: View at the individual designation side, antennas on the left.

Figure 4-2: Connection side view

As ordered by the customer only the WLan antenna was measured. All other ports were terminated during measurement.

4.5 Performed measurements and evaluation

4.5.1 *Pattern measurement*

Antenna pattern measurements (amplitude and phase) of the DUT have been performed as follows:

Measured frequencies:
2412 MHz, 2430MHz, 2448 MHz, 2466 MHz,2484 MHz.

Three-dimensional measurements:

Phi:	0° to 360° step width 5°
Theta:	0° to 180° step width 5°
Measurement antenna:	two orthogonal polarisations.

The results have been exported as ASCII/Excel file.

4.5.2 *Matching measurement*

The matching measurement has been performed as follows:

Measured frequencies:
2 GHz to 3 GHz step width 625 kHz (1601 evenly spaced frequency points).

The results have been exported as ASCII/Excel file

4.5.3 *Evaluation*

From the pattern and matching measurement results the following evaluations have been done:

- Realised gain over frequency for every measured angle and polarisation
- Efficiency over frequency
- S_{11} over frequency

The results of all evaluations have been reported as PNG-formatted graph and Excel file.

4.6 Notes

4.6.1 *Accuracy of the measurement*

- The accuracy of the pattern and gain measurement will be stated with +/- 1 dB.

4.6.2 *Other notes*

-/-

5 MEASUREMENT

5.1 Measurement environment and measurement devices

All measurements have been performed in the air conditioned and completely shielded anechoic chamber (Range II) 007-A34-089/99A of IMST GmbH. This minimizes measurement errors caused by variations in temperature, disturbing signals and reflections.

5.2 Used measurement devices

All calibrations and measurements have been done with the devices that are stated in the following table. The date of the last calibration is shown in the column "Cal. Date".

Type	Device	Ser. No.	Cal./Check Date
ZVL 13 Rohde & Schwarz	Network/Spectrum analyser 9 kHz – 13.6 GHz	10114	01.2024
SH800 Satimo	Dual ridged Horn (Ref. Ant.) 0.8 -12.0GHz	157	08.2019
LB-OSJ-0460-SF AInfo	Quad ridged Horn (Meas. Ant.) 0.4 -6.0GHz	2100015000011	06.2024
B83117-A1431-T161 Siemens Matsushita	Anechoic Chamber	Project No. 007-A34-089/99A	N/A
AL-DBDR-3G/AL-560 Orbit/FR	Roll-over-azimuth positioner	434	03.2024
AL-4164-MC Orbit/FR	Controller	25	03.2024
DARIC 2.0 IMST	Control and measurement software		N/A
Rohacell bracket	Free space mounting		N/A
PNA_E8363B Agilent	Network analyser 10 MHz -40 GHz	MY43030308	10.2022
02CK10A-150 Rosenberger	Calibration Kit DC – 40 GHz	U3901	01.2024

Table 5-1: Devices used for calibration and measurement

5.3 Pattern measurement

The pattern measurement was performed in our anechoic chamber. Movement of the DUT during pattern measurement has been done by a „Roll over Azimuth"-positioner. The accuracy of the positioner is 0.3°.

Figure 7-1 shows the principle setup for pattern measurement.

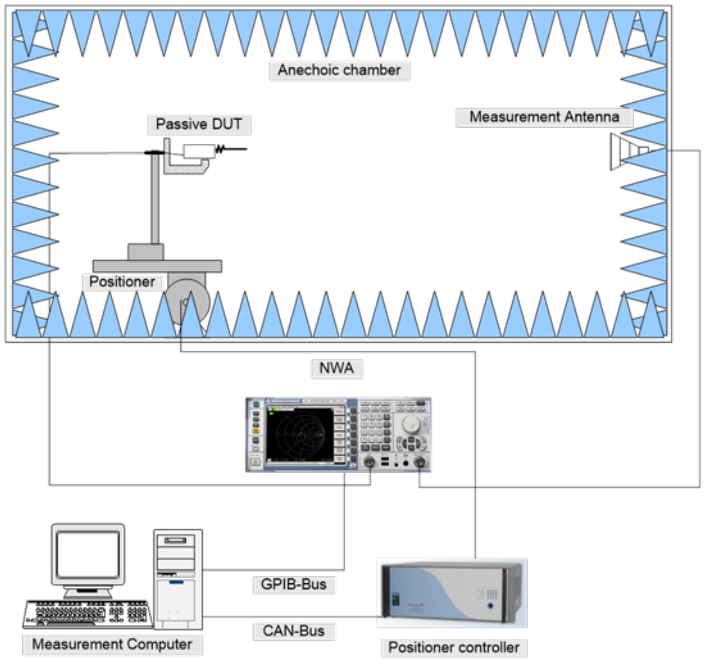

Figure 5-1: Standard set up (electrical)

5.3.1 *Measurement Setup*

Figure 5-2 shows measurement setup for the DUT.

Figure 5-2: Pattern measurement setup.

Before the calibration was done, the position of the measurement and the calibration antenna was checked by a positioning laser. The aperture of the calibration antenna and the aperture of DUT were positioned into the centre of rotation of the azimuth positioner.

During measurement the DUT was used as transmit antenna.

To avoid measurement errors caused by reflections the DUT was mounted on a Rohacell®-bracket.

The distance between the measurement antenna and the rotation centre of the DUT was about 2.23 m during measurement (Far field conditions).

To minimize errors caused by mismatching the feeding cable was equipped with an attenuator with a very low VSWR. The SMA-connector of the attenuator was the reference plane for the pattern measurement.

All unused connectors were terminated by 50 Ω loads.

5.3.2 *Coordinate system during measurement*

The following figures show the axis relation during pattern measurement.

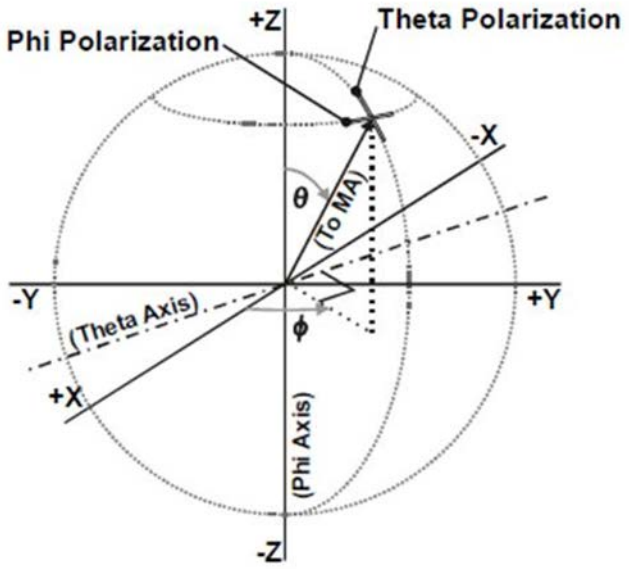

Figure 5-3: Theta/Phi coordinate system.

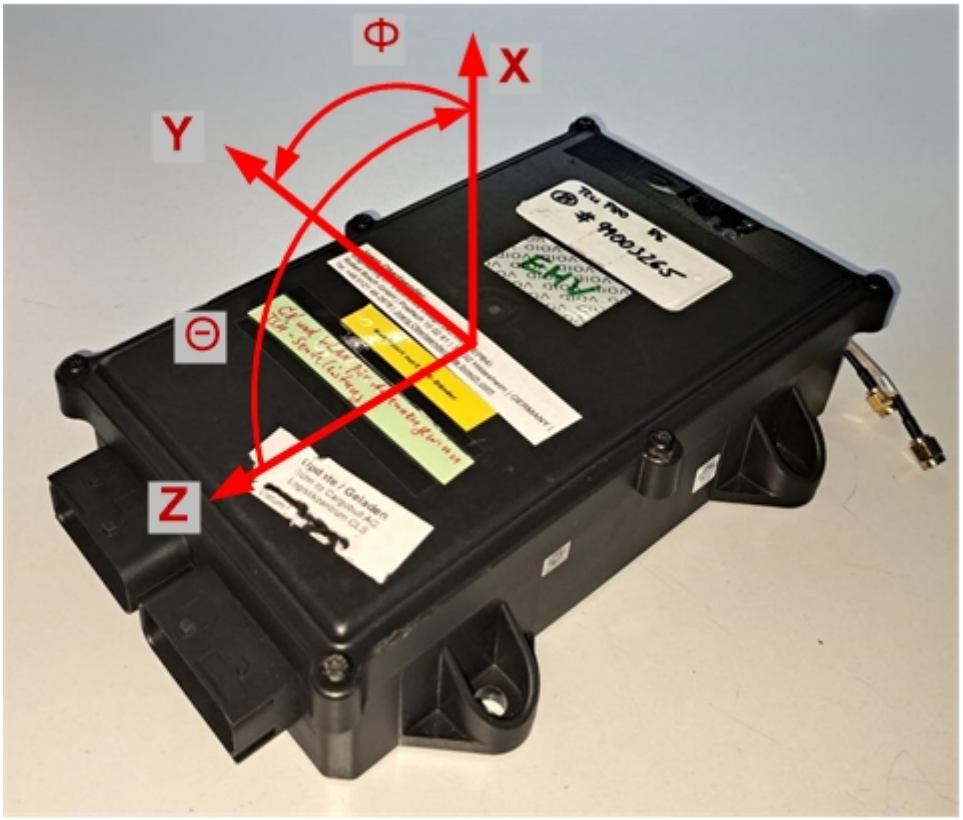

Figure 5-4: Position of the DUT in the theta/phi coordinate system.

5.4 Matching Measurement

The following picture shows the setup of the matching (S_{11}) measurement.

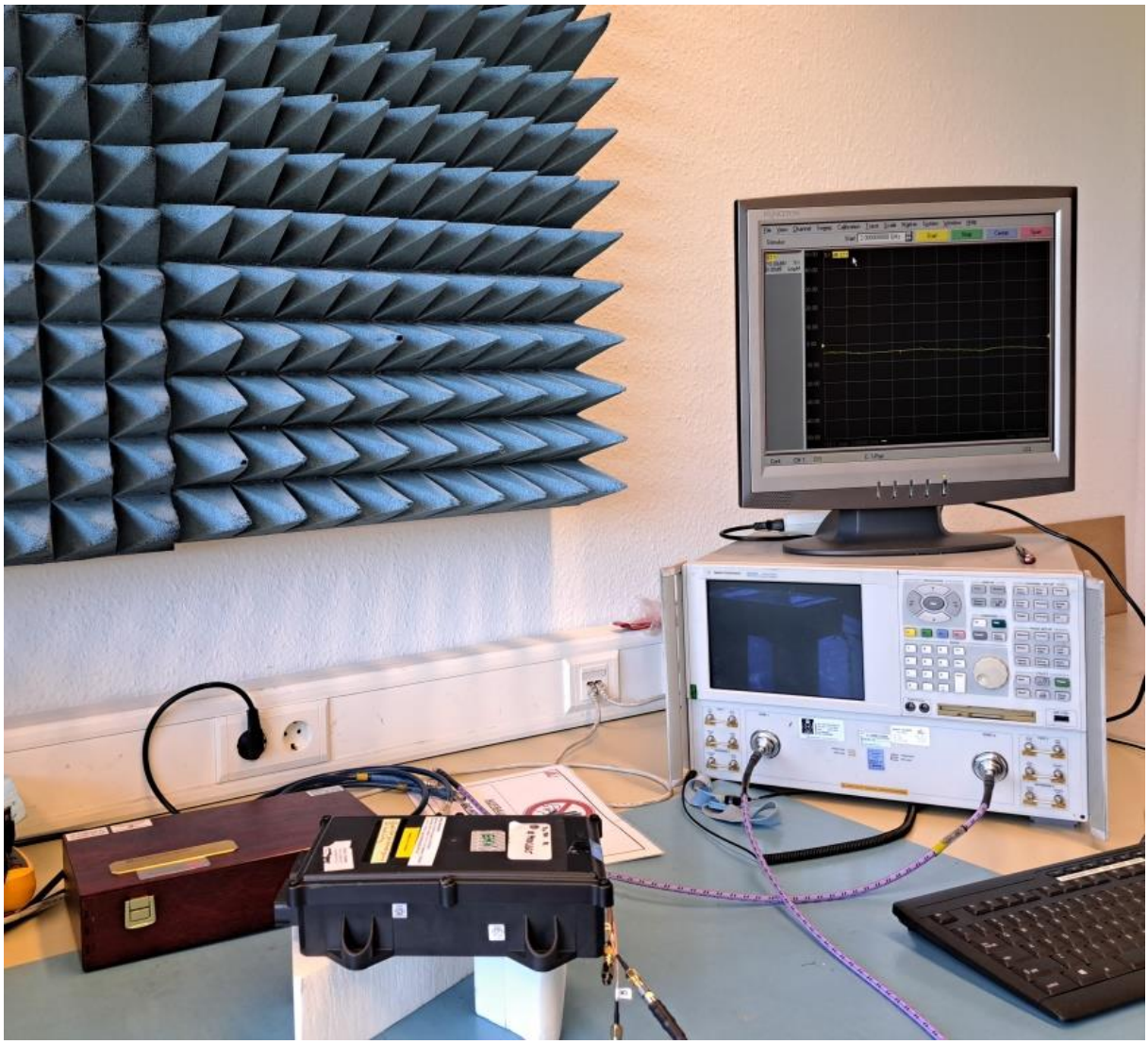

Figure 5-5: Matching measurement setup.

During matching measurement the DUT was located on Rohacell® block. This minimizes external influence of the measurement results. Before the matching measurement one port of the VNA was calibrated with a full-one-port calibration.

6 Far Field Measurement Report

The "Far field measurement report" shows a survey about the performed measurements.

FF-Measurement-Report

Operator: SW
Date from: 28.09.2024
Project: 8000_6240589
Object: 2.4 GHz WLan antenna
Temp: 23°C +/-1°

Setup-Files	Frequencies / MHz	
S1: n/a	f1: 2000 - 3000	1601 points
S2: Bosch.dam	f2: 2412 - 2484	5 points

No.	File	Frequency /MHz	Meas.-Axis	Step-Axis		Remarks	Setupfile
			Roll/°	Azimuthl/°	Polarisation		
1	Bosch_WLan_2.4GHz.s1p	f1	n/a	n/a	n/a		
2	20240828_165113_CTU-Pro_WLan.dmdf	f2	0/+355 (5)	0/+180 (5)	Theta/Phi		S2

Table 6-1: Far field measurement report

7 Environmental Conditions During Measurement

- Temperature: 23 °C +/- 1 °
- Rel. Humidity: 50 % +/- 20%

8 RESULTS

8.1 Max. gain, efficiency and matching values

The following table shows the matching and efficiency values of the DUT. Also measurement angles with maximum gain values are shown.

	f	S11	η	Max. Gain at Polarisation Θ			Max. Gain at Polarisation Φ			Max. Gain absolut		
	MHz	dB	%	dBi	Θ [°]	Φ [°]	dBi	Θ [°]	Φ [°]	dBi	Θ [°]	Φ [°]
CTU-Pro Wlan Antenna	2412	-4.1	26.1	0.9	180	80	0.9	175	170	0.9	175	185
	2430	-3.7	20.3	-1.6	150	260	-2.8	175	160	-1.5	150	260
	2448	-4.5	28.0	0.6	150	255	0.5	175	170	1.0	145	225
	2466	-4.5	30.1	1.0	180	75	1.4	175	170	1.6	175	180
	2484	-4.6	31.9	1.4	180	80	1.8	175	170	2.0	175	180

Table 8-1: S11, efficiency and maximum gain of CTU-Pro WLan antenna.

8.2 Matching diagrams of CTU-Pro WLan antenna

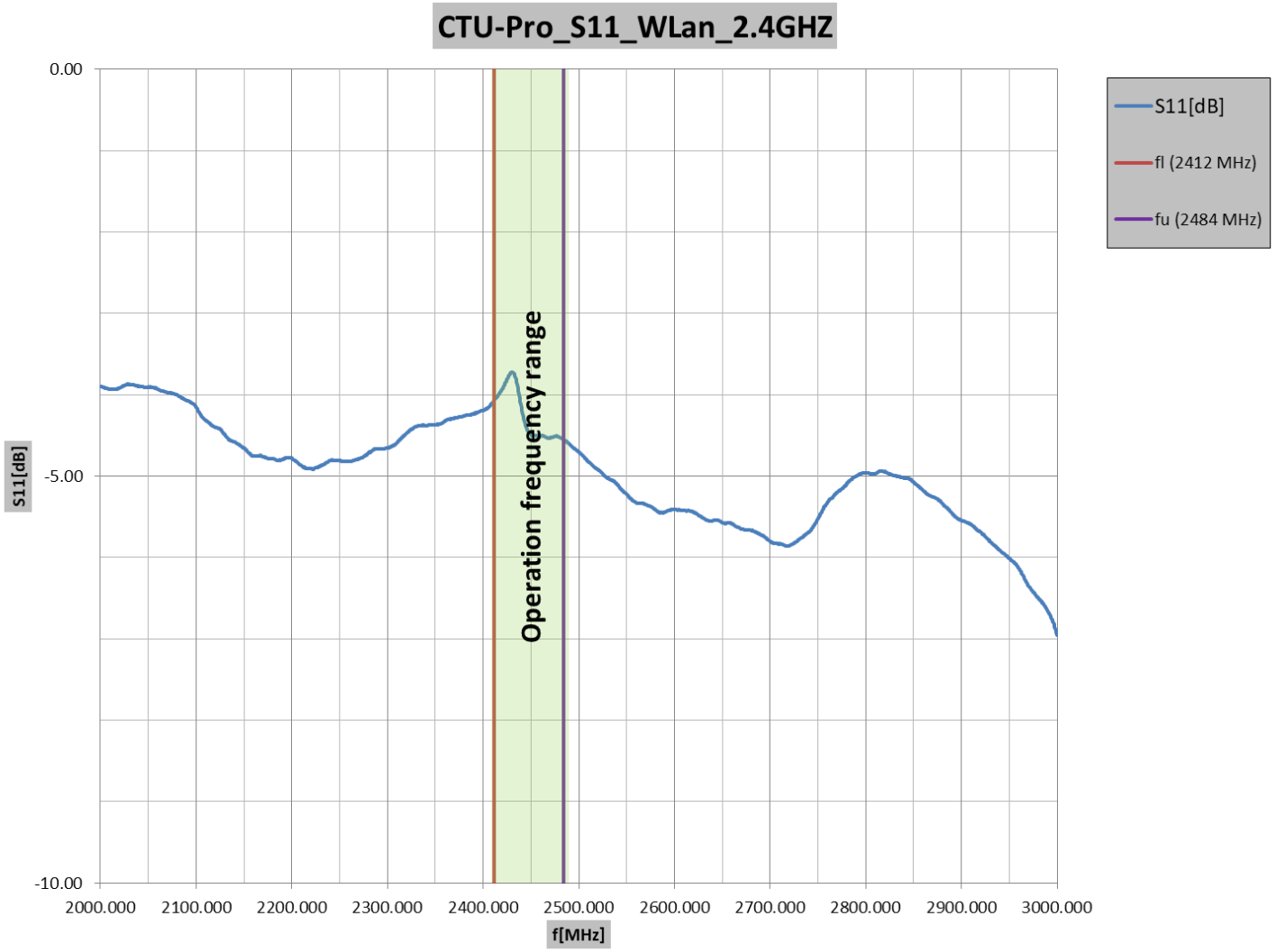

Figure 8-1: Matching diagram CTU-Pro WLan-antenna.

8.3 Pattern diagrams of CTU-Pro WLan antenna

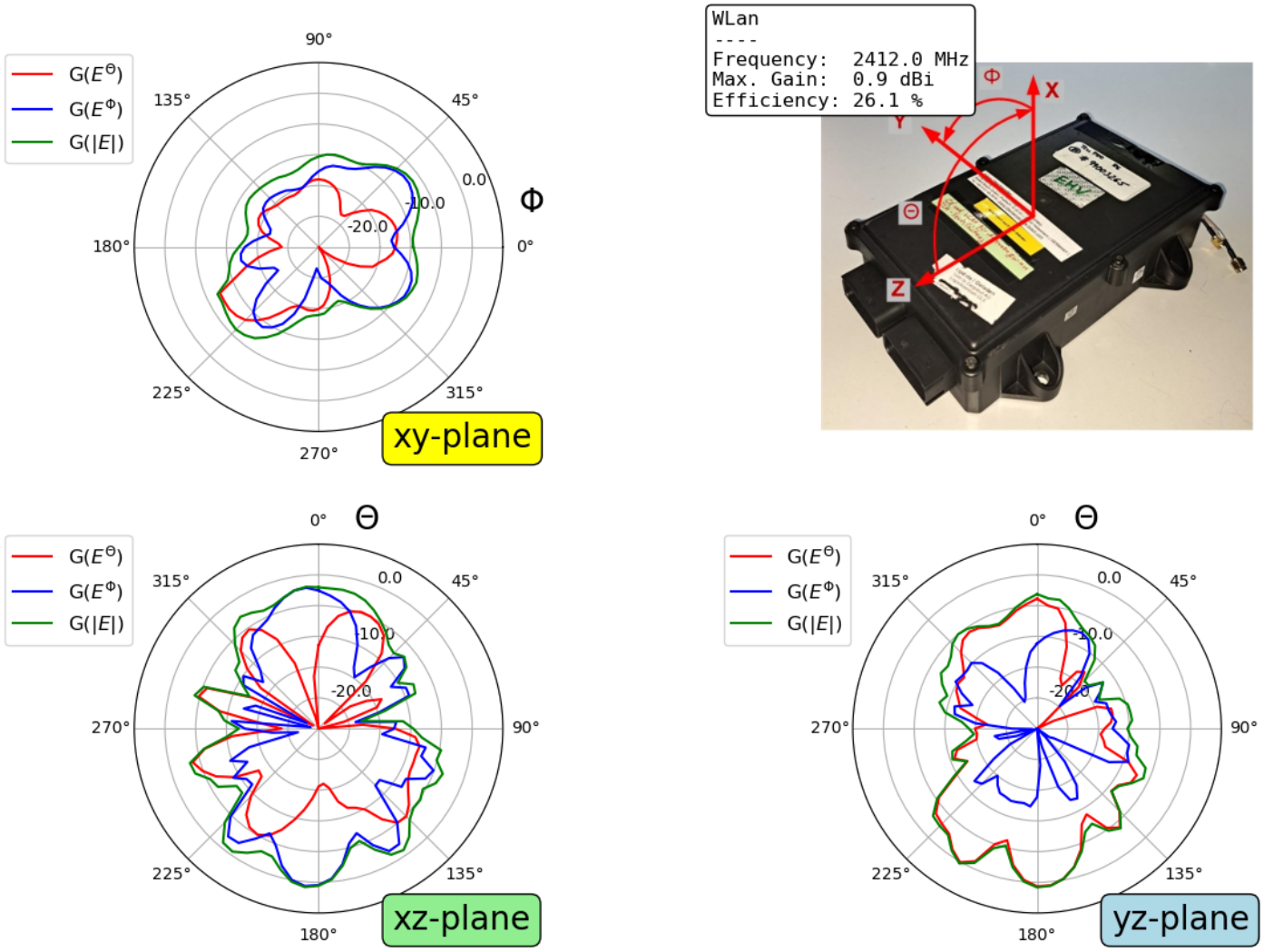

Figure 8-2: E-Theta/E-Phi/Sum polar diagram, CTU-Pro WLan antenna @ 2412 MHz.

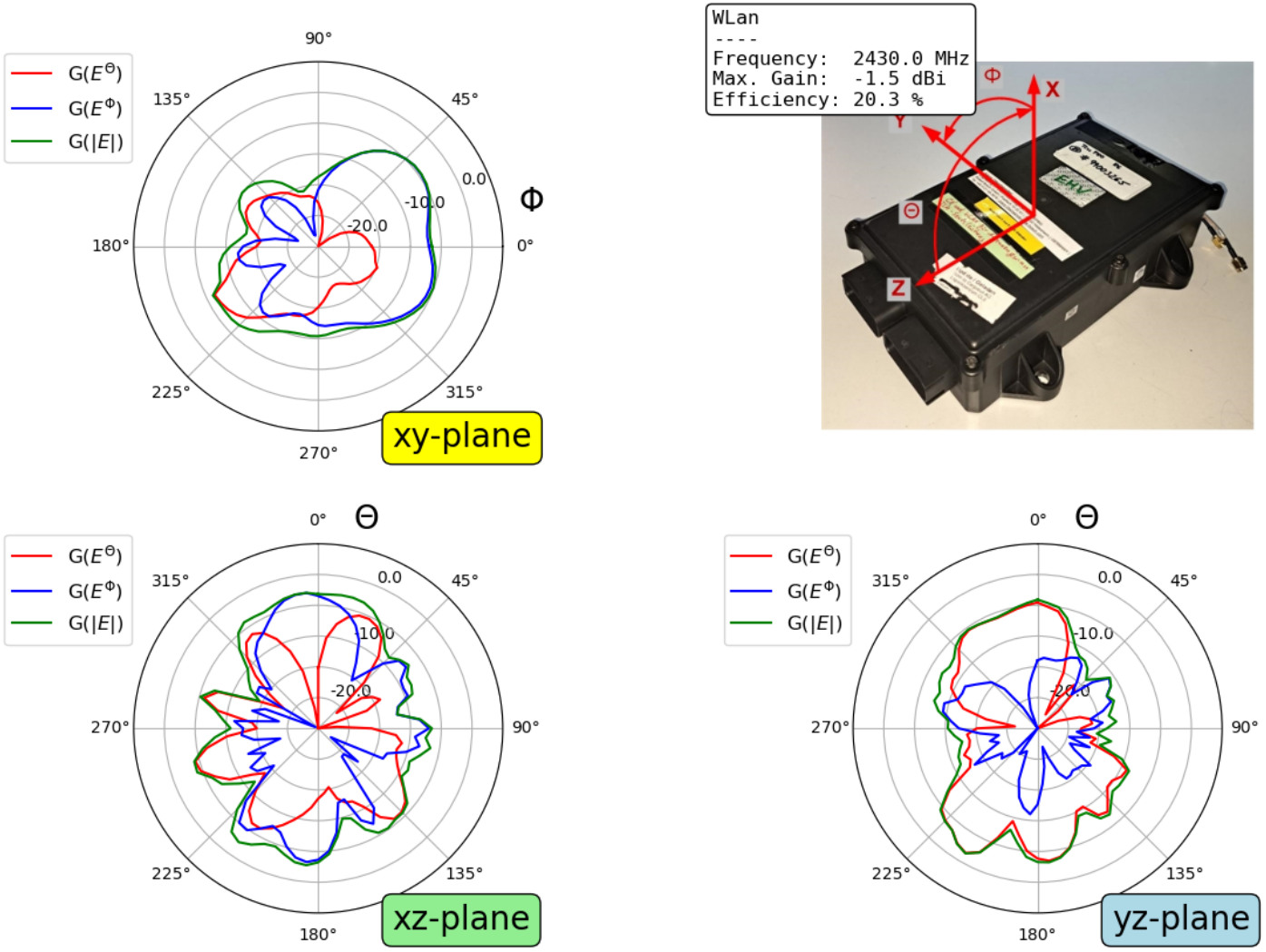

Figure 8-3: E-Theta/E-Phi/Sum polar diagram, CTU-Pro WLan antenna @ 2430 MHz.

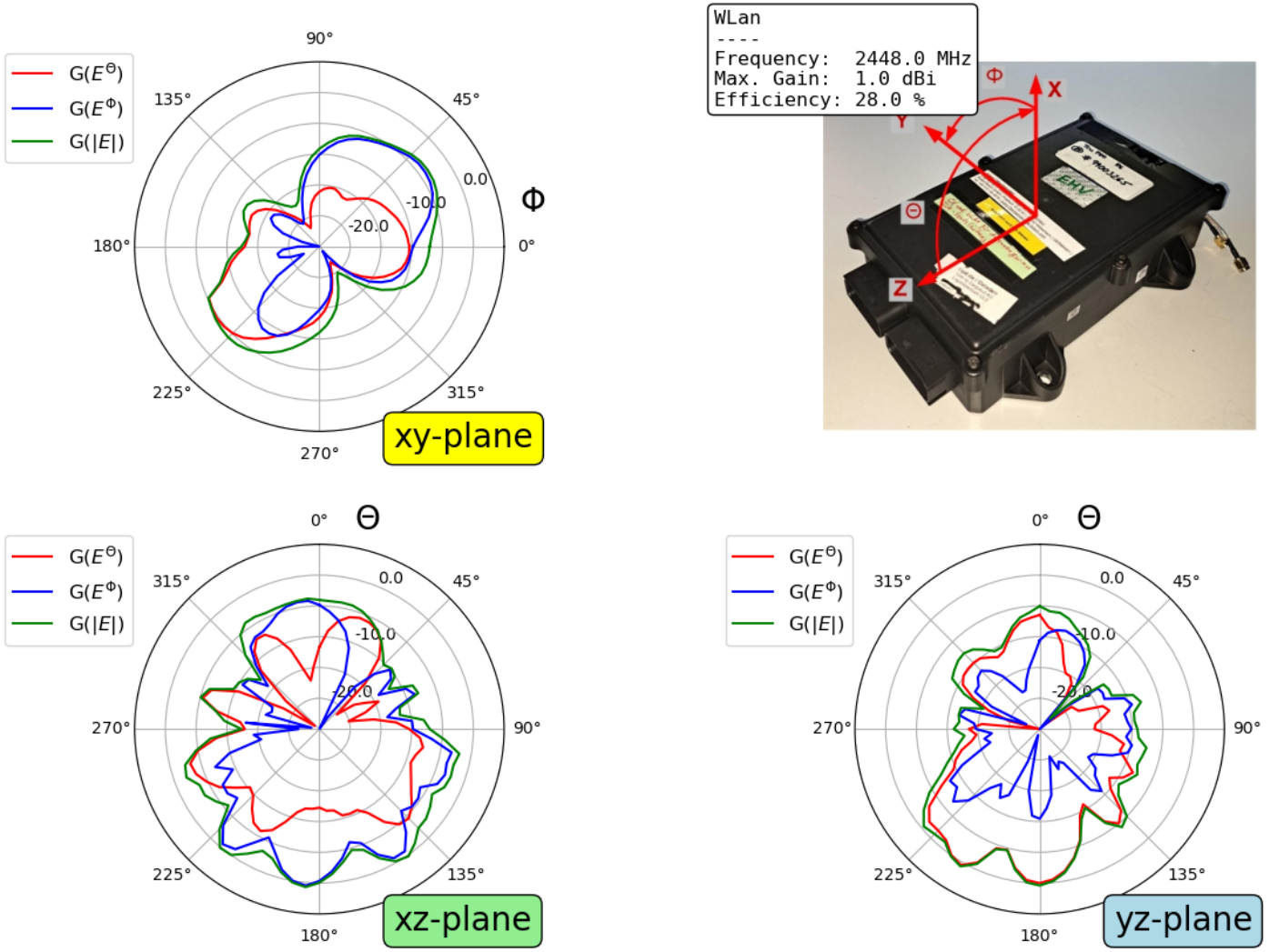

Figure 8-4: E-Theta/E-Phi/Sum polar diagram, CTU-Pro WLan antenna @ 2448 MHz.

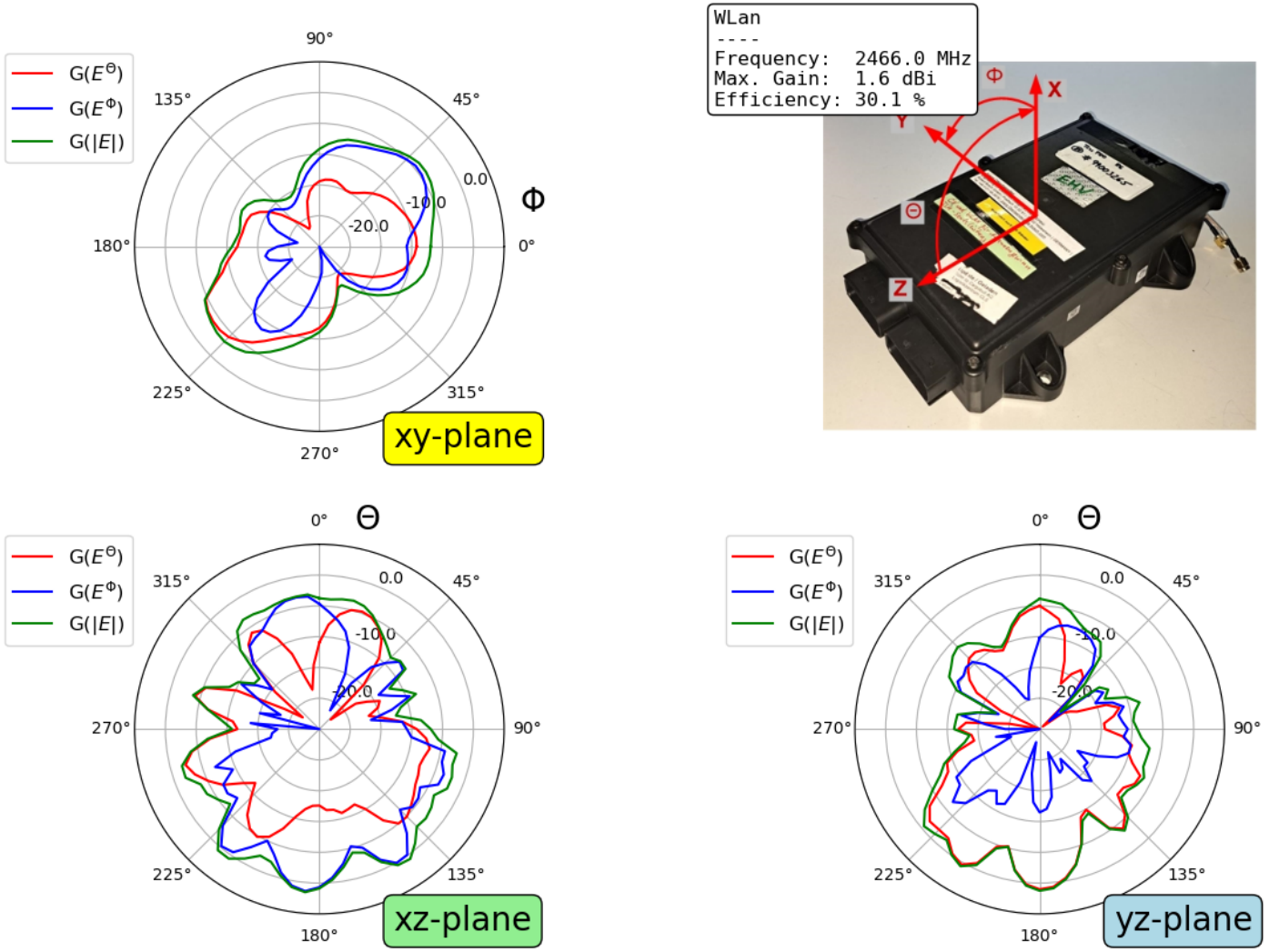

Figure 8-5: E-Theta/E-Phi/Sum polar diagram, CTU-Pro WLan antenna @ 2466 MHz.

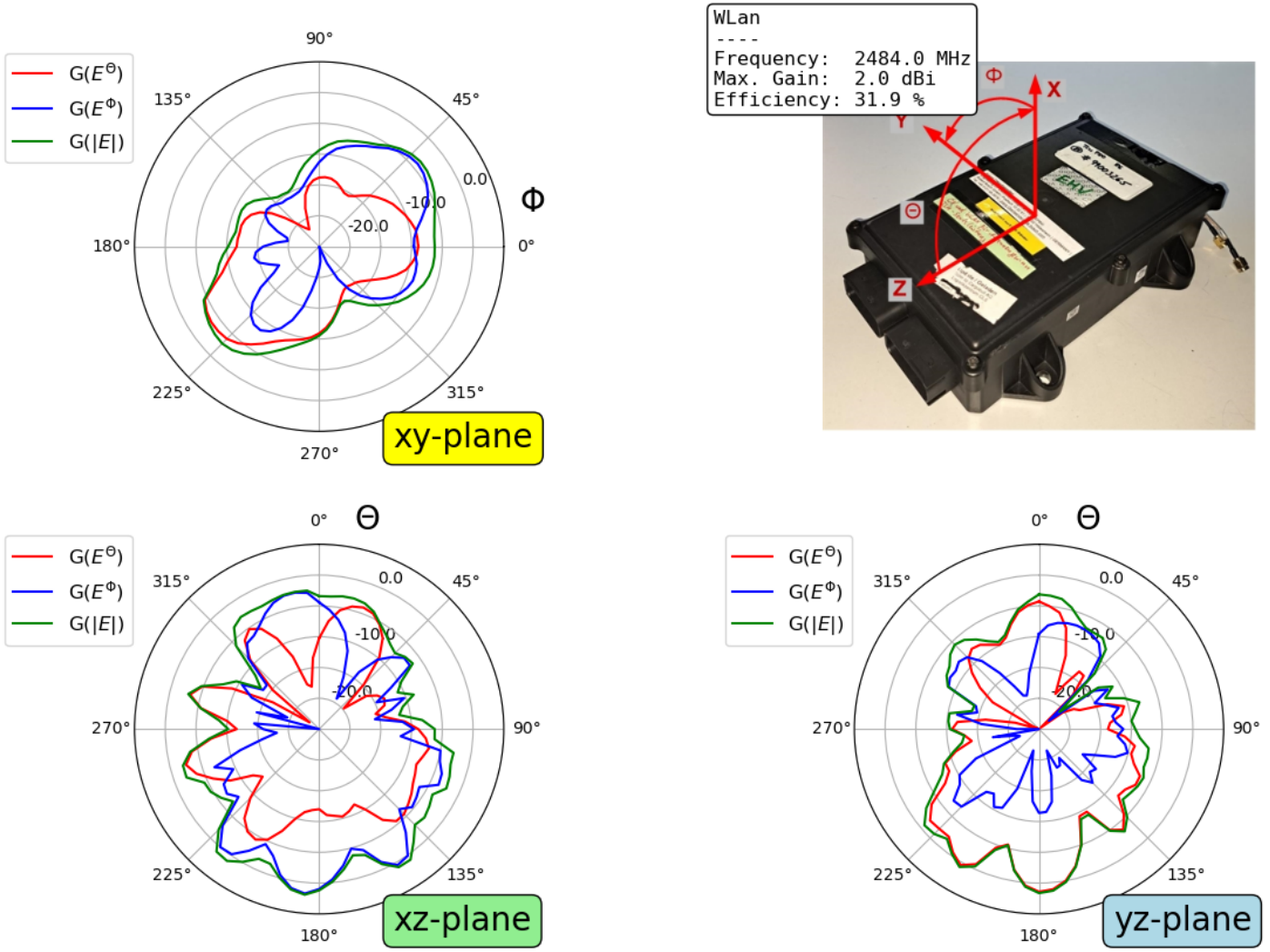

Figure 8-6: E-Theta/E-Phi/Sum polar diagram, CTU-Pro WLan antenna @ 2484 MHz.