Radiation performance of MHF4 antennas for the ST67W611M1A6U module

Introduction

This document gives an overview of the diagram patterns of 12 MHF4 antennas connected to the ST67W611M1A6U module. The STDES-67W61BU-U5 reference design is used as example of implementation.

Figure 1. ST67W611M1A6U module

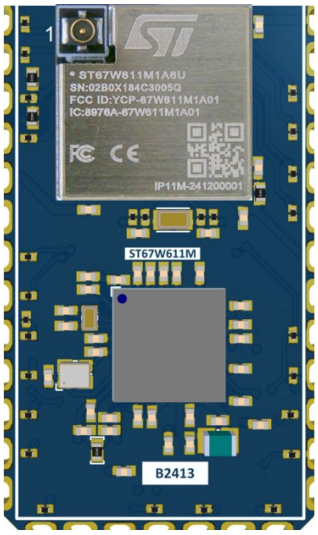
DT77581V1

1 Measurement setup

1.1 Board overview

The evaluation is conducted on the reference design STDES-67W61BU-U5 (board B2413) populated with the ST67W611M1A6U version:

Figure 2. Board B2413 with ST67W611M1A6U version



DT79315V1

This U version of the module contains a connector called MHF4. The manufacturer reference is the following: Speedtech C87P101-C0001-H.

A first conducted measurement is necessary to determine the power level at the output of the module. To perform this measurement, it is necessary to connect an MHF4 cable to the module and a spectrum analyzer.

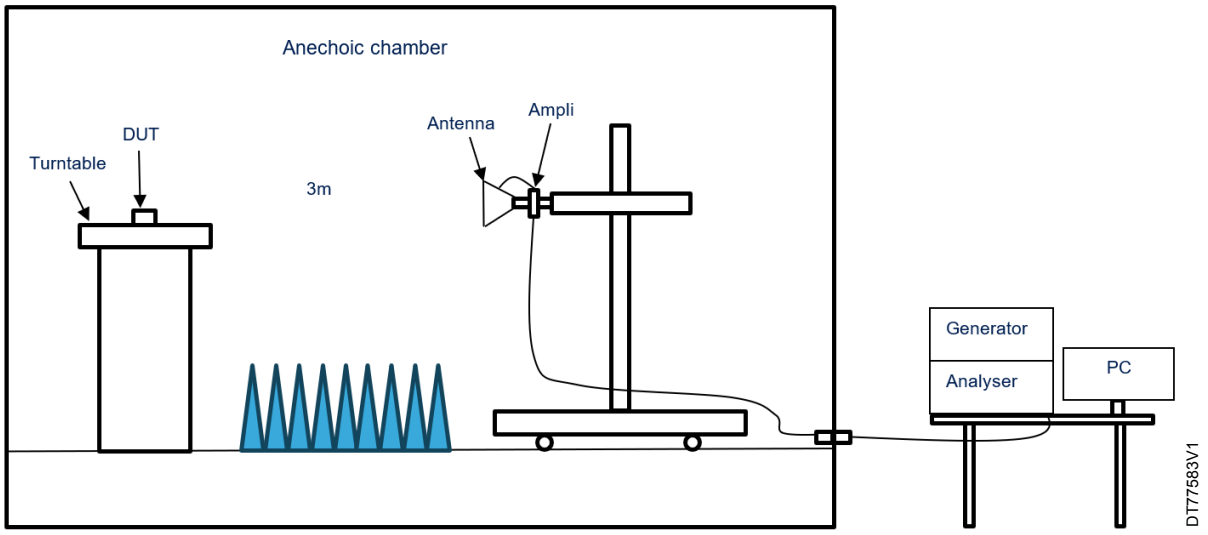
Figure 3. MHF4 connector and cable references

DT77582V1

1.2 Anechoic chamber description

The following figure shows the main equipment inside and outside of the anechoic chamber.

Figure 4. **Anechoic chamber description**



1.3 Test equipment

This tables lists the test equipment used for radiated emission.

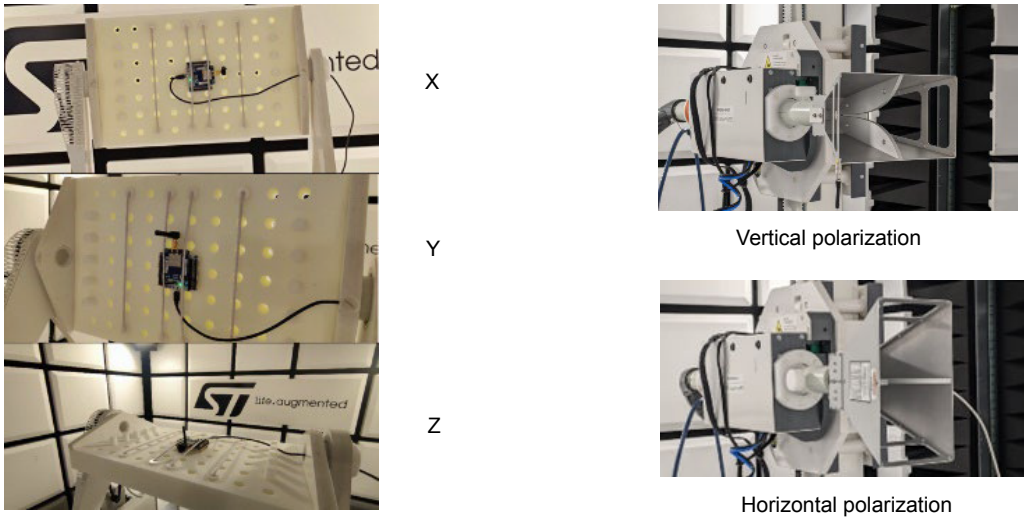
Table 1. **Anechoic chamber test equipment**

Description	Manufacturer	Model	Identifier
Horn antenna	SCHWARZBERCK	BBHA 9120D	EMC_002
RF cable	-	-	Cable Antenna
RF cable	-	-	Cable_FilterAmpli_2
Semi anechoic room	COMTEST	1766-1221 Ma	-
Antenna mast	Innco- Systems	MA2000-XP-ET	-
Turntable	Innco- Systems	-	MISC_0012A
Controler	Innco- Systems	CO3000	MISC_0012
Spectrum analyzer	Rohde&Schwarz	FSV3030	SPAN_0049
Pre-amplifier	SCHWARZBERCK	BBV 9718C 1-18GHz	EMC_001
Radiated TEST BENCH SUITE	STMicroelectronics	-	-

1.4 Tested position

The module can be set in three positions (X, Y, Z), and the received antenna can be polarized horizontally or vertically:

Figure 5. **Tested position**



Here are the possible measurements combinations:

- [Pos X, Ant H] ; [Pos X, Ant V]
- [Pos Y, Ant H] ; [Pos Y, Ant V]
- [Pos Z, Ant H] ; [Pos Z, Ant V]

The two first configurations listed above are equivalent. The configurations retained for the measurements are listed below:

- [Pos Y, Ant H] ; [Pos Y, Ant V]
- [Pos Z, Ant H] ; [Pos Z, Ant V]

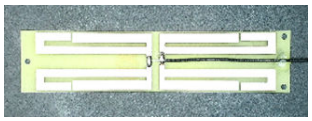
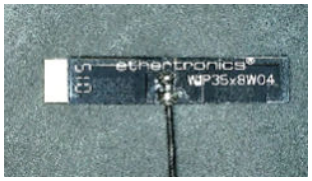
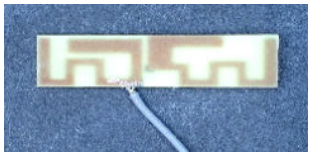
The figure below shows an anechoic chamber:

Figure 6. **Anechoic chamber illustration**

1.5 Antennas list

Antennas are available from the standards distributors:

Table 2. Antenna illustration

INPAQ “RFPCA521010EMABY01” PCB dipole antenna with adhesive on bottom side	
INPAQ “RFPCA501010EMABY01” PCB monopole antenna with adhesive on bottom side	
INPAQ “RFPCA441010EMABY01” PCB PIFA antenna with adhesive on bottom side	
LINX “ANT-2.4-FPC-LH100M4” Flex dipole antenna with adhesive on bottom side	
EZURIO “EBL2400A1-10MH4L” PCB antenna – patented PCB microsphere technology No adhesive	
TAOGLAS “FXP830.24.0100B” Flex dipole antenna with adhesive on bottom side	
PULSE “W3513BD0080” PCB dipole antenna, no adhesive	
KYOCERA / AVX “W1P35X8W04-H100D3B0A” PCB dipole antenna with adhesive on bottom side	
EBDS wireless and antennas: “EBDS-1” PCB dipole antenna, no adhesive	

EBDS wireless and antennas: “EBDS-3”

PCB monopole antenna with adhesive on bottom side

EBDS wireless and antennas: “EBDS-4”

PCB PIFA antenna with adhesive on bottom side

EBDS wireless and antennas: “EBDS-5”

PCB dipole antenna with adhesive on bottom side

1.6 ST67W611M1 settings

The module is programmed with the manufacturing mode firmware.

The main RF set parameters are listed below:

- Channel 7: F=2442 MHz
- Output power = 20 dBm
- Standard 802.11 b – 1 Mbps.

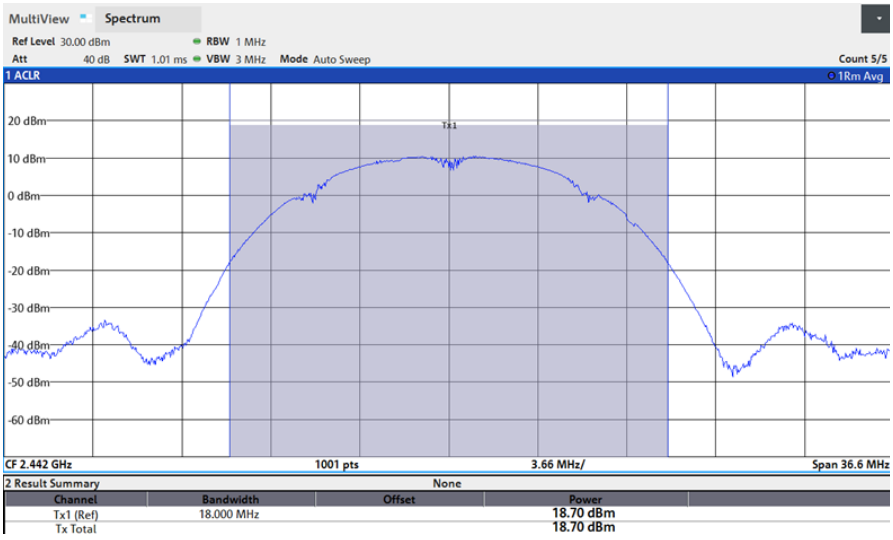
1.7 Spectrum analyzer settings and conducted output power measurement

Spectrum analyzer settings used in conducted and radiated mode:

- Detector type: RMS
- Detector mode: power
- Average count: 100 acquisition
- RBW = 1 MHz
- VBW = 3 MHz
- Attenuator = 20 dB

The output power is measured in 18 MHz band. The preliminary measurements conducted with the spectrum analyzer give the following results:

Figure 7. Conducted output power



DT77586V1

P_{out} = 18.7 dBm + 0.6 dB (cable losses) = 19.3 dBm.

2 Return loss evaluation

The centering frequency of the antennas depends on the support on which it has been tested. Most of the antenna providers give recommendations on the material on which the antenna must be set (permittivity and thickness).

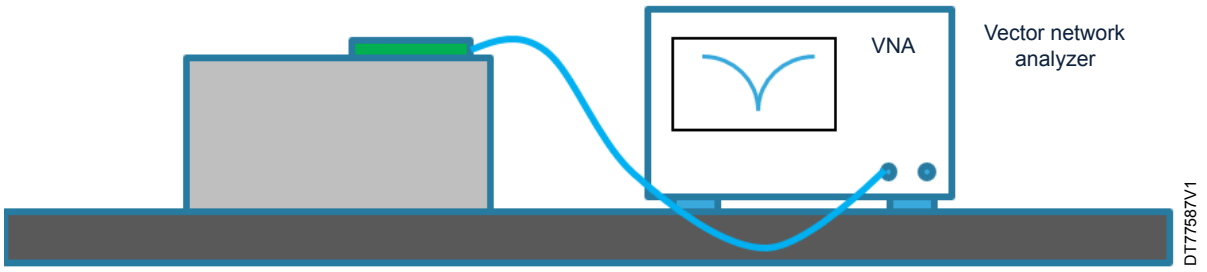
The antennas have been tested:

- In the air
- On a PLA (poly lactic acid – 3D printer) plate of 1.6 mm thickness
- On a plexiglass plate of 2.8 mm thickness

The permittivity value is between 2 to 2.8 F/m for the PLA and 3.5 F/m for the plexiglass.

The return loss is measured thanks to a vector network analyzer (VNA). The antenna is placed on a box to avoid the ground effect of the test bench:

Figure 8. VNA measurement illustration



A return loss of 10 dB is often regarded as acceptable for many applications, indicating that about 10% of the power is reflected and 90% is transmitted.

The table below summaries the return loss values and their implications:

Table 3. Anechoic chamber test equipment

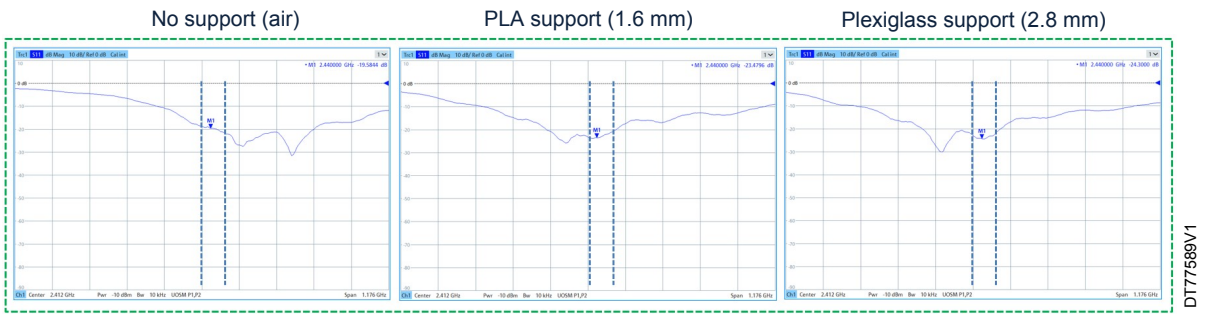
Return loss (dB)	Reflection (%)	Power transmitted (%)	VSWR
10	10	90	2
15	3	97	1.4
20	1	99	1.2

2.1 INPAQ dipole antenna

The following sections show S11 with no support with these two types of plate. The MHF4 cable is replaced by a SMA probe with the same cable length connected to the VNA.

This antenna gives correct matching in all conditions but performances are better using no support.

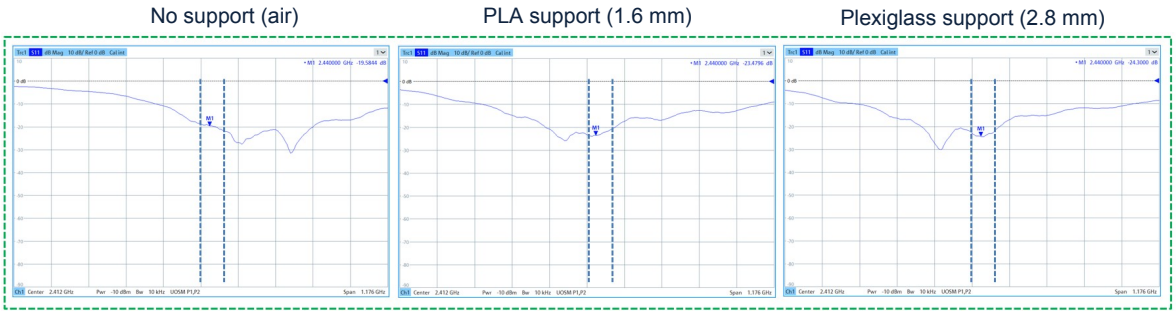
Figure 9. S-parameters INPAQ dipole antenna



2.2 INPAQ monopole antenna

This antenna gives correct matching in all conditions (more or less <= - 20 dB).

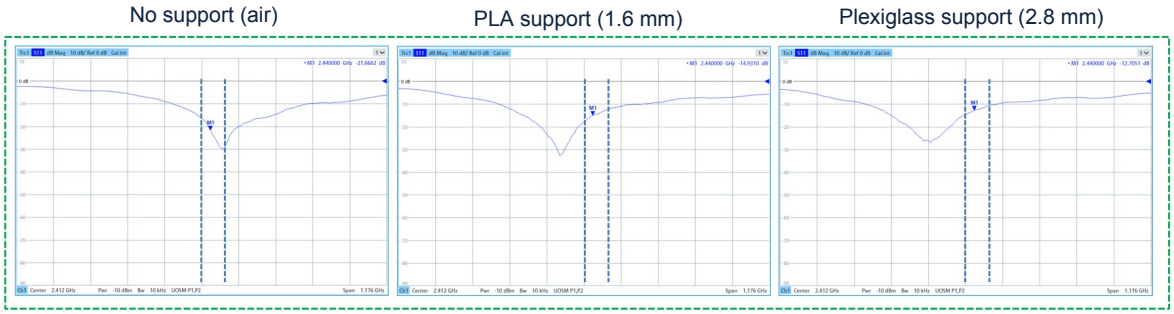
Figure 10. S-parameters INPAQ monopole antenna



2.3 INPAQ PIFA antenna

This antenna gives correct matching in all conditions.

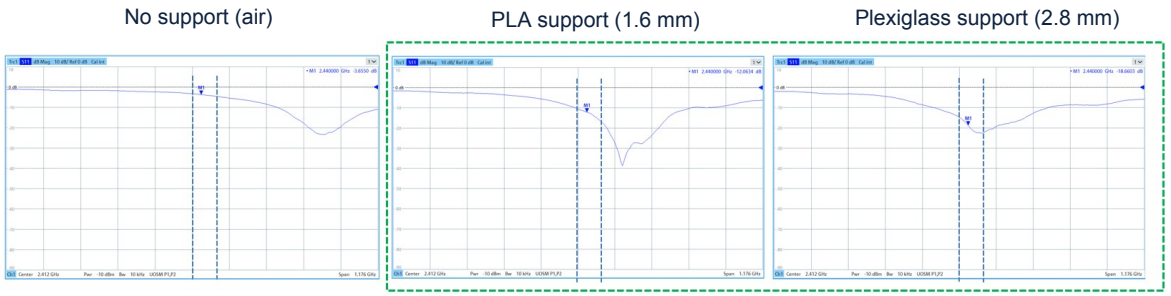
Figure 11. S-parameters INPAQ PIFA antenna



2.4 Kyocera antenna

PLA and plexiglass support are recommended for this antenna.

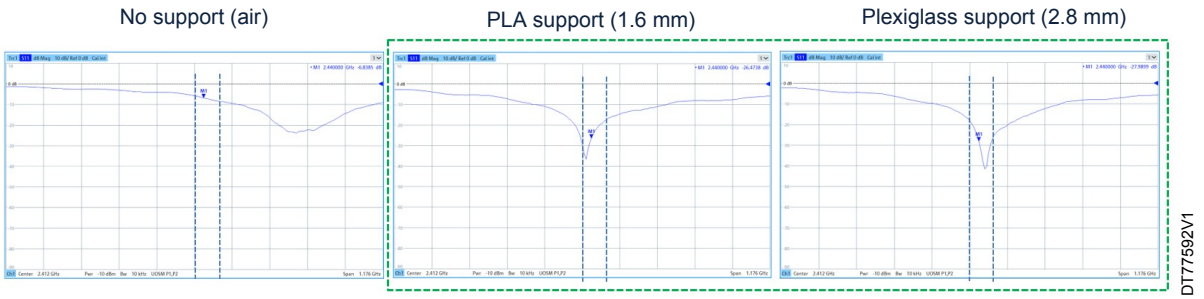
Figure 12. S-parameters Kyocera antenna



2.5 Linx antenna

PLA and plexiglass support are recommended for this antenna.

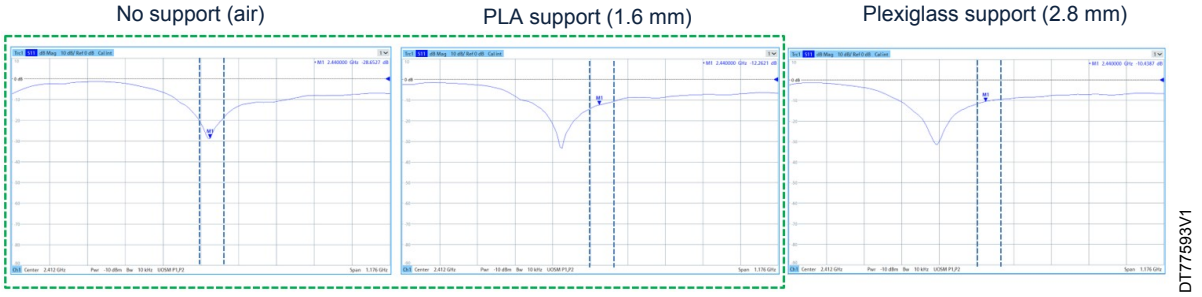
Figure 13. **S-parameters Linx antenna**



2.6 Pulse antenna

No support or PLA thin support is recommended for this antenna.

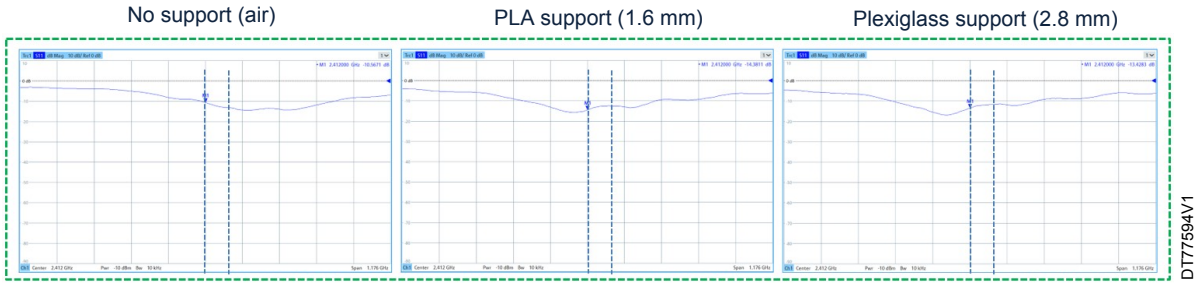
Figure 14. **S-parameters Pulse antenna**



2.7 Ezurio antenna

This antenna is recommended for all configurations.

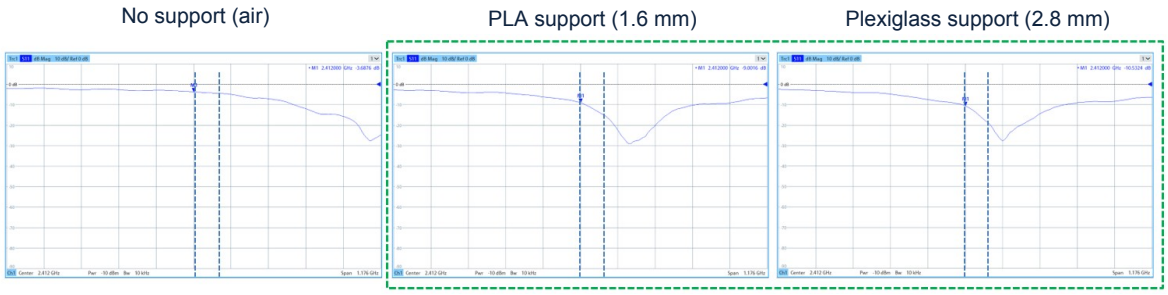
Figure 15. **S-parameters Ezurio antenna**



2.8 Taoglas antenna

PLA and plexiglass support are recommended for this antenna.

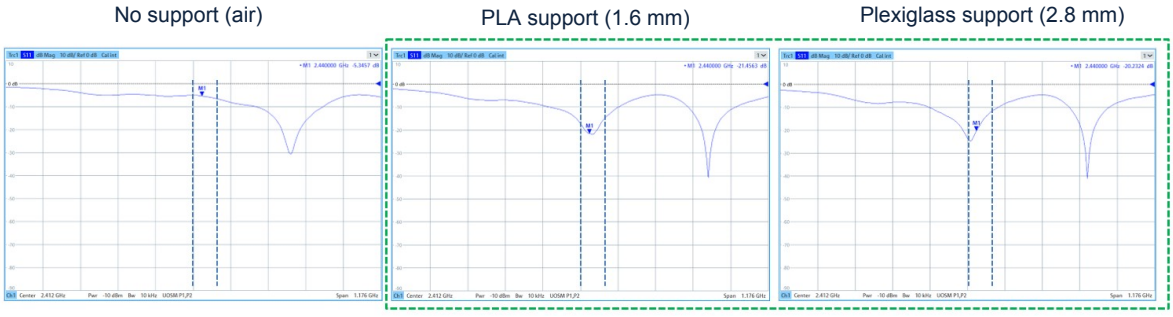
Figure 16. **S-parameters Taoglas antenna**



2.9 EBDS - PCB1

PLA and plexiglass support are recommended for this antenna.

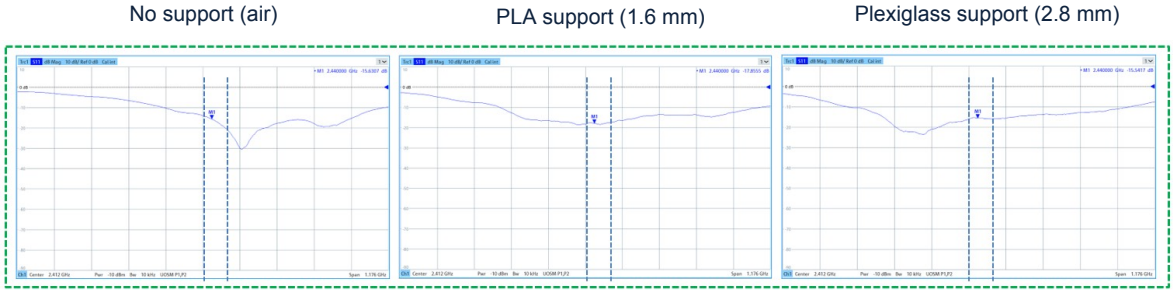
Figure 17. **S-parameters EBDS-PCB1 antenna**



2.10 EBDS - PCB3

This antenna gives correct matching in all conditions.

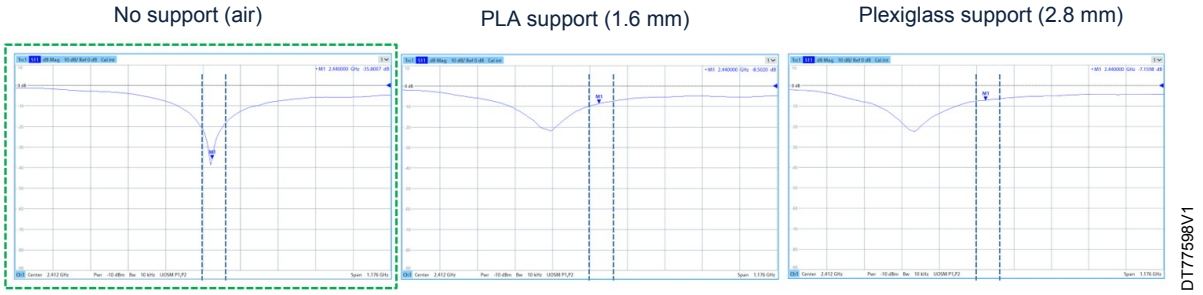
Figure 18. **S-parameters EBDS-PCB3 antenna**



2.11 EBDS - PCB4

No support or PLA thin support is recommended for this antenna.

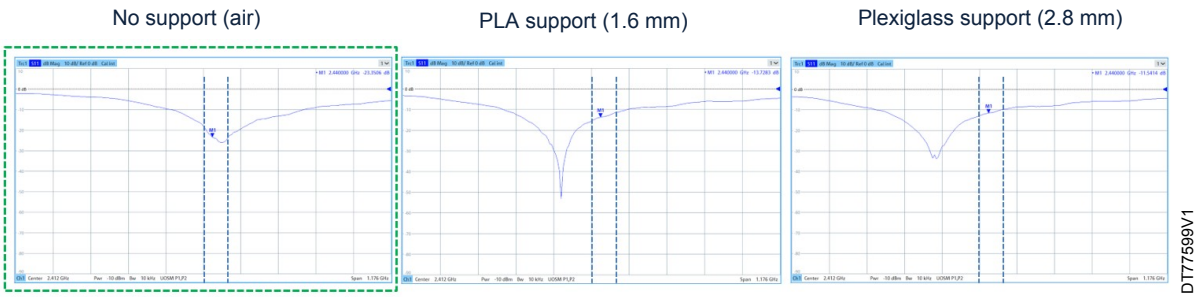
Figure 19. S-parameters EBDS-PCB14 antenna



2.12 EBDS - PCB5

No support or PLA thin support is recommended for this antenna.

Figure 20. S-parameters EBDS-PCB5 antenna



3 Radiated diagram patterns

Some antennas are measured with or without support depending on the S11 matching results.

3.1 INPAQ dipole antenna (diagram patterns)

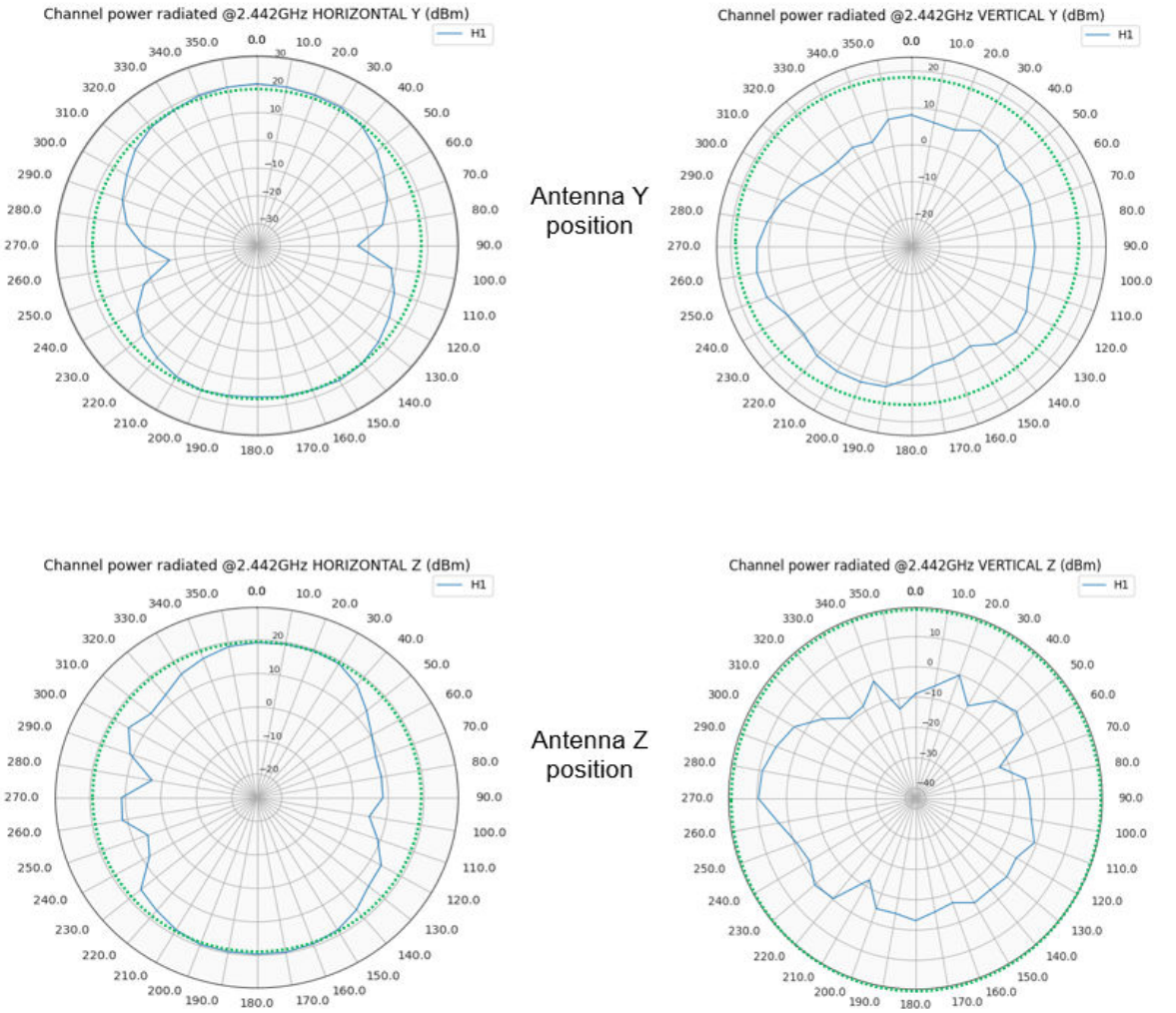
Maximum output power with no support under the antenna:

Table 4. Max output power and gain – INPAQ dipole antenna

Board position	Polarization	P_{min} [dBm]	P_{max} [dBm]	Angle P_{max}(°)	$P_{average}$ [dBm]	Max gain [dBi]
Y	Horizontal	-7.9	20.4	0	13.2	1.1
Y	Vertical	2.4	13.7	260	7.4	
Z	Horizontal	3	19.7	170	14.2	0.4
Z	Vertical	- 13.4	9.6	270	-3.1	

Radiation diagram patterns (green circle: ~19.3 dBm):

Figure 21. Radiation diagram INPAQ dipole antenna



3.2 INPAQ monopole antenna (diagram patterns)

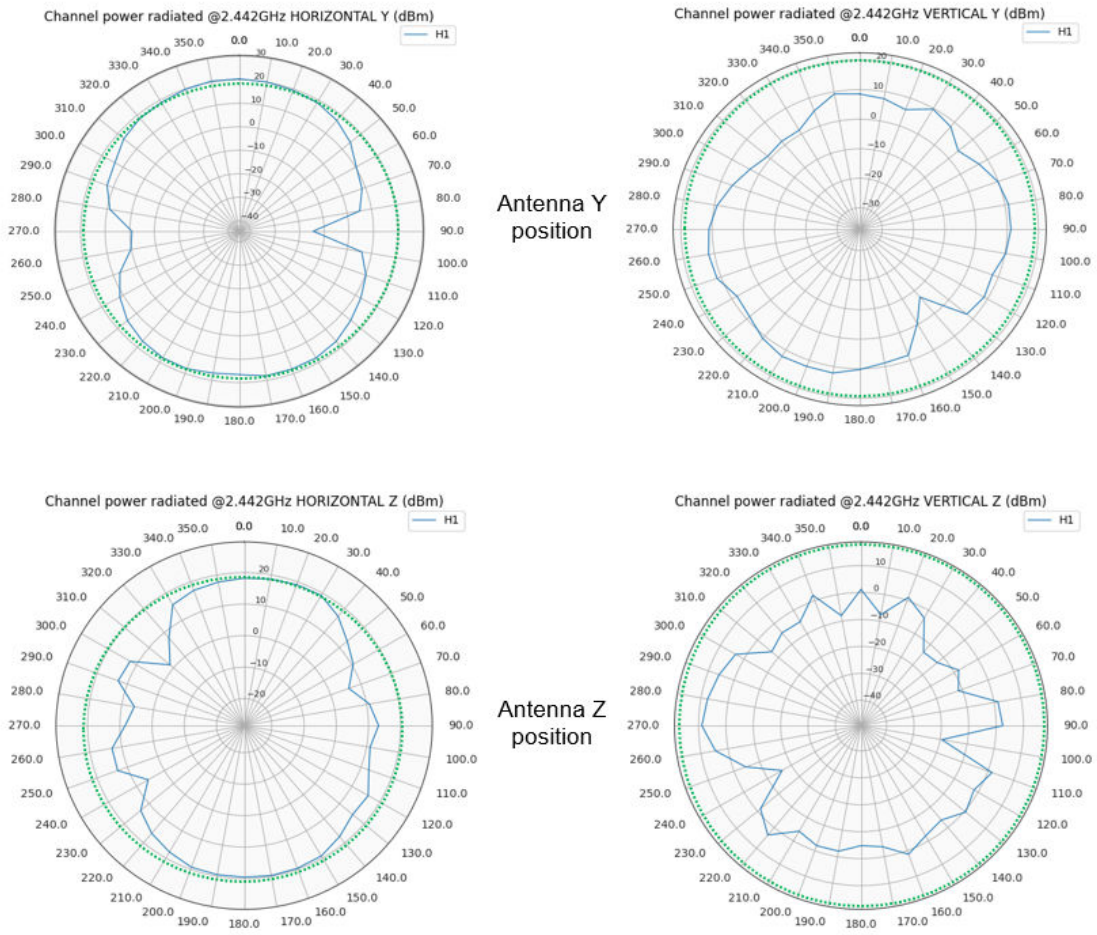
Maximum output power with no support under the antenna:

Table 5. Max output power and gain – INPAQ monopole antenna

Board position	Polarization	P_{min} [dBm]	P_{max} [dBm]	Angle P_{max} (°)	$P_{average}$ [dBm]	Max gain [dBi]
Y	Horizontal	-14.5	20.4	350	13.4	1.1
Y	Vertical	-7.2	12.5	210	7.6	
Z	Horizontal	1.4	19.8	170	14.3	0.5
Z	Vertical	- 19.4	8.8	270	-2.8	

Radiation diagram patterns (green circle: ~19.3 dBm):

Figure 22. Radiation diagram INPAQ monopole antenna



3.3 INPAQ PIFA antenna (diagram patterns)

Maximum output power with no support under the antenna:

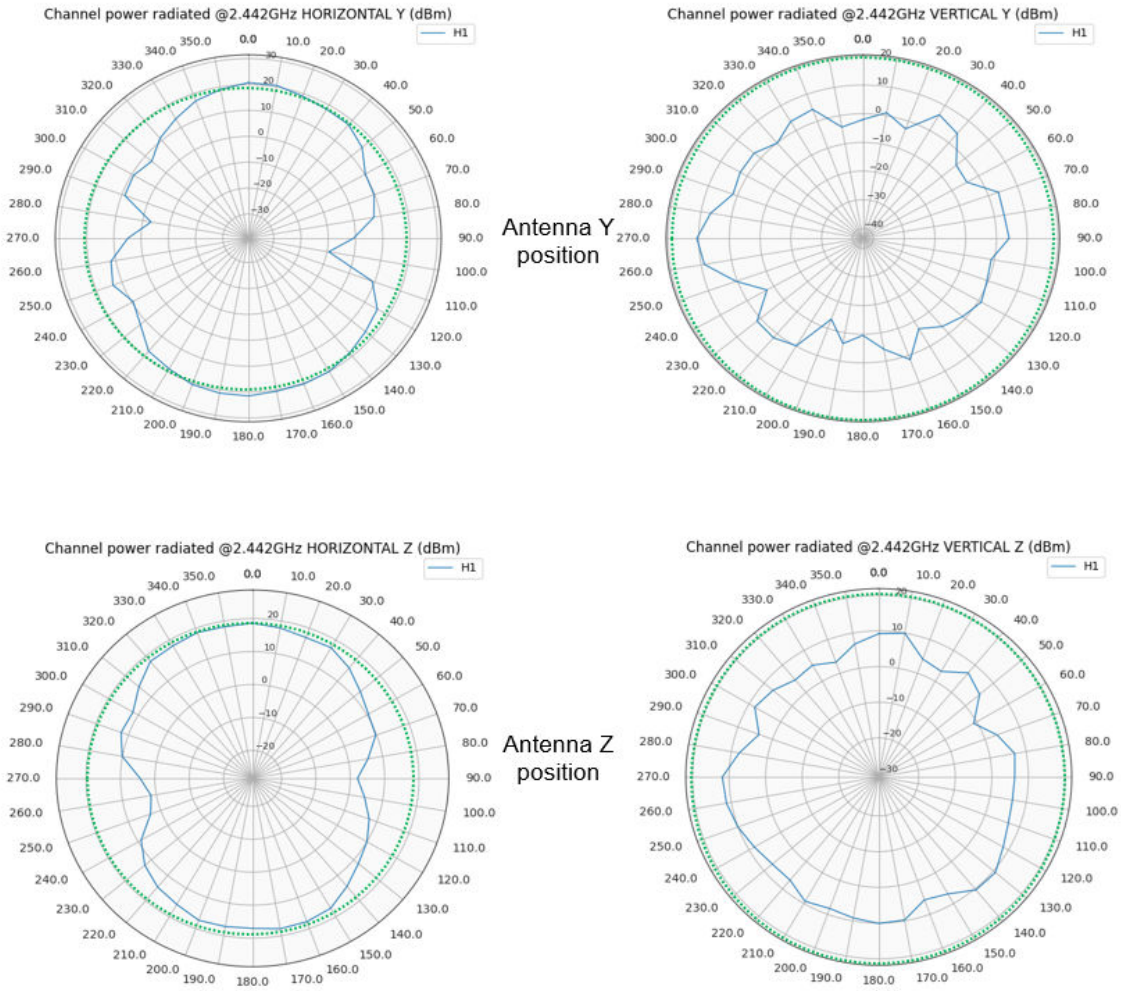
Table 6. Max output power and gain – INPAQ PIFA antenna

Board position	Polarization	P_{min} [dBm]	P_{max} [dBm]	Angle P_{max} (°)	$P_{average}$[dBm]	Max gain [dBi]
Y	Horizontal	-9.4	21.5	180	13.5	2.2

Board position	Polarization	P_{min} [dBm]	P_{max} [dBm]	Angle P_{max} (°)	$P_{average}$[dBm]	Max gain [dBi]
Y	Vertical	-13.5	10.6	270	0	2.2
Z	Horizontal	1.5	18.7	0	12.8	0.6
Z	Vertical	- 0.9	11.8	270	7.2	

Radiation diagram patterns (green circle: ~19.3 dBm):

Figure 23. Radiation diagram INPAQ PIFA antenna



3.4 Linx antenna (diagram patterns)

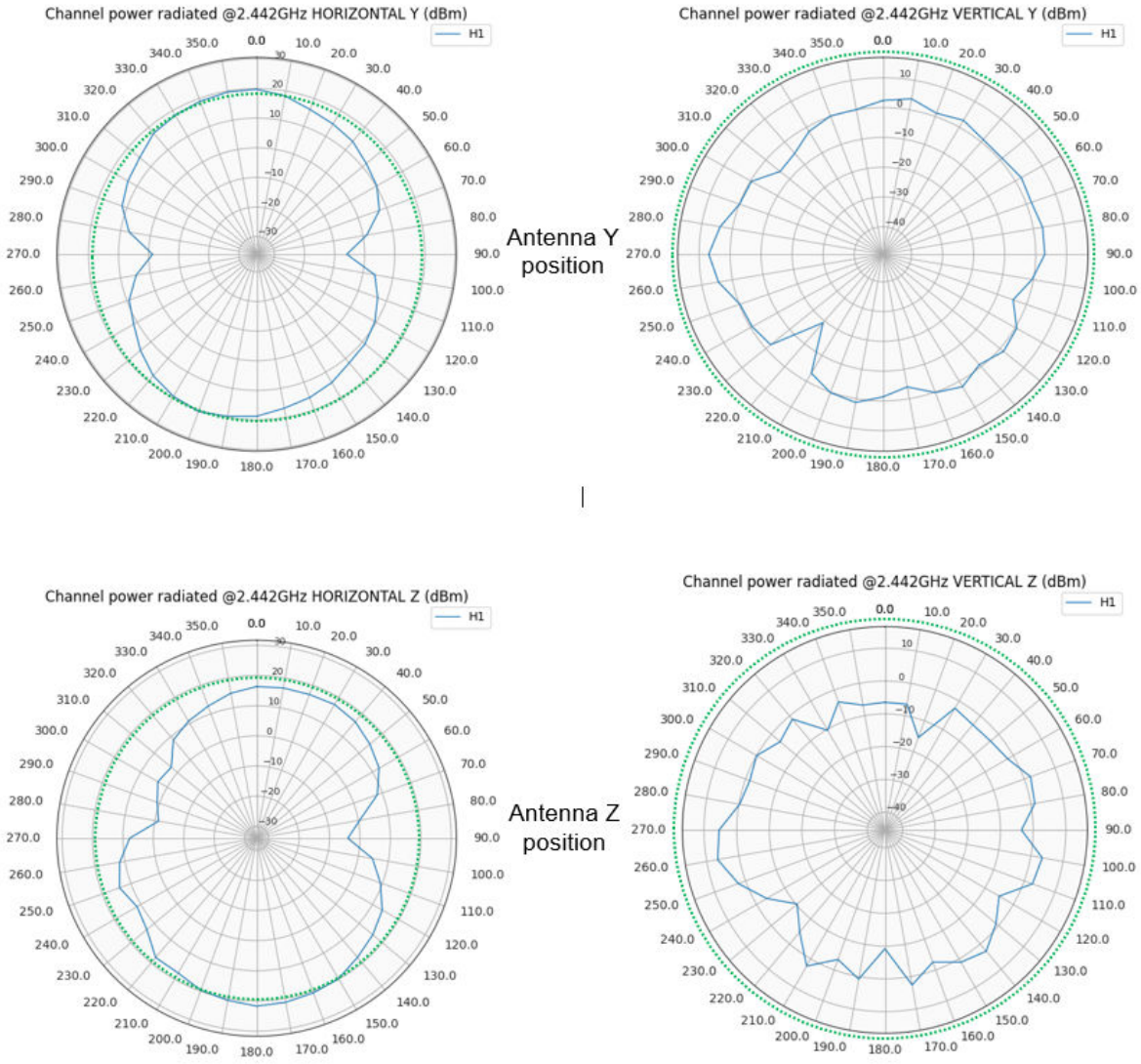
Maximum output power with no support under the antenna:

Table 7. Max output power and gain – Linx antenna

Board position	Polarization	P_{min} [dBm]	P_{max} [dBm]	Angle P_{max} (°)	$P_{average}$ [dBm]	Max gain [dBi]
Y	Horizontal	-5.9	20.5	200	12.6	1.2
Y	Vertical	-19.2	6.9	270	-0.2	
Z	Horizontal	- 4	21.7	180	12.4	2.4
Z	Vertical	- 15.4	6.6	260	-2.1	

Radiation diagram patterns (green circle: ~19.3 dBm):

Figure 24. Radiation diagram Linx antenna



3.5 Kyocera antenna (diagram patterns)

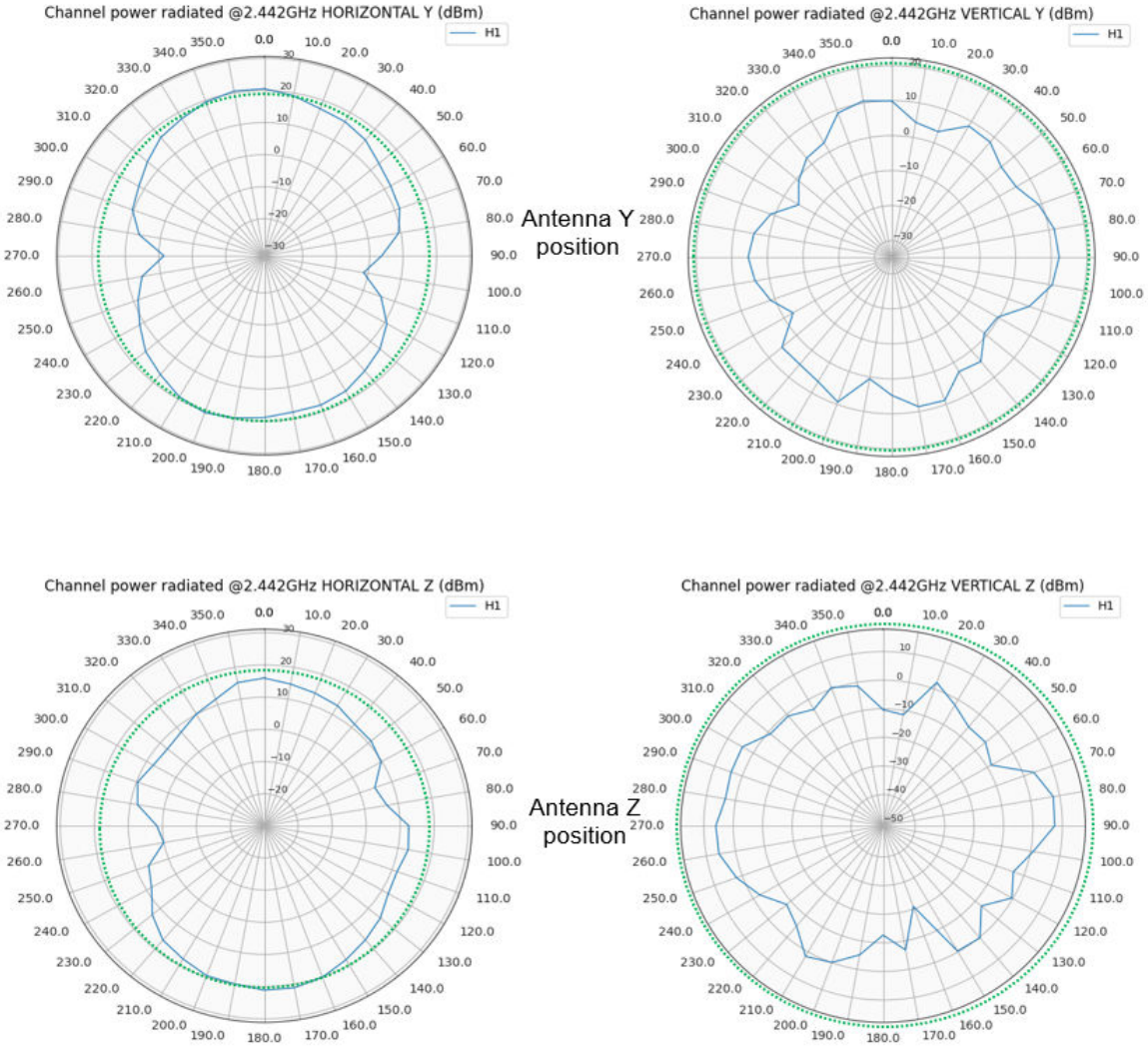
Maximum output power with no support under the antenna:

Table 8. Max output power and gain – Kyocera antenna

Board position	Polarization	P_{min} [dBm]	P_{max} [dBm]	Angle P_{max} (°)	$P_{average}$ [dBm]	Max gain [dBi]
Y	Horizontal	-1.5	20.6	350	13.5	1.3
Y	Vertical	-4.8	12.2	90	5.1	
Z	Horizontal	0.1	21.1	170	12.3	1.8
Z	Vertical	- 20.9	7.8	80	-2	

Radiation diagram patterns (green circle: ~19.3 dBm):

Figure 25. **Radiation diagram Kyocera antenna**



3.6 Pulse antenna (diagram patterns)

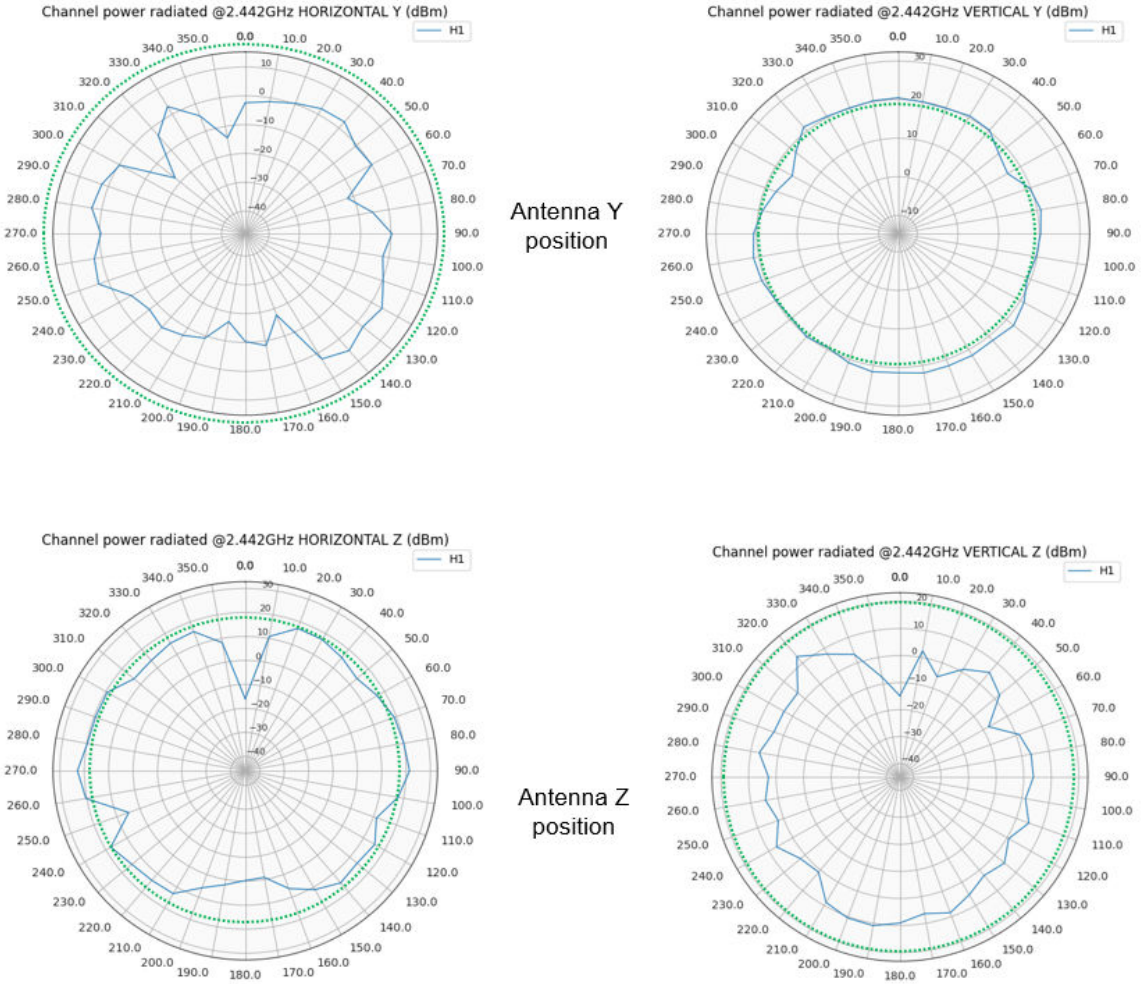
Maximum output power with no support under the antenna:

Table 9. **Max output power and gain – Pulse antenna**

Board position	Polarization	P_{min} [dBm]	P_{max} [dBm]	Angle P_{max} (°)	$P_{average}$ [dBm]	Max gain [dBi]
Y	Horizontal	-17.8	5.2	140	-3.2	3.1
Y	Vertical	15.3	22.4	130	20.1	
Z	Horizontal	-16	22.8	270	12.9	3.5
Z	Vertical	- 14.9	13.3	320	3.3	

Radiation diagram patterns (green circle: ~19.3 dBm):

Figure 26. **Radiation diagram pulse antenna**



3.7 Ezurio antenna (diagram patterns)

3.7.1 No support under the antenna

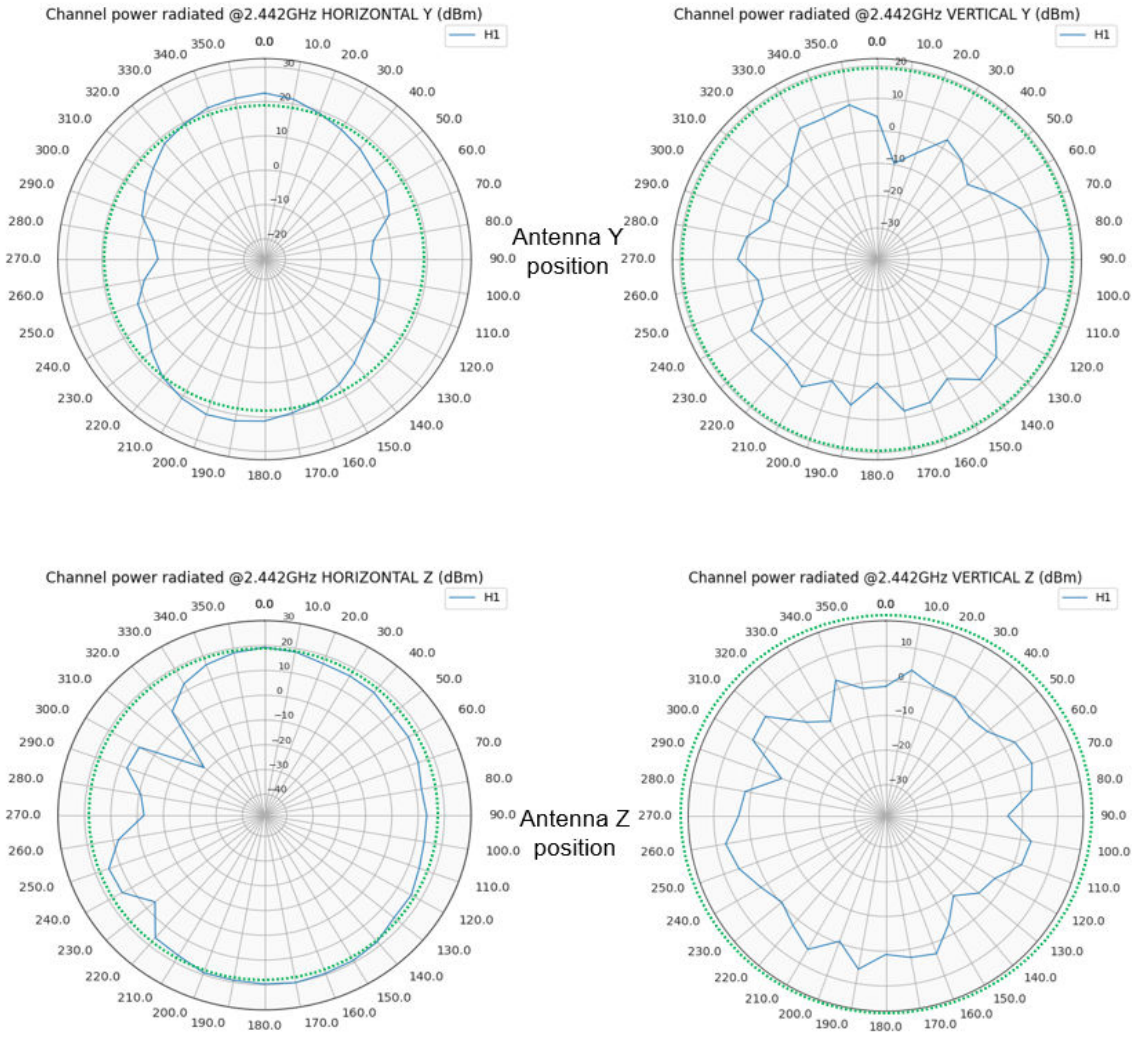
Maximum output power with no support under the antenna:

Table 10. **Max output power and gain – Ezurio antenna – No support**

Board position	Polarization	P_{min} [dBm]	P_{max} [dBm]	Angle P_{max} (°)	$P_{average}$ [dBm]	Max gain [dBi]
Y	Horizontal	4.1	22.4	0	14.8	3.1
Y	Vertical	-9.6	12.3	90	2.8	
Z	Horizontal	-18.5	20.2	170	13.1	0.9
Z	Vertical	- 9	7.3	260	0.7	

Radiation diagram patterns (green circle: ~19.3 dBm):

Figure 27. **Radiation diagram Ezurio antenna**



3.7.2 Thick support under the antenna

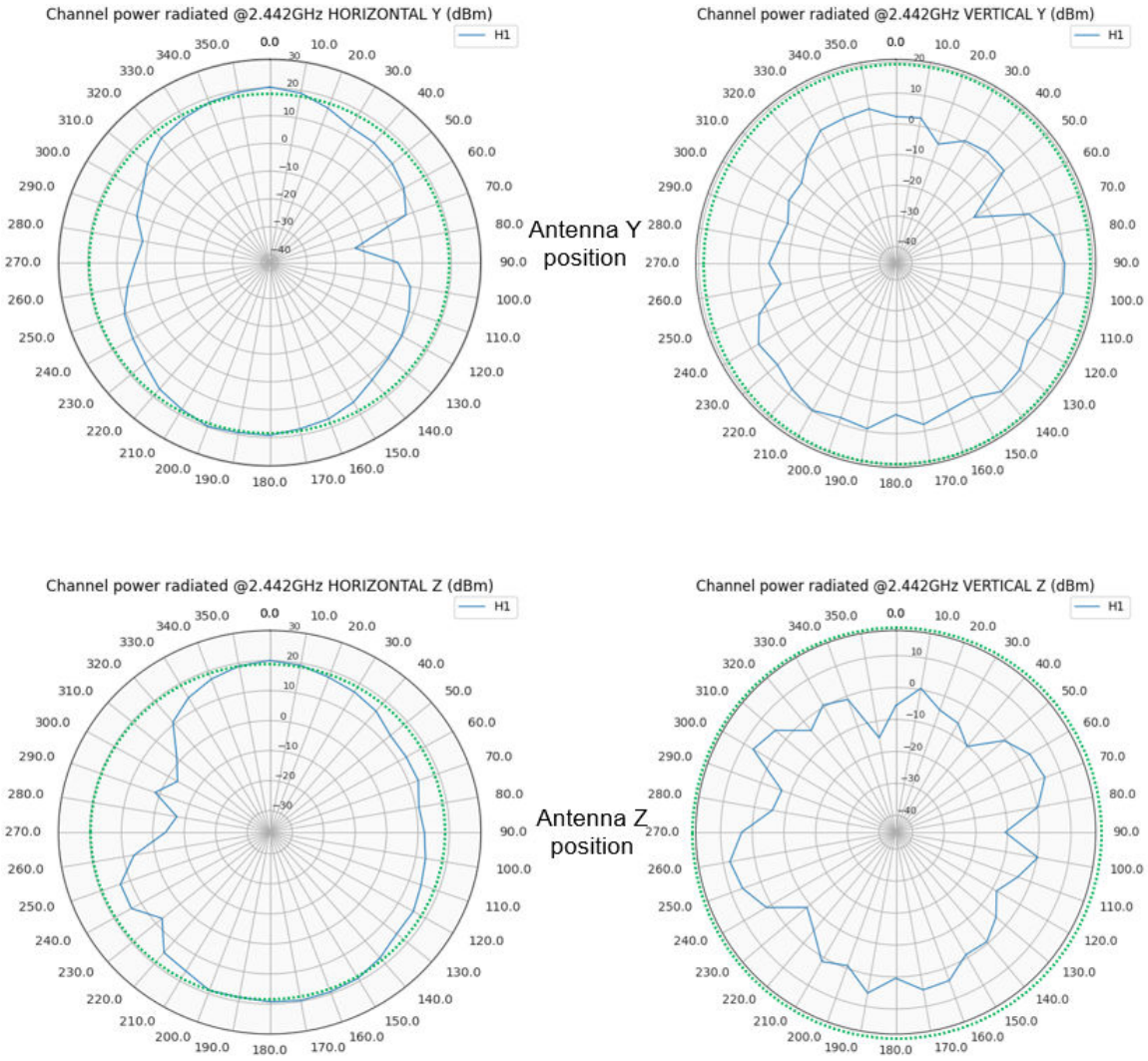
Maximum output power with plexiglas support under the antenna:

Table 11. **Max output power and gain Ezurio antenna – Plexiglass support**

Board position	Polarization	P_{min} [dBm]	P_{max} [dBm]	Angle P_{max} (°)	$P_{average}$ [dBm]	Max gain [dBi]
Y	Horizontal	-12.9	20.3	0	12.2	1
Y	Vertical	-15.4	11	100	3	
Z	Horizontal	-7.2	20	0	12.9	0.7
Z	Vertical	-15.3	7.9	260	-1.3	

Radiation diagram patterns (green circle: ~19.3 dBm):

Figure 28. **Radiation diagram Ezurio antenna – Plexiglass support**



3.8 Taoglas antenna (diagram patterns)

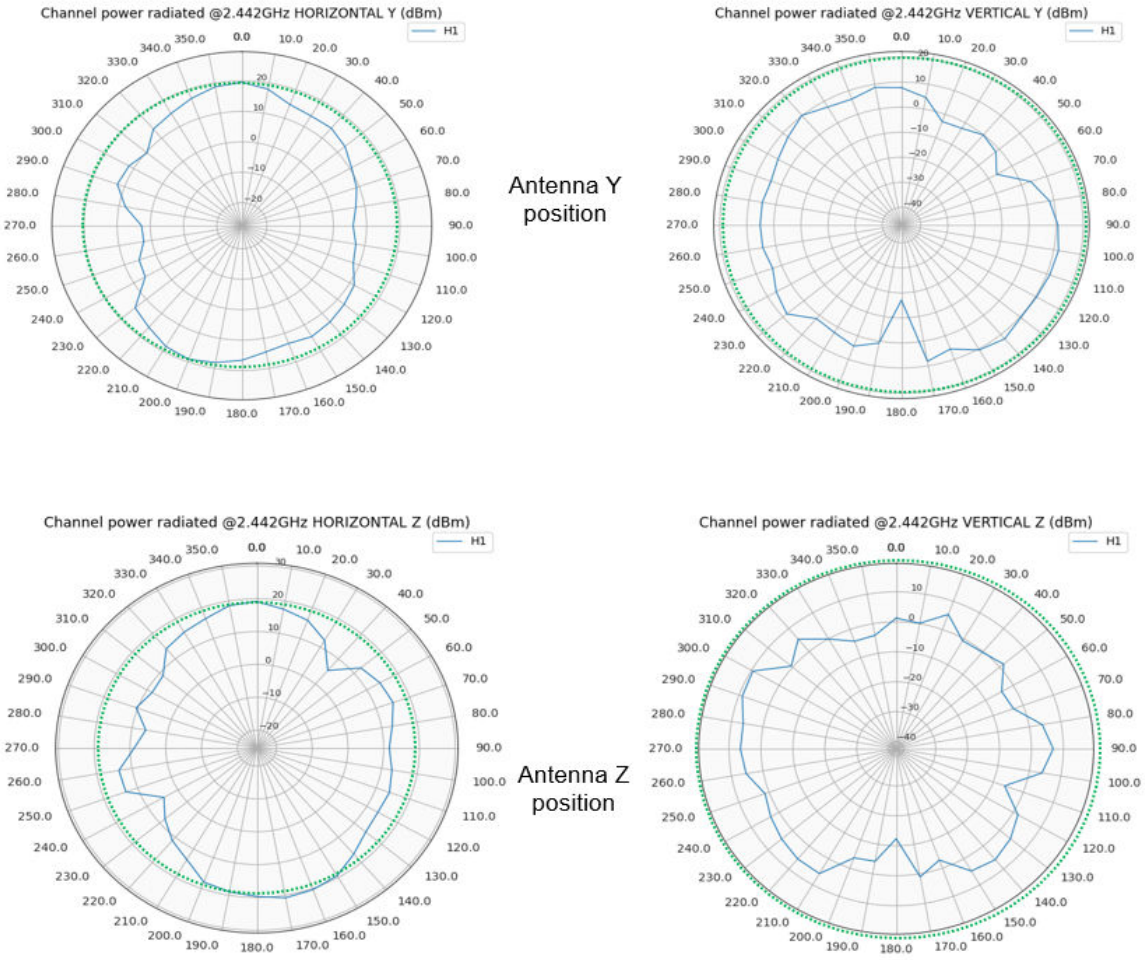
Maximum output power with plexiglas support under the antenna:

Table 12. **Max output power and gain Taoglas antenna**

Board position	Polarization	P_{min} [dBm]	P_{max} [dBm]	Angle P_{max} (°)	$P_{average}$ [dBm]	Max gain [dBi]
Y	Horizontal	2.4	19.6	0	12.4	0.3
Y	Vertical	-17.1	12.2	140	4.9	
Z	Horizontal	4.5	20.8	170	13.8	1.5
Z	Vertical	-12.4	9.5	300	1.6	

Radiation diagram patterns (green circle: ~19.3 dBm):

Figure 29. **Radiation diagram Taoglas antenna**



3.9 EBDS - PCB1 (diagram patterns)

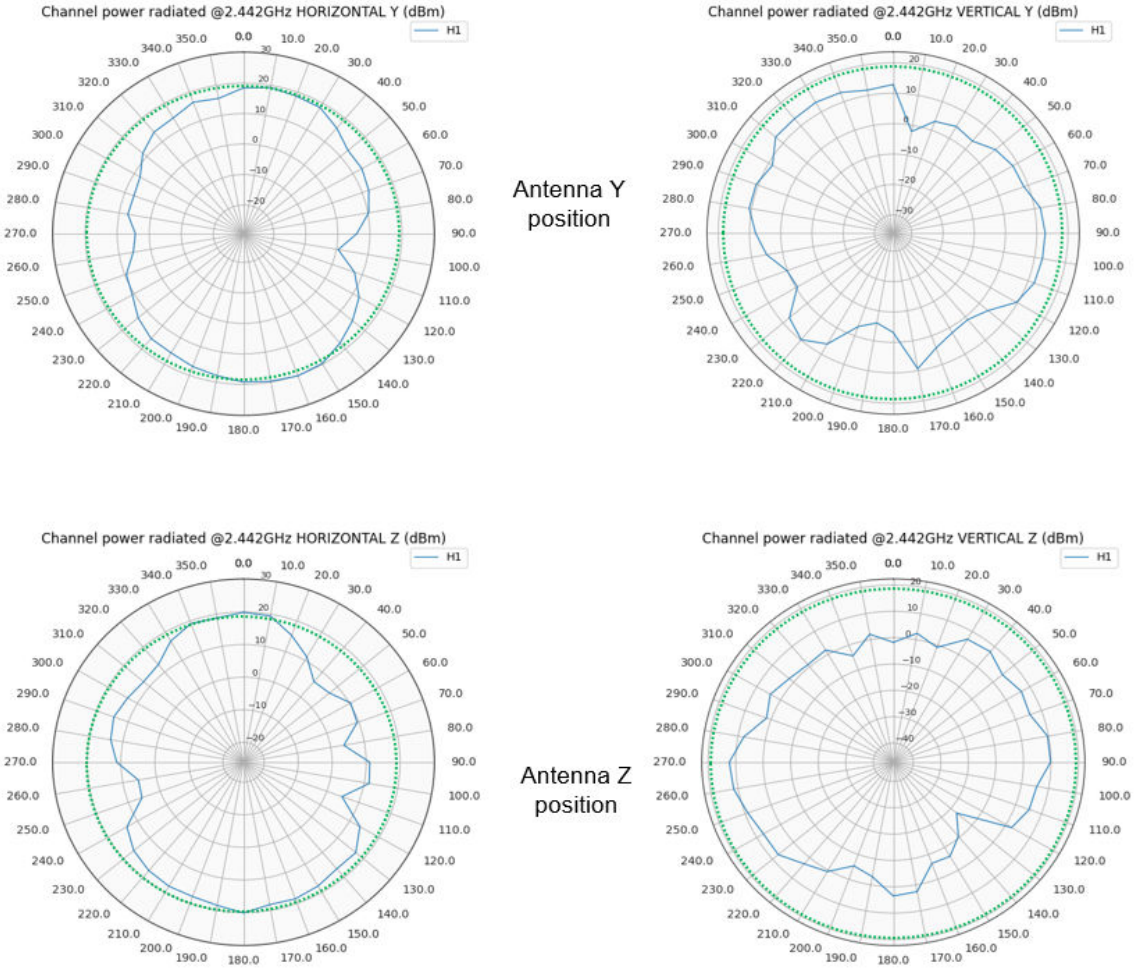
Maximum output power with no support under the antenna:

Table 13. **Max output power and gain EBDS-PCB1 antenna**

Board position	Polarization	P_{min} [dBm]	P_{max} [dBm]	Angle P_{max} (°)	$P_{average}$ [dBm]	Max gain [dBi]
Y	Horizontal	0.6	20.2	160	13.4	0.9
Y	Vertical	-6	13.6	330	6.8	
Z	Horizontal	3.9	20.2	180	13.8	0.9
Z	Vertical	-17.3	12.3	270	2.5	

Radiation diagram patterns (green circle: ~19.3 dBm):

Figure 30. **Radiation diagram EBDS-PCB1 antenna**



3.10 EBDS - PCB3 (diagram patterns)

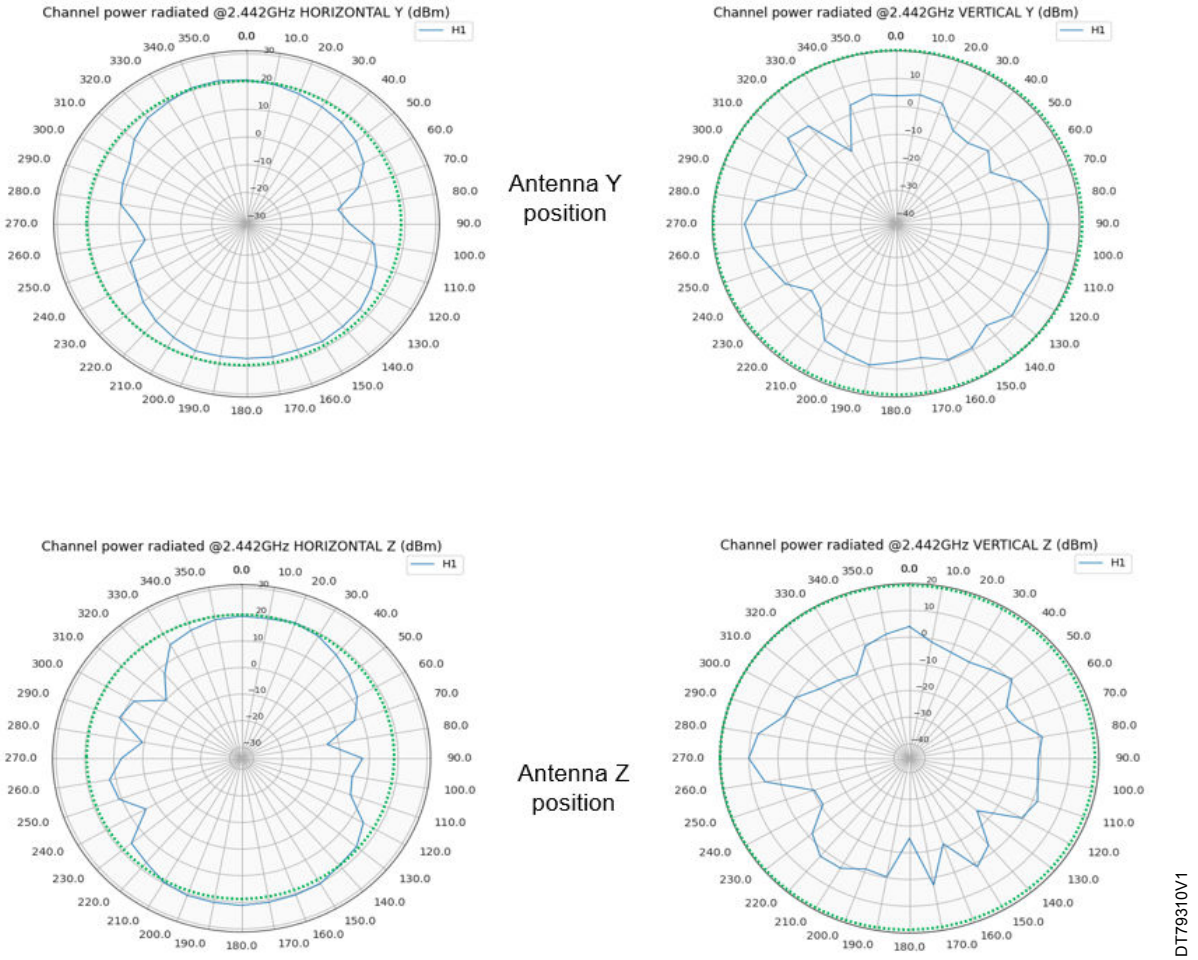
Maximum output power with no support under the antenna:

Table 14. **Max output power and gain EBDS-PCB3 antenna**

Board position	Polarization	P_{min} [dBm]	P_{max} [dBm]	Angle P_{max} (°)	$P_{average}$ [dBm]	Max gain [dBi]
Y	Horizontal	-1.3	21.1	350	14	1.8
Y	Vertical	-12	9.9	100	3.5	
Z	Horizontal	-4.1	21.2	180	13.4	1.9
Z	Vertical	-15.4	10.1	270	-2	

Radiation diagram patterns (green circle: ~19.3 dBm):

Figure 31. **Radiation diagram EBDS-PCB3 antenna**



3.11 EBDS - PCB4 (diagram patterns)

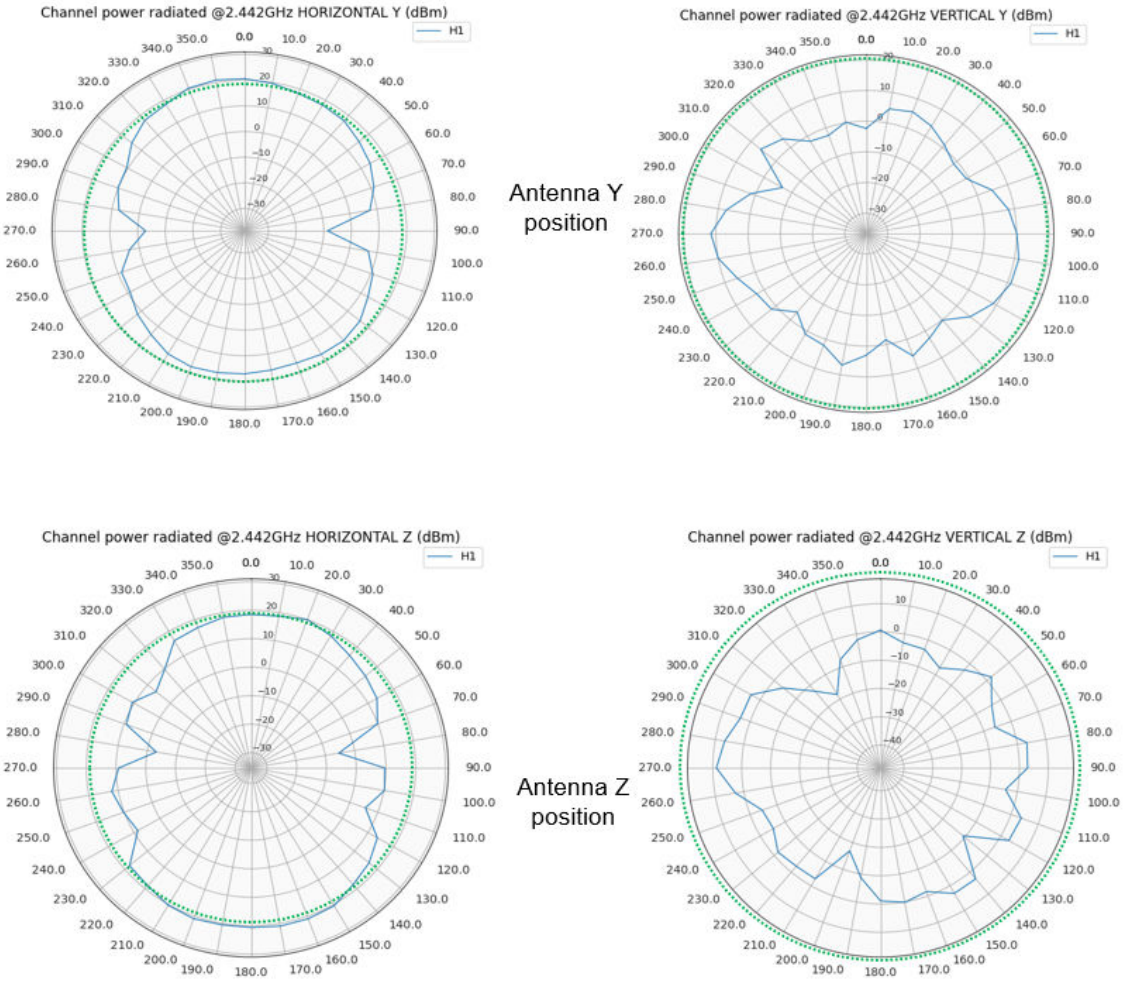
Maximum output power with no support under the antenna:

Table 15. **Max output power and gain EBDS-PCB4 antenna**

Board position	Polarization	P_{min} [dBm]	P_{max} [dBm]	Angle P_{max} (°)	$P_{average}$ [dBm]	Max gain [dBi]
Y	Horizontal	-8.7	21	350	13.3	1.7
Y	Vertical	-6.6	11.6	270	3.5	
Z	Horizontal	-5.4	21	170	14	1.7
Z	Vertical	-18.1	8.8	270	-2.3	

Radiation diagram patterns (green circle: ~19.3 dBm):

Figure 32. **Radiation diagram EBDS-PCB4 antenna**



3.12 EBDS - PCB5 (diagram patterns)

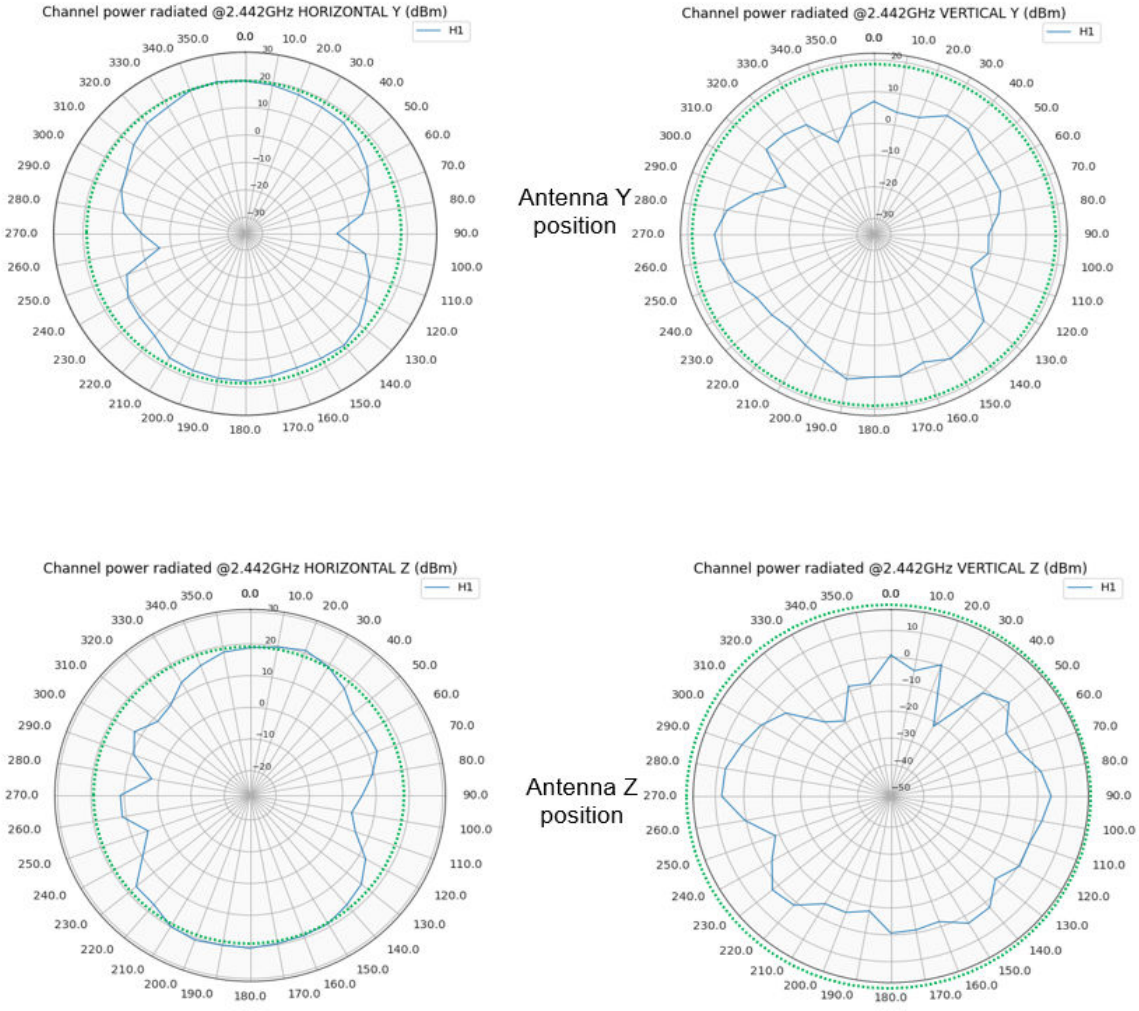
Maximum output power with no support under the antenna:

Table 16. **Max output power and gain EBDS-PCB5 antenna**

Board position	Polarization	P_{min} [dBm]	P_{max} [dBm]	Angle P_{max} (°)	$P_{average}$ [dBm]	Max gain [dBi]
Y	Horizontal	-6	20.3	350	12.8	1
Y	Vertical	-5	12.1	270	5.3	
Z	Horizontal	2.3	20.9	20	13.9	1.6
Z	Vertical	-21.6	7.8	270	-2.4	

Radiation diagram patterns (green circle: ~19.3 dBm):

Figure 33. **Radiation diagram EBDS-PCB5 antenna**



4 Conclusion

The table below summarizes the main features of the MHF4 - PCB-antennas:

Table 17. MHF4 - PCB-antenna main features summary

Manufacturer	Reference	Antenna type	Adhesive	Dimensions	Cable length	Max gain dBi (standalone)	Tested support	Max gain dBi (with ST67W611M1)
INPAQ	RFPCA521010EMABY01	PCB - Dipole	Y	52 × 10 × 0.6 mm	100 mm	3.37	No	1.1
INPAQ	RFPCA501010EMABY01	PCB -Monopole	Y	50 × 10 × 0.6 mm	100 mm	3.12	No	1.1
INPAQ	RFPCA441010EMABY01	PCB -PIFA	Y	44 × 10 × 0.6 mm	100 mm	3.19	No	2.2
Kyocera	W1P35X8W04-H100D3B0A	PCB -Antenna	Y	35.2 × 8.5 × 0.4 mm	100 mm	2.8	Plexiglass	1.8
Pulse / Yageo	W3513BD0080	PCB - Dipole	No	48 × 15 × 0.6 mm	80 mm	2	Plexiglass	3.5
Linx	ANT-2.4-FPC-LH100M4	Flex antenna	Y	45 × 7 × 0.1 mm	100 mm	4.1	Plexiglass	2.4
Ezurio	EBL2400A1-10MH4L	PCB -Antenna (patch)	No	44.45 × 12.7 × 0.81 mm	100 mm	2	Plexiglass / No	3.1 / 1
Taoglas	FXP830.24.0100B	Flex dipole antenna	Y	42 × 7 × 0.1 mm	100 mm	3.3	Plexiglass	1.5
EBDS wireless antenna	EBDS-1	PCB - Dipole	No	29.8 × 9.7 × 0.6 mm	100 mm	2	Plexiglass	0.9
EBDS wireless antenna	EBDS-3	PCB - Monopole	Y	50 × 10 × 0.6 mm	100 mm	2	No	1.9
EBDS wireless antenna	EBDS-4	PCB -PIFA	Y	44 × 10 × 0.6 mm	100 mm	2	No	1.7
EBDS wireless antenna	EBDS-5	PCB - Dipole	Y	52 × 10 × 0.6 mm	100 mm	2	No	1.6

Recommendations for the choice of antenna:

- Search on the web with the following text: "2.4 GHz ipex MHF4 antenna”
- Check in the datasheet of the antenna what kind of material is recommended.
  - Test the antenna in standalone on the final application support:
    - Replace the MHF cable to a SMA cable (same length).
    - Verify that SWR < 2 (or S11 < -10 dBm), meaning that 90% of the power is transmitted).
- Test the antenna connected to the module inside an anechoic chamber.

Most of the antennas mentioned in this document have a maximum of gain when they are set in front of the receiver:

Figure 34. **MHF4 antenna-Y position**

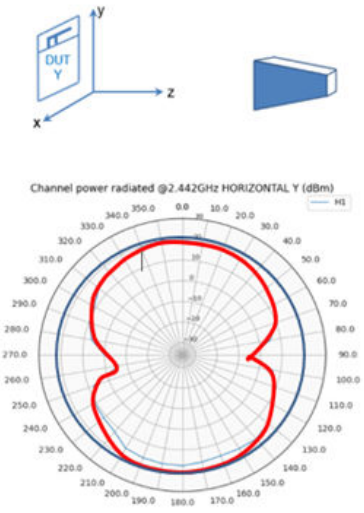
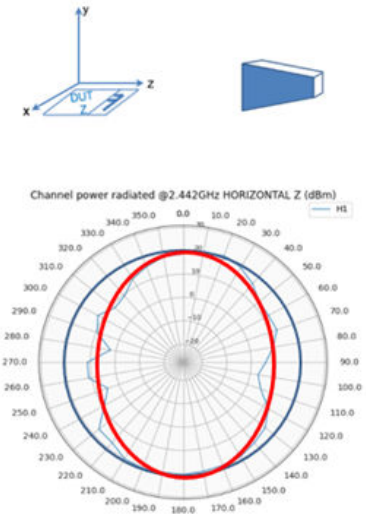


Figure 35. **MHF4 antenna-Z position**



Revision history

Table 18. **Document revision history**

Date	Version	Changes
25-Jun-2025	1	Initial release.

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