

TX-4042_24_R2 Antenna Performance Measurement

Date: February 29th, 2024
Company: Leap Development B.V.
Author: Jan ten Thije

Document revision: Issue_1.0

Internal project nr: 10056.14
Internal project name: Musca-2S TX-4042_24_R2
Client project nr: -
Client project name: -

FEASYCOM)))



1. Contents

1. Contents.....	2
2. Document revision history	3
3. Client	3
3. Preface	3
4. Description of measurement	3
4.1. Equipment used.....	3
4.2. Measurement / execution	4
4.3. S11 Parameters Test Setup.....	4
4.4. Radiated Measurements Test Setup	5
5. Measurements.....	7
5.1. S11 Parameters Results	7
5.2. Radiated Results	8
5.3. Efficiency Determination using Radiated Power	14
5.4. Efficiency Determination using Wheeler Cap Method	15
6. Antenna Drawing	17
7. Test results	17
8. Conclusion	17

2. Document revision history

Revision	Date	Author	Description
0.1	February 19 th , 2024	Jan ten Thije	Initial setup & release
1.0	March 5 th , 2024	Doy Lubbers	Review and Release

3. Client

Tyro Products B.V.
Bedrijvenpark Twente 299
7602 KK Almelo
Contact person: Mr. John Nijkrake

3. Preface

Tyro Products has integrated a Feasycom Bluetooth Low Energy module in Musca-2S TX-4042_24_R2 Remote Control and designed a pcb-trace antenna. Leap Development tuned the antenna for optimum performance. The purpose of this measurement is to measure the antenna Peak Gain , directivity and efficiency. The antenna tuning process is not described here because it's beyond the scope of this document.

4. Description of measurement

4.1. Equipment used

- Spectrum analyzer Rigol DSA875TG [9kHz~7.5GHz with tracking Generator] with EMC package
- Vector Network Analyzer (VNA) Copper Mountain Planar R54 [85MHz ~5.4GHz]
- Molex Dipole Antenna type 146186 [Gain 3.0dBi @2.4GHz]
- ASTRO 18S Horn Antenna
- Low Noise Amplifier [40dB]
- Full Anechoic chamber with Rotation platform synchronized with analyzer sweep
- Device Under Test (DUT) Musca-2S PCB : TX-4042_24_R2

4.2. Measurement / execution

First we perform a S11 parameter measurement. This gives us insight in the Return Loss, Voltage Standing Wave Ratio and Impedance. We use the “Wheeler cap method” to measure the antenna’s efficiency. We will also calculate the efficiency from the radiated power measured from the DUT and the reference antenna. We will do this only in the horizontal plane. The result will be more of an indication than it is an actual figure.

Following we will perform Radiated measurements to measure the gain and directivity. This will be done in a full anechoic chamber.

4.3. S11 Parameters Test Setup



FIGURE 1

View of the test setup used to measure the S11 parameters.

4.4. Radiated Measurements Test Setup



FIGURE 2

View of the **Radiated Emissions** test setup in the anechoic chamber. The DUT is placed on the table that is placed on the rotating platform. The rotation of the platform is synchronized with the analyzer's sweep. The floor is covered with ferrite tiles and absorbing cones to minimize reflections. Measurements were performed with the DUT and Horn Antenna in the horizontal and vertical polarization.
(Picture left; Horn in Horizontal polarization)



FIGURE 3

DUT in horizontal position on the rotating platform.
The DUT is placed onto the tables center.

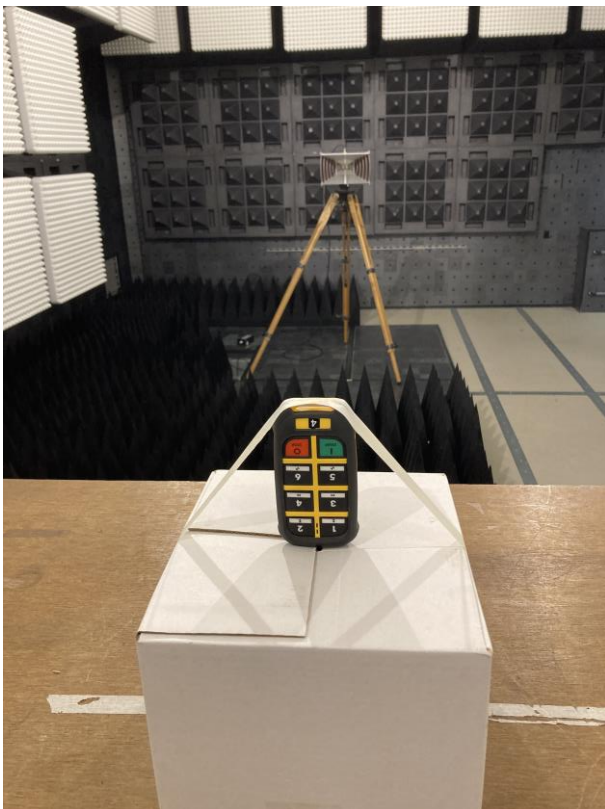


FIGURE 4

DUT in vertical position on the rotating platform.
For best routing of the coax cable the DUT was placed upside down. This has no effect on the measurements.



5. Measurements

5.1. S11 Parameters Results

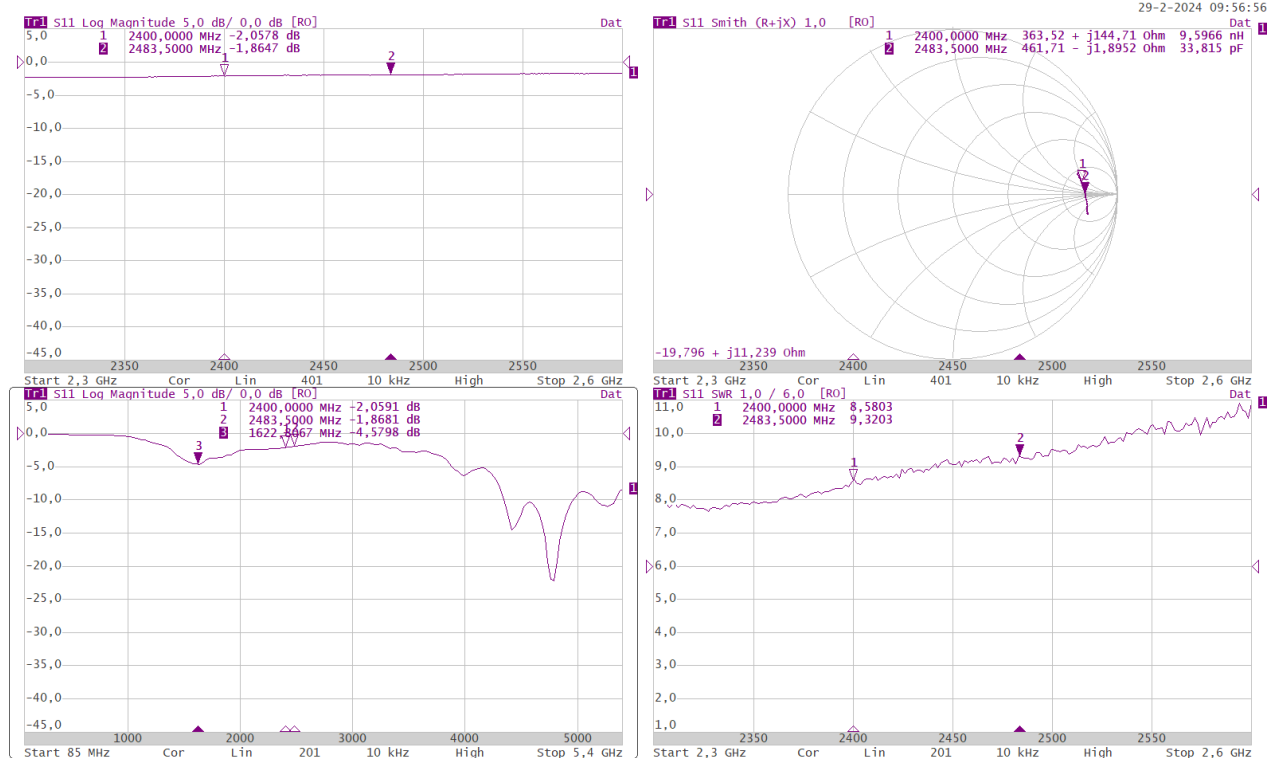


FIGURE 5 INITIAL S11 PARAMETERS (NO RESONANCE ON 2.4GHz)

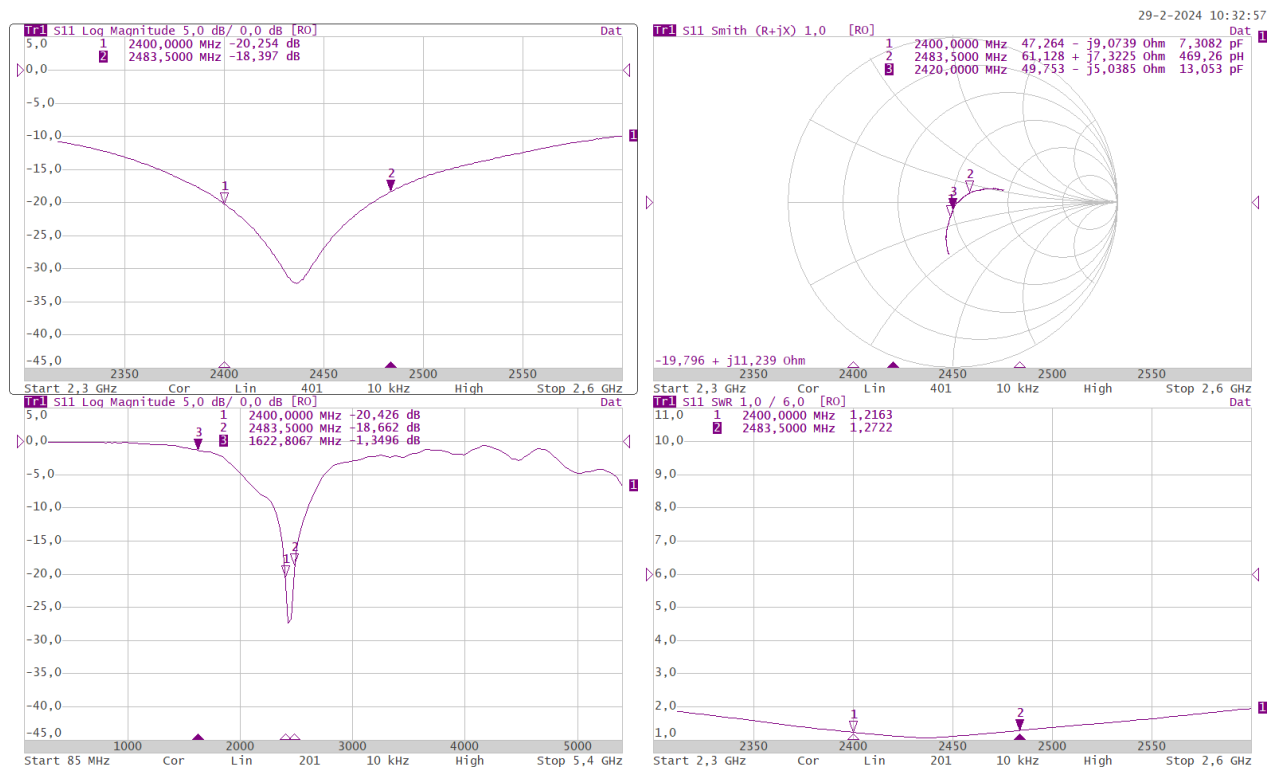


FIGURE 6 FINAL RESULT AFTER TUNING THE ANTENNA. DUT HELD IN HAND.
Antenna trace cut to 24.3mm and capacitor 1.0pF NP0/COG in series.



5.2. Radiated Results

Radiation Pattern TX-4042_24_R2
2400 MHz DUT Horizontal
Horn Antenna Horizontal

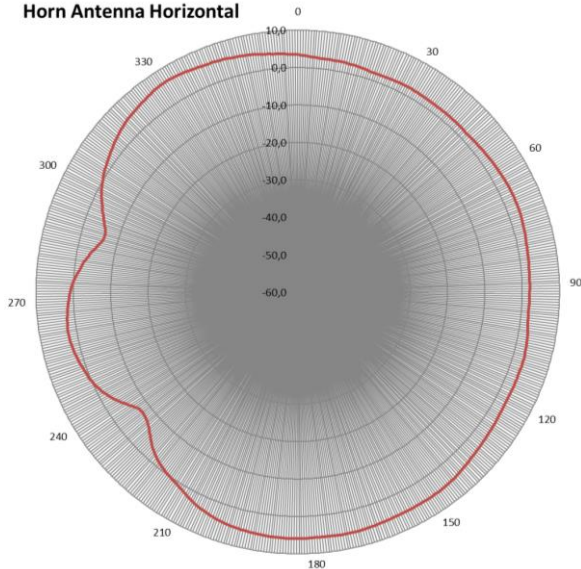


FIGURE 7

Peak Gain is 6.4dBi
Average Gain is 2.4dBi

Radiation Pattern TX-4042_24_R2
2442 MHz DUT Horizontal
Horn Antenna Horizontal

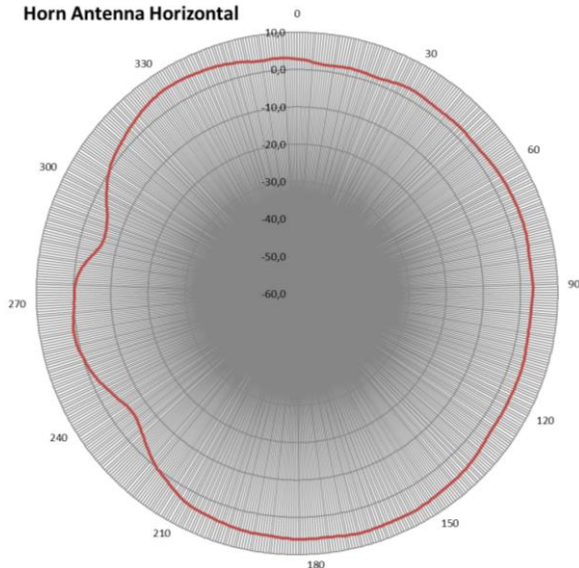


FIGURE 8

Peak Gain is 6.4dBi
Average Gain is 2.3dBi



Radiation Pattern TX-4042_24_R2
2484 MHz DUT Horizontal
Horn Antenna Horizontal

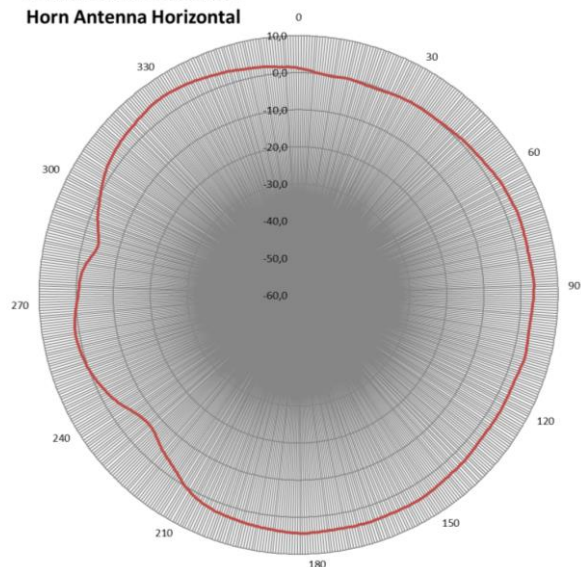


FIGURE 9

Peak Gain is 4.8dBi
Average Gain is 1.5dBi

Radiation Pattern TX-4042_24_R2
2400 MHz DUT Horizontal
Horn Antenna Vertical

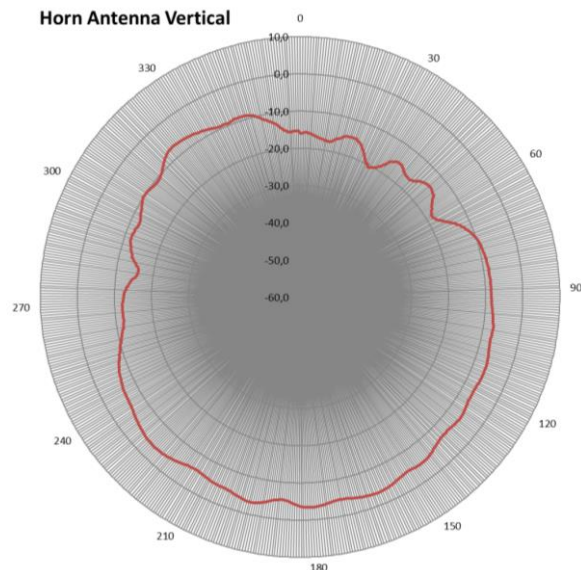


FIGURE 10

Peak Gain is -3.3dBi
Average Gain is -9.4dBi
(Cross Pol)

Radiation Pattern TX-4042_24_R2
2442 MHz DUT Horizontal
Horn Antenna Vertical

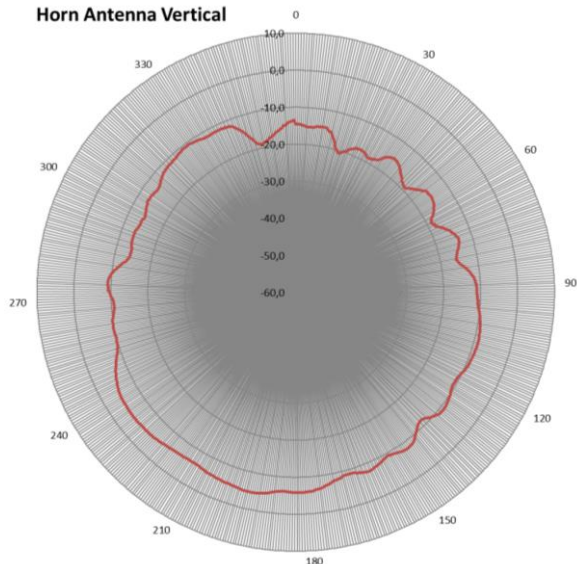


FIGURE 11

Peak Gain is -4.6dBi
 Average Gain is -11.2dBi
 (Cross Pol)

Radiation Pattern TX-4042_24_R2
2484 MHz DUT Horizontal
Horn Antenna Vertical

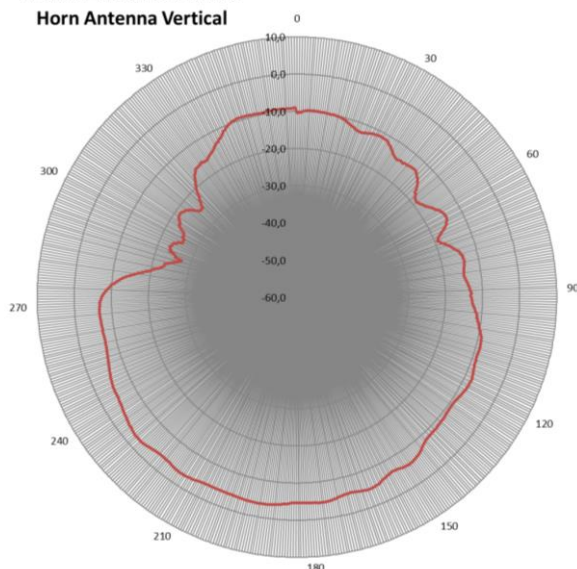


FIGURE 12

Peak Gain is -2.8dBi
 Average Gain is -10.7dBi
 (Cross Pol)

Radiation Pattern TX-4042_24_R2
2400 MHz DUT Vertical
Horn Antenna Vertical

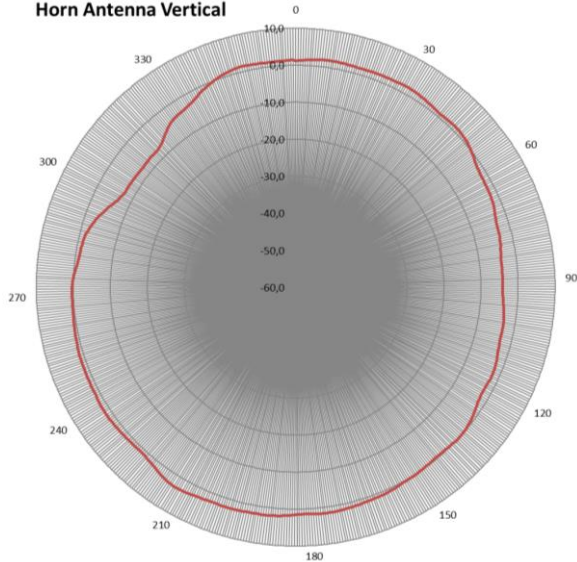


FIGURE 13

Peak Gain is 3.1dBi
 Average Gain is -0.6dBi

Radiation Pattern TX-4042_24_R2
2442 MHz DUT Vertical
Horn Antenna Vertical

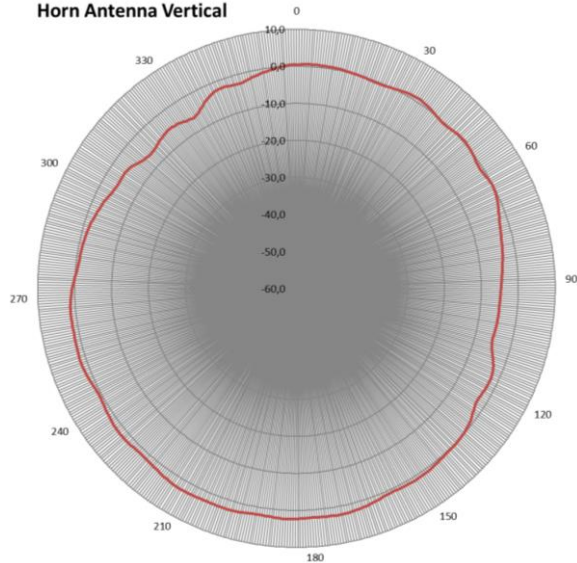


FIGURE 14

Peak Gain is 2.7dBi
 Average Gain is -0.7dBi

Radiation Pattern TX-4042_24_R2
2484 MHz DUT Vertical
Horn Antenna Vertical

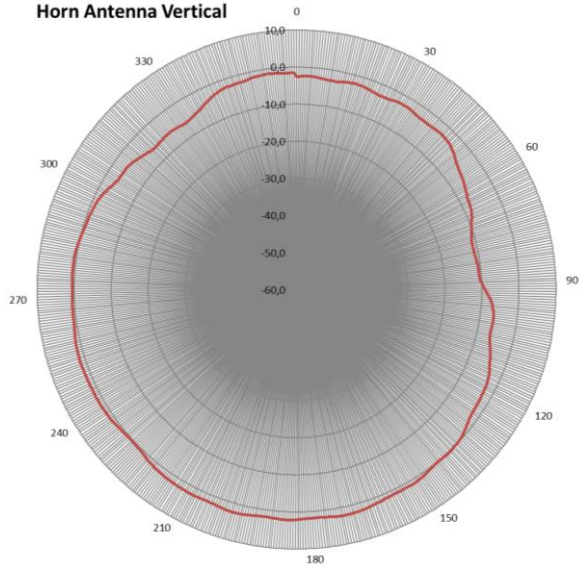


FIGURE 15

Peak Gain is 2.5dBi
 Average Gain is -2.0dBi
 (Cross Pol)

Radiation Pattern TX-4042_24_R2
2400 MHz DUT Vertical
Horn Antenna Horizontal

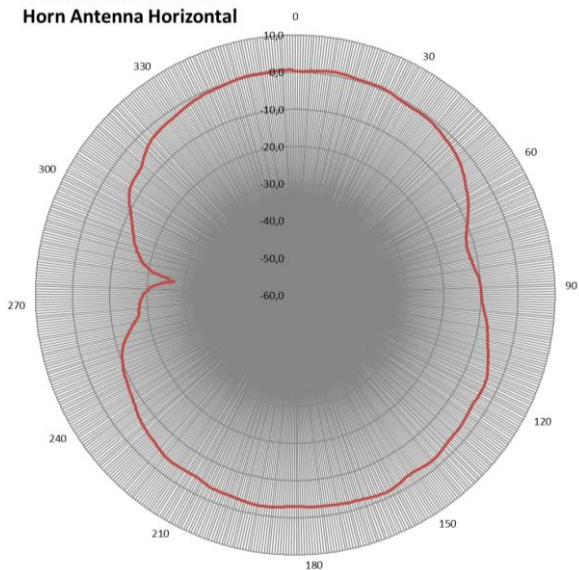


FIGURE 16

Peak Gain is 0.9dBi
 Average Gain is -5.5dBi
 (Cross Pol)

Radiation Pattern TX-4042_24_R2
2442 MHz DUT Vertical
Horn Antenna Horizontal

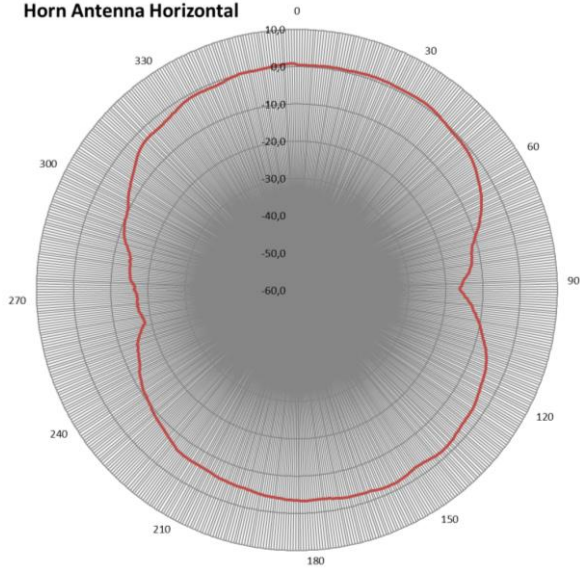


FIGURE 17

Peak Gain is 0.9dBi
 Average Gain is -5.7dBi
 (Cross Pol)

Radiation Pattern TX-4042_24_R2
2484 MHz DUT Vertical
Horn Antenna Horizontal

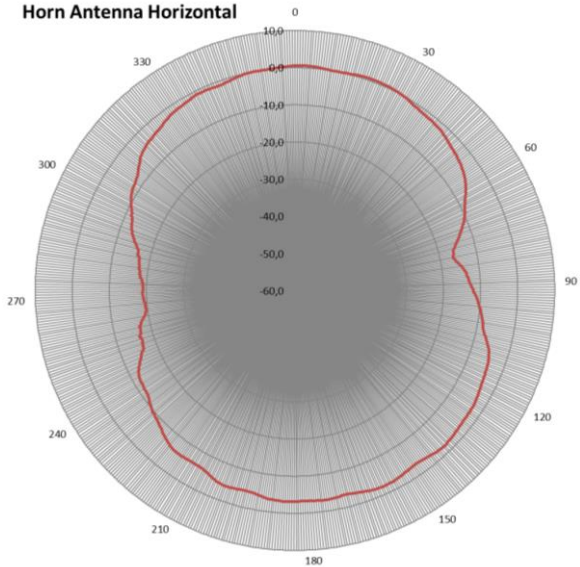


FIGURE 18

Peak Gain is 0.6dBi
 Average Gain is -6.4dBi
 (Cross Pol)

5.3. Efficiency Determination using Radiated Power

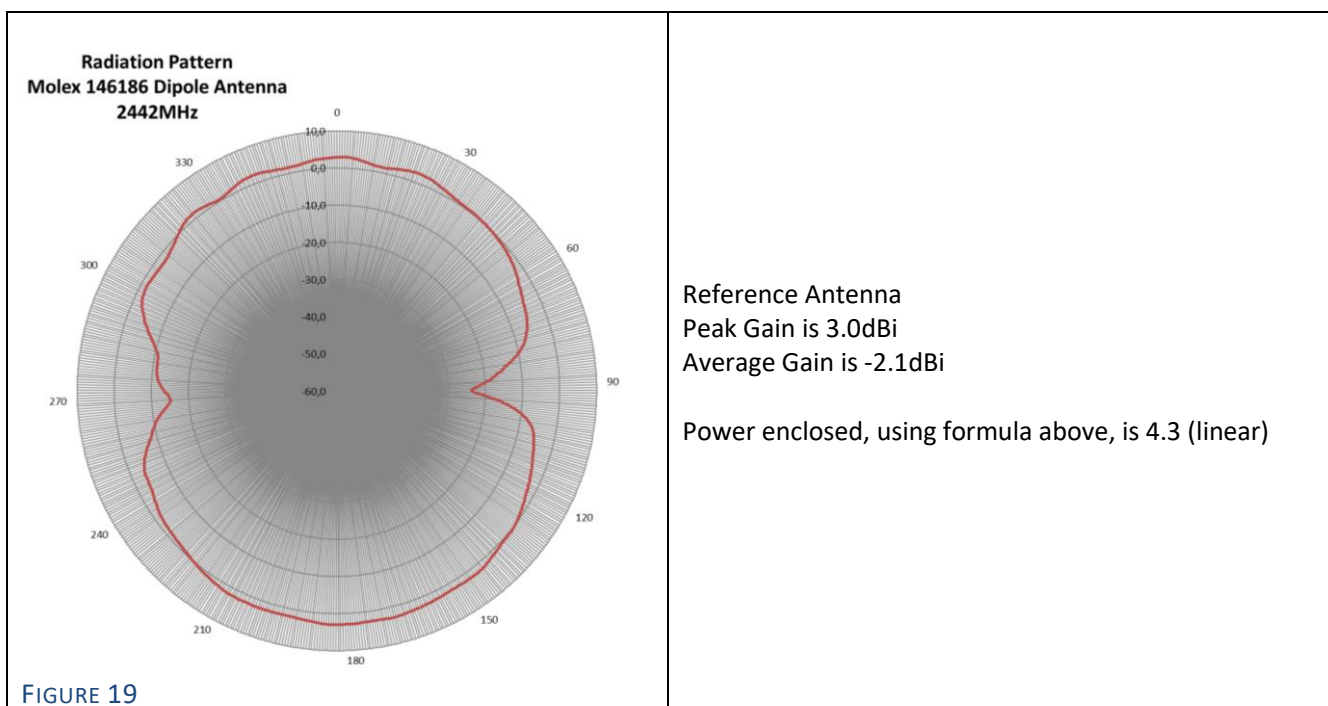
The radiation patterns are buildup of 601 sweep points resulting in 601 circle segments. The enclosed power in a radiation pattern can be approached by summing all segments using the formula below. This calculation will only give an idea of the efficiency of the DUT antenna, in comparison to a reference antenna, in the horizontal plane.

$$P = \sum_{n=1}^{n=601} \frac{\left(\left(10^{\frac{\text{Signal Level[dBm]}}{10}} \right)^2 \right) * \tan(\alpha)}{2}$$

$$\alpha = 360^\circ / 601$$

$$\tan(\alpha) = Y(\text{segment}) / X(\text{segment})$$

$$\text{Power volume of one segment is } (X * Y) / 2$$



$$\text{Efficiency}(\eta) = \frac{\text{Pradiated}}{\text{Pin}}$$

Efficiency of the Reference Antenna is specified to be >70% i.e. 0.7 or -1.55dB

Reference Antenna Pradiated measured =4.3 -> Pin_antenna =6.14

DUT Antenna Pradiated Measured =5.55 (Total average power in radiation patterns of figure 8,11,14,17)

Efficiency DUT Antenna is greater than 5.55/6.14 = i.e. 90% or -0.44dB

5.4. Efficiency Determination using Wheeler Cap Method

The Wheeler Cap method is an accurate method to measure the Antenna Efficiency. The condition is that the antenna is completely enclosed within a sphere with a radius $r = \lambda/2\pi$ and is in this case (2.442GHz) radius $r = 19.5\text{mm}$.

The handheld is too big to fulfill the wheeler cap criteria with a spherical enclosure.

But wrapping the handheld in multiple layers of aluminum foil so it can't radiate, comes as close as possible to the Wheeler Cap criteria.

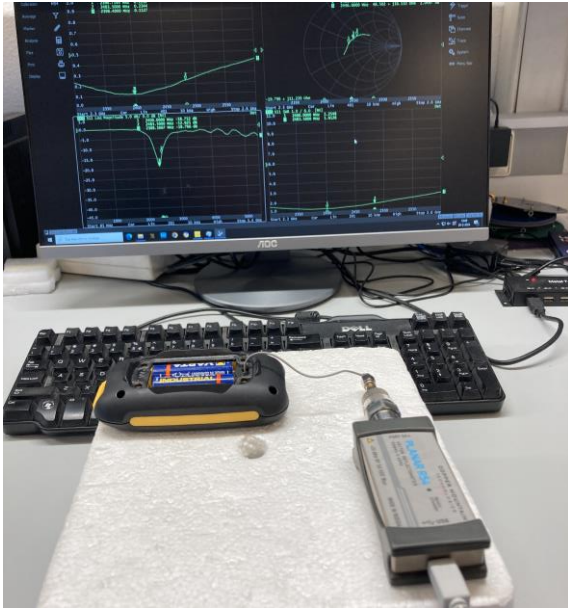


FIGURE 20

Measuring reflection coefficient in free space.

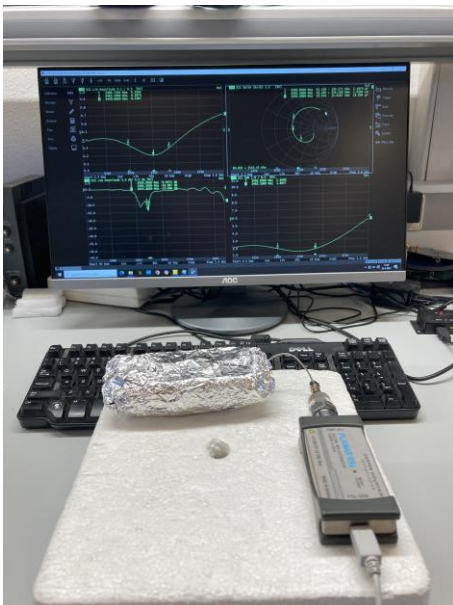


FIGURE 21

Measuring the reflection coefficient using the Wheeler Cap method. The DUT inside the RF-enclosure is completely wrapped in aluminum foil. It can be checked easy if the device radiates or not by putting a hand on the device. If the S11 parameters do not change, there is no radiation coming through the aluminum foil.

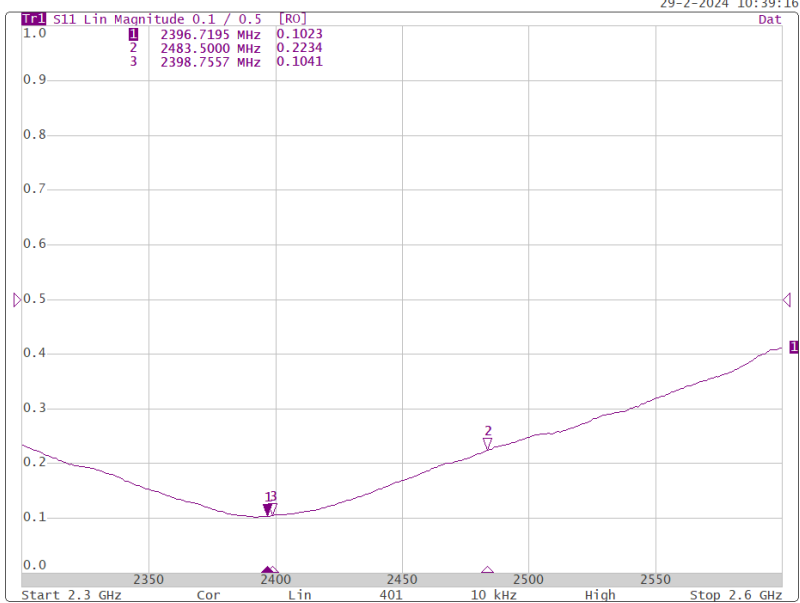


FIGURE 22

DUT in free space
Reflection coefficient $\Gamma_1=0.1041$

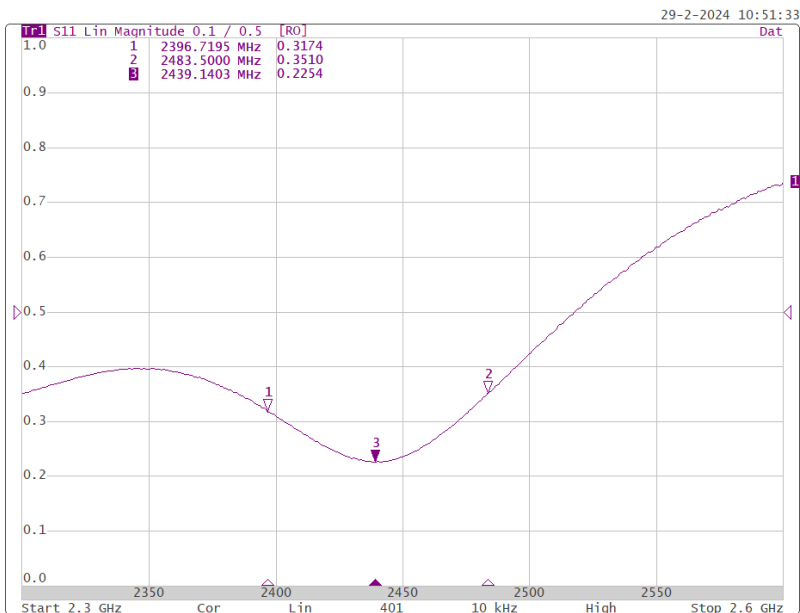


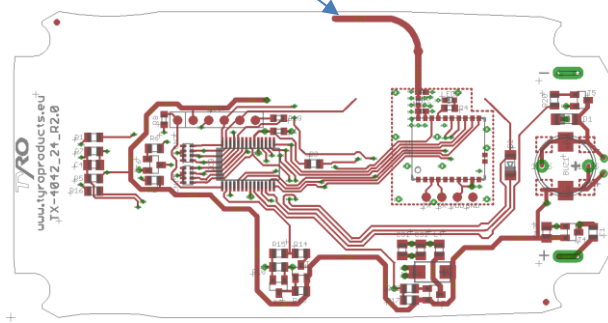
FIGURE 23

DUT in Wheeler Cap.
Reflection coefficient $\Gamma_2=0.2254$

$$Efficiency(\eta) = \frac{\Gamma_2^2 - \Gamma_1^2}{1 - \Gamma_1^2} = (0.05080516 - 0.01083681) / (1 - 0.01083681) = 0.045 \triangleq 4.5\%$$

6. Antenna Drawing

The pcb-trace antenna



Antenna trace cut to 24.3mm and capacitor 1.0pF NP0/COG in series.

7. Test results

The radiated power measured from figure 8 is much larger than the power measured from figure 11,14 and 17. Therefore the average of these four measurements was used to calculate the efficiency from the radiation patterns. The reflection coefficient Γ_2 is lower than expected.

- The Antenna Peak Gain is 6.4dBi at midband frequency
- The Antenna Average Gain is 2.3dBi at midband frequency
- Efficiency calculated using Wheeler Cap method is 4.5%.
- Efficiency calculated using the radiated power measurement gives 90%

8. Conclusion

The antenna shows excellent S11 parameters.

The radiation patterns are in line with the mechanical antenna construction. The radiation patterns show no 'black spots'. Due to the bend-antenna construction there is only little separation between the horizontal and vertical polarizations. This might be beneficiary in the end user application.

The efficiency calculated using the Wheeler Cap Method and the radiated power measurements give quite different results. The average gain measured at midband frequency from the DUT is 4.5dB higher than from the reference dipole antenna. Therefore we conclude that the Wheeler Cap Method didn't work since we should get an efficiency better than 70%. The reason might be that VNA measurement signal is being absorbed in the antenna-surrounding-materials. The rough surface of the crumpled aluminum foil is likely to scatter the signals in all directions where it passes certain materials, who absorb a bit of the signal, many times before reaching the antenna strongly weakened again.

In this case the Radiated Average Power Measurement method, using 4 different planes, is the best we can do. The calculated efficiency of 90% is in line with the expectation.

===== # =====