Cetus 2S TRX-3033_R1
Antenna Performance Measurement

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Company:	Leap Development B.V.
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Client project nr:	-
Client project name:	-

1. Contents

2. Document revision history

Revision	Date	Author	Description
0.1	March 25th, 2024	Jan ten Thije	Initial setup & release
1.0	March 29th, 2024	Mart Vlas	Review and Release
1.1	April 3rd, 2024	Jan ten Thije	Small textual changes (PCB No.)
1.2	April 5th, 2024	Jan ten Thije	Small textual changes (issue No. & PCB No.)

3. Client

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Contact person: Mr. John Nijkrake

3. Preface

Tyro Products has integrated a Feasycom Bluetooth Low Energy module in a Cetus 2S Remote Control and designed a pcb-trace antenna. Leap Development tuned the antenna for optimum performance at 2.4GHz.
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) Cetus 2S PCB : TRX-3033_R1

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. Following we will tune the antenna for maximum performance.

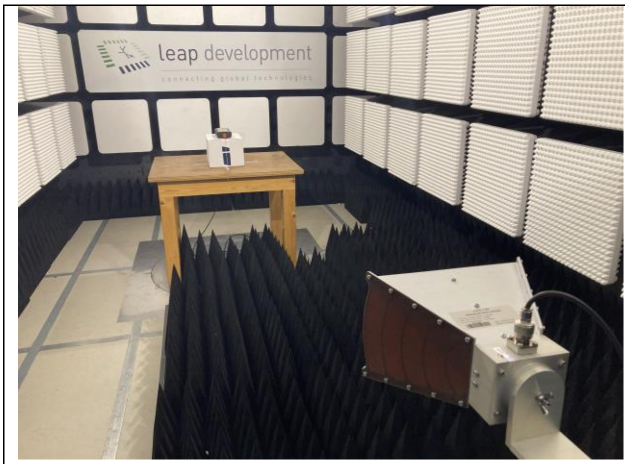
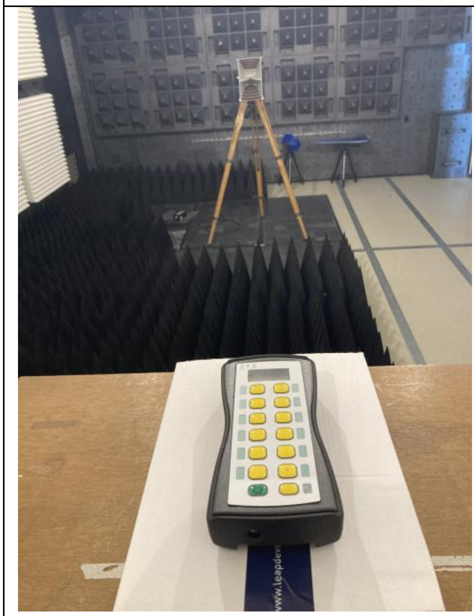
Due to the size of the DUT with its integrated antenna we cannot use the “Wheeler cap method” to measure the antenna’s efficiency. We will calculate the efficiency from the radiated power measured from the DUT and the reference antenna. The input for the calculation on the midband frequency will be derived from the radiation patterns from all three planes and both polarities.

4.3. S11 Parameters Test Setup

	View of the test setup used to measure the S11 parameters. The connecting coax cable leads through the battery compartment directly to the antenna.

4.4. Radiated Measurements Test Setup

Normally the base station antenna of a wireless remote control system is vertically orientated and most sensitive in the vertical polarization. Therefore we mark the measurements with the horn antenna in the horizontal polarization as Cross Polarization (Cross Pol)

	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 vertical polarization)
	DUT in horizontal position on the rotating platform. The DUT is placed onto the tables center. Horn antenna in Cross Pol orientation.

	DUT on side position on the rotating platform.
	DUT in vertical position on the rotating platform.

5. Measurements

5.1. S11 Parameters Results

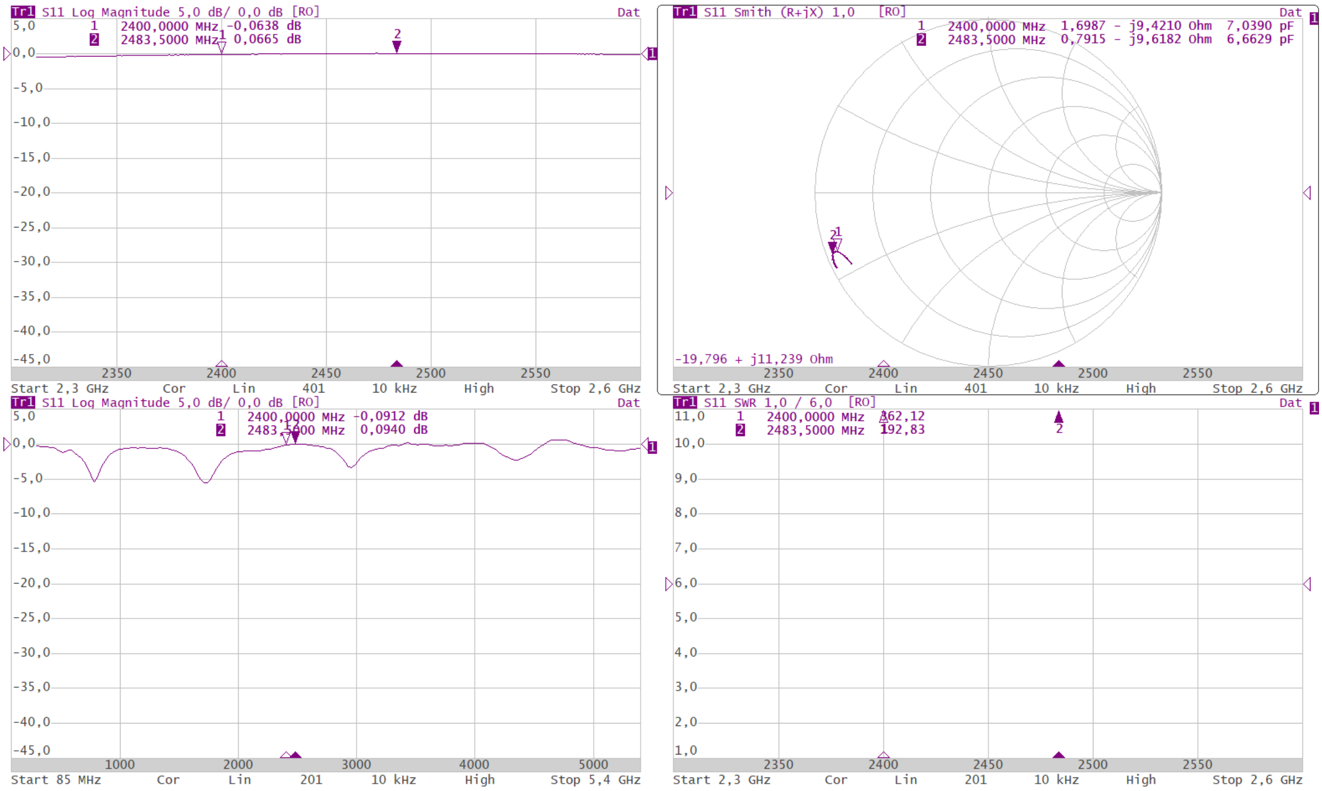


FIGURE 1

S11 parameters before tuning.
There is no resonance in the desired frequency band.

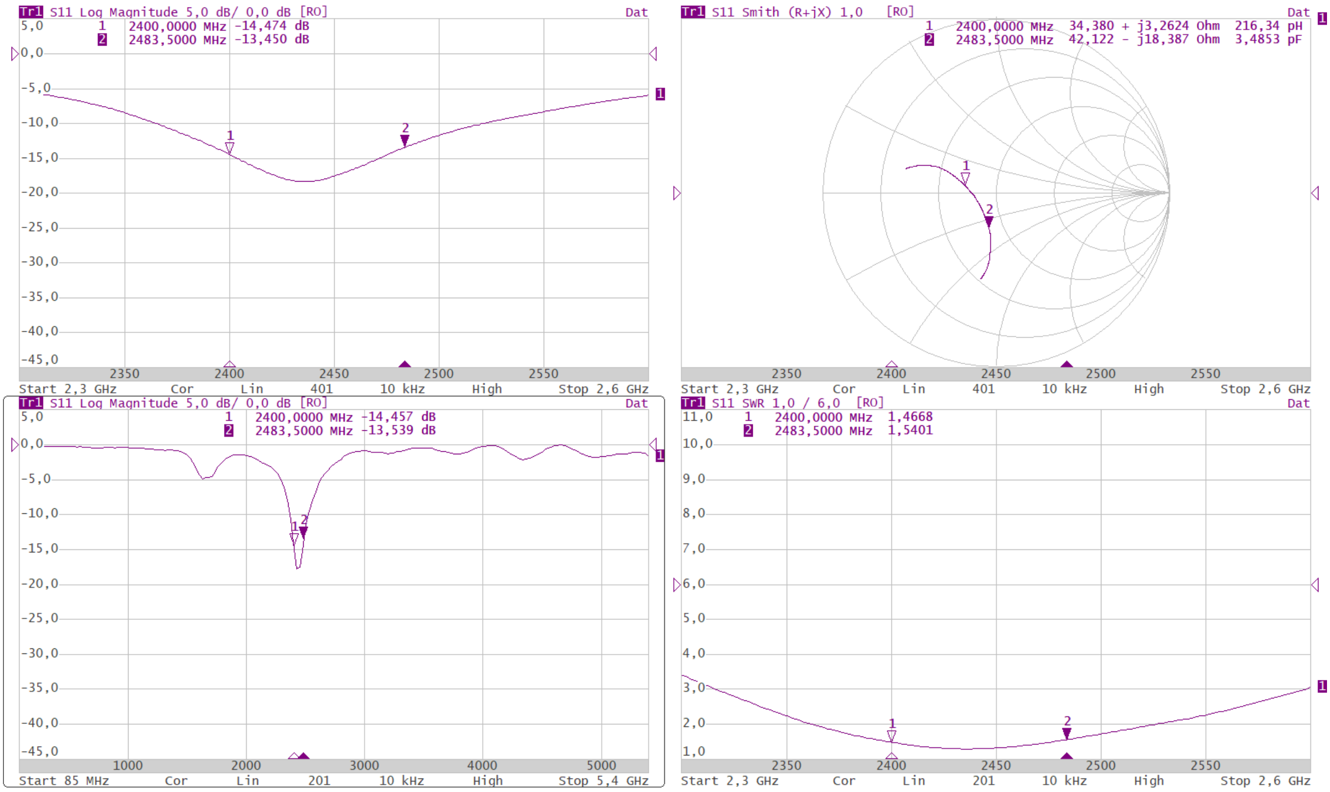
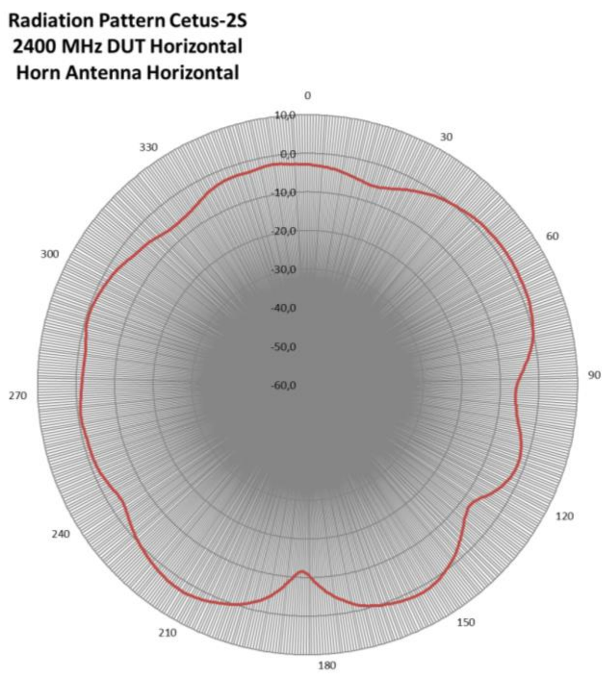
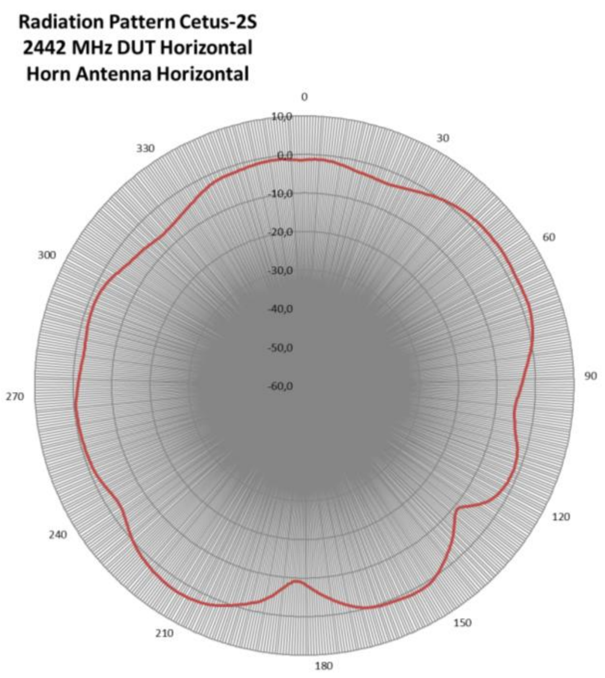


FIGURE 2

S11 parameters after tuning the trace antenna to a quarter wave resonant antenna.
As can be seen in the Smith chart, the real part of the impedance is close to the theoretical 36.6 Ohm for a quarter wave antenna.

5.2. Radiated Results

 FIGURE 3	Peak Gain is 2.7dBi Average Gain is -2.2dBi (Cross Pol)
 FIGURE 4	Peak Gain is 2.9dBi Average Gain is -1.8dBi (Cross Pol)

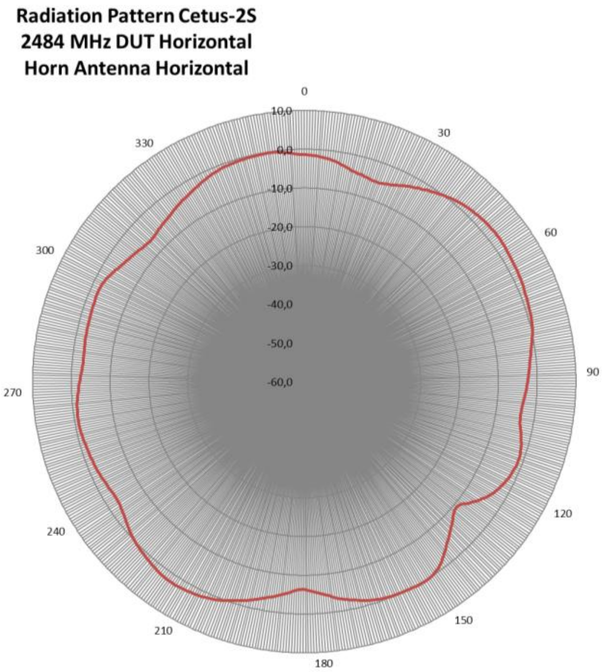


FIGURE 5

Peak Gain is 2.4dBi
Average Gain is -1.9dBi
(Cross Pol)

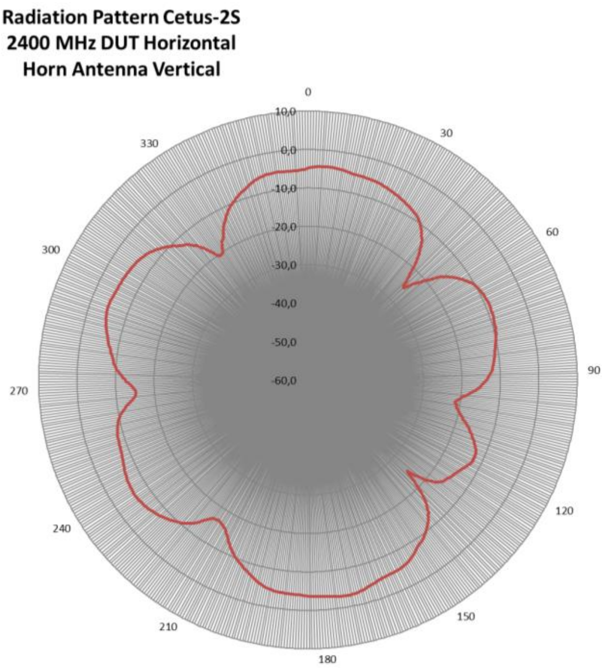


FIGURE 6

Peak Gain is -2.9dBi
Average Gain is -9.9dBi

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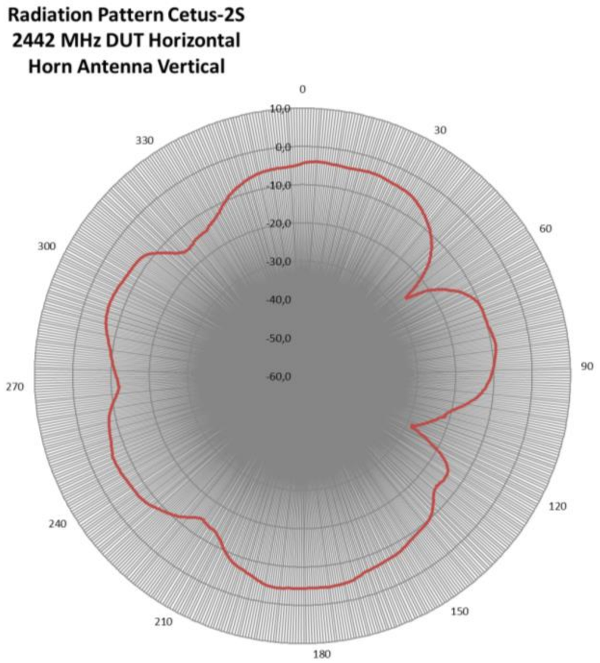

FIGURE 7
</td>
<td>Peak Gain is -3.9dBi
Average Gain is -9.8dBi</td>
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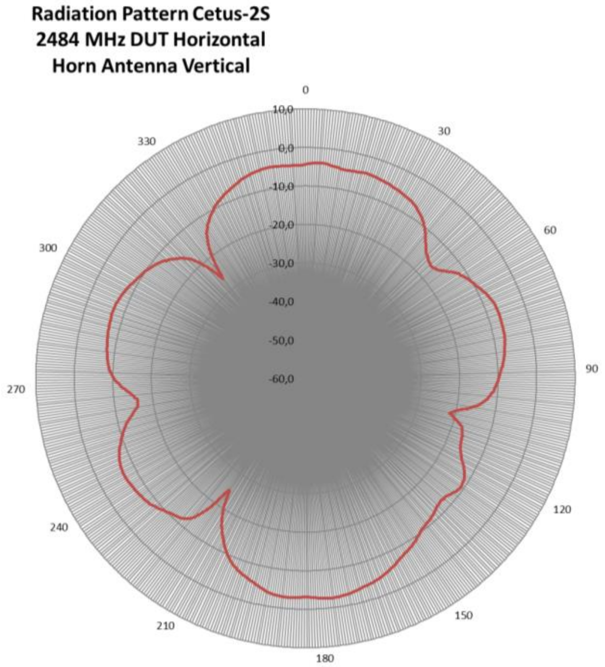

FIGURE 8
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<td>Peak Gain is -2.5dBi
Average Gain is -9.5dBi</td>
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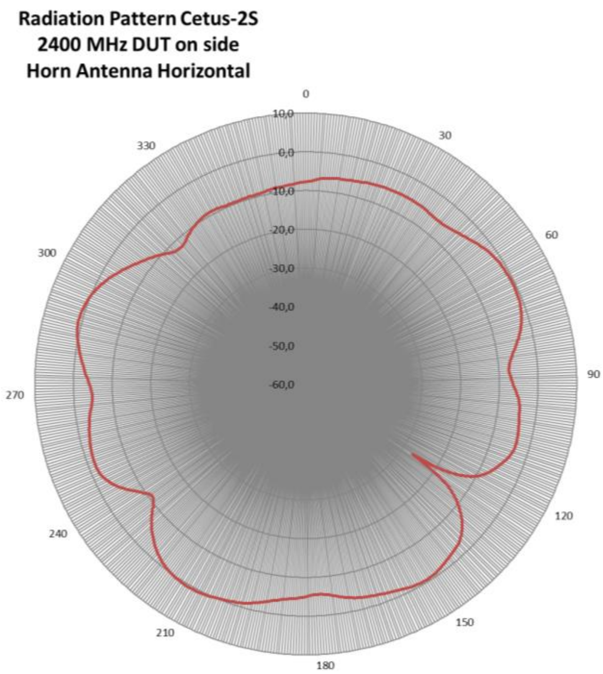
<td>

FIGURE 9</td>
<td>Peak Gain is 0.9dBi
Average Gain is -4.8dBi
(Cross Pol)</td>
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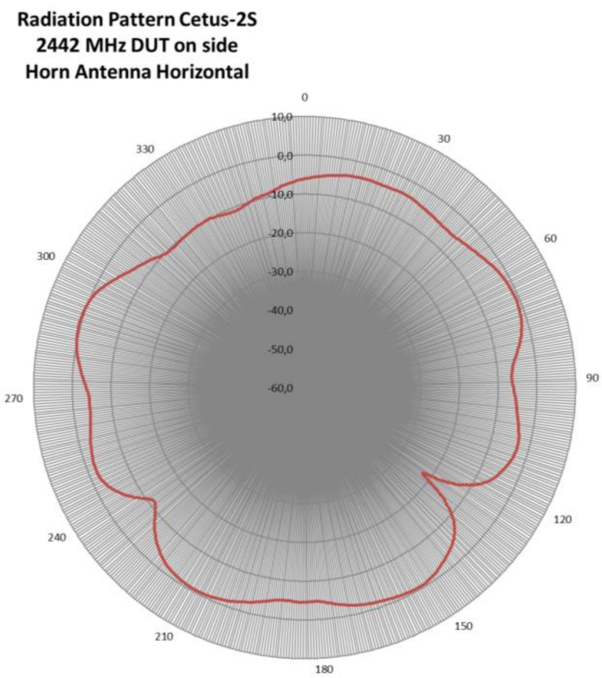
<td>

FIGURE 10</td>
<td>Peak Gain is 0.5dBi
Average Gain is -4.7dBi
(Cross Pol)</td>
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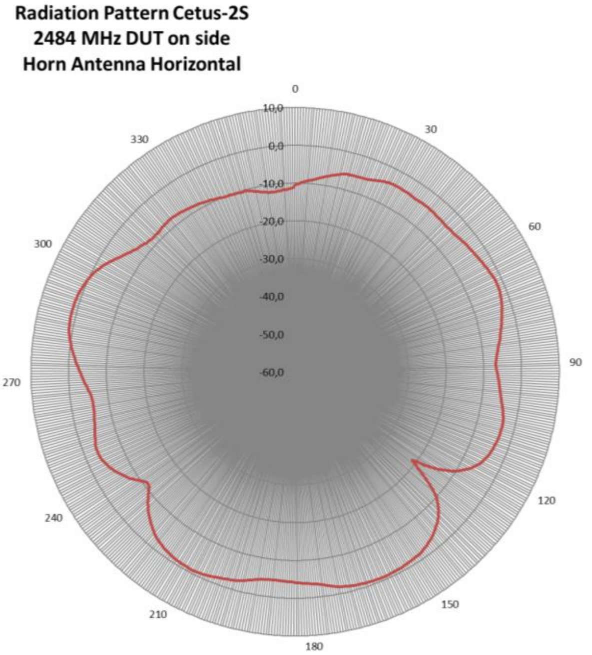
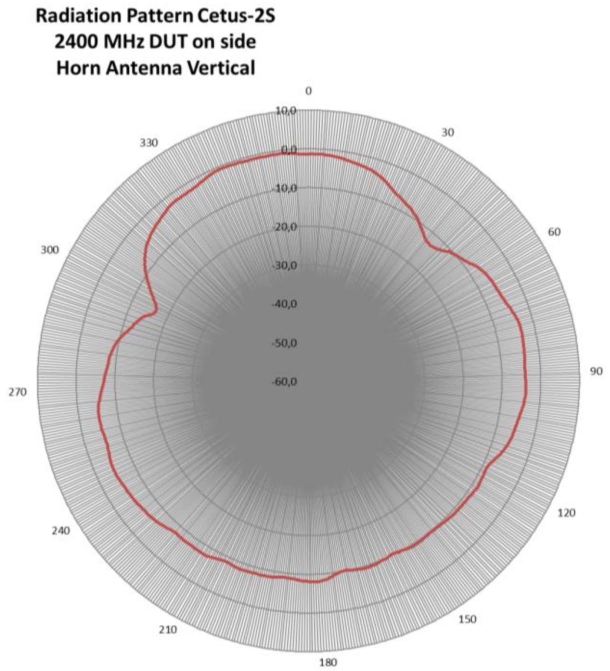
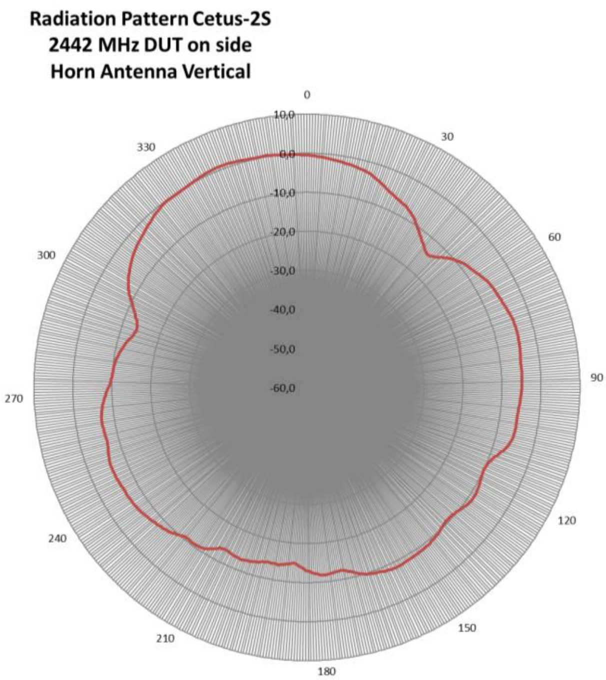
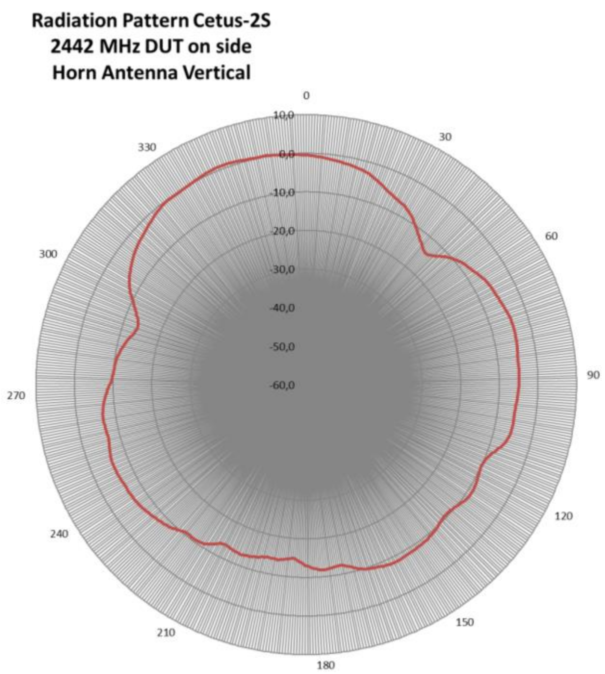
 FIGURE 11	Peak Gain is 1.2dBi Average Gain is -4.9dBi (Cross Pol)
 FIGURE 12	Peak Gain is -0.7dBi Average Gain is -6.7dBi

 FIGURE 13	Peak Gain is 0.9dBi Average Gain is -7.3dBi
 FIGURE 14	Peak Gain is 0.8dBi Average Gain is -7.4dBi

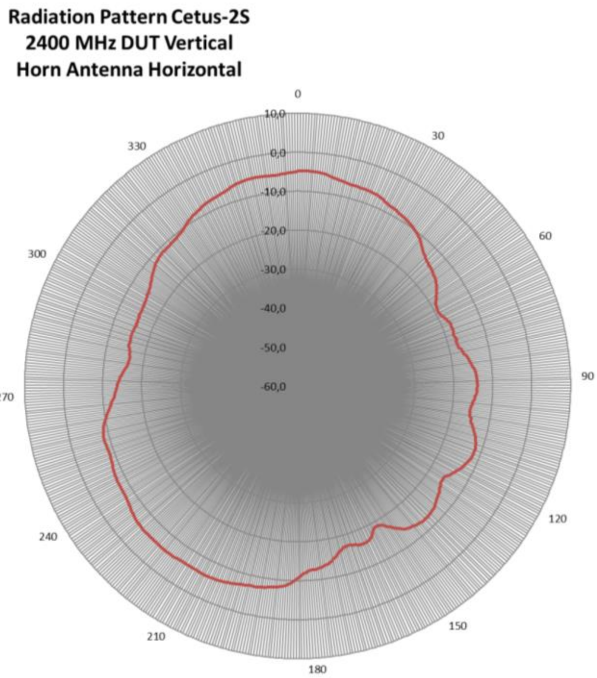


FIGURE 15

Peak Gain is -4.8dBi
Average Gain is -11.4dBi
(Cross Pol)

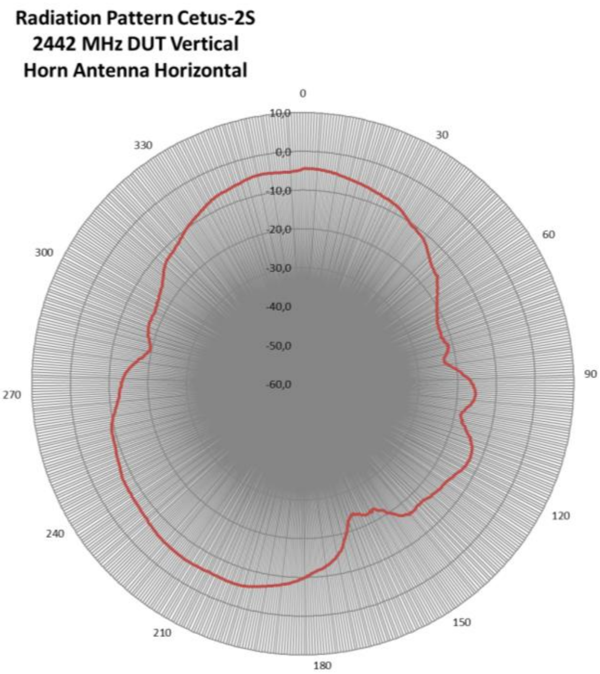
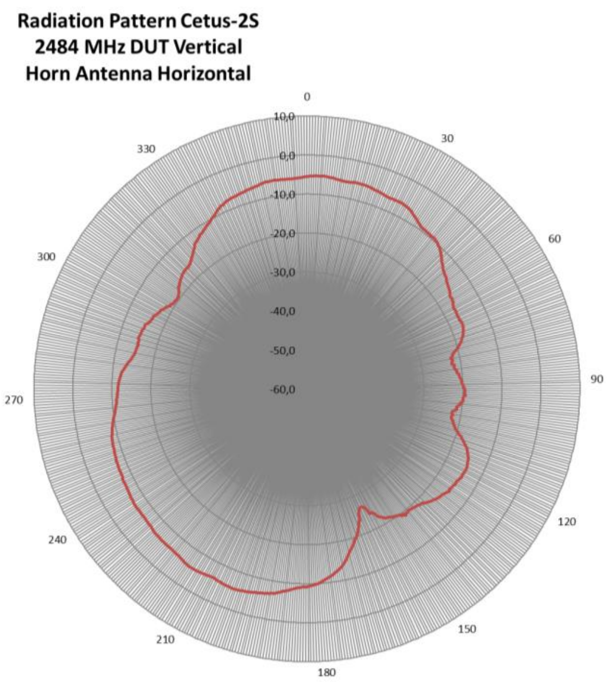
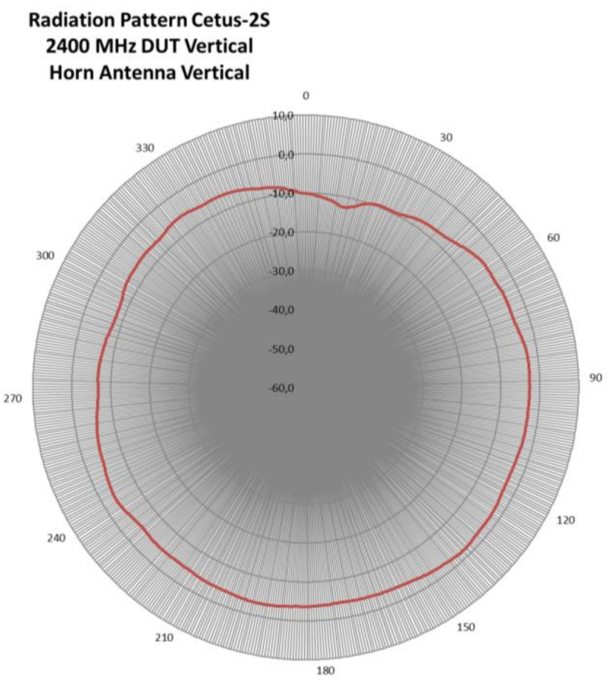
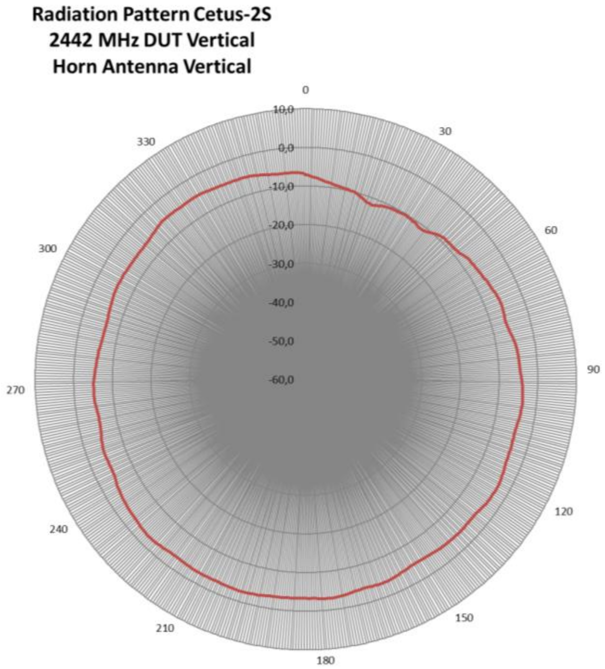
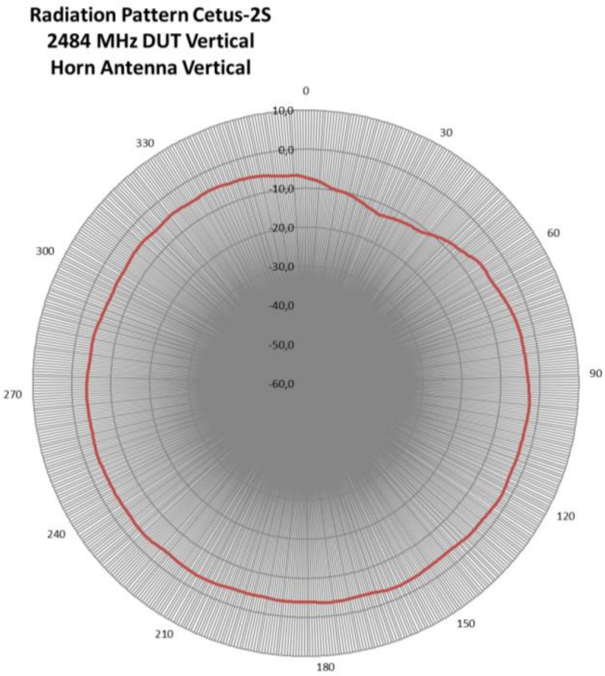


FIGURE 16

Peak Gain is -4.4dBi
Average Gain is -12.4dBi
(Cross Pol)

 FIGURE 17	Peak Gain is -5.3dBi Average Gain is -12.5dBi (Cross Pol)
 FIGURE 18	Peak Gain is -1.8dBi Average Gain is -5.3dBi

 FIGURE 19	Peak Gain is -2.5dBi Average Gain -5.3dBi
 FIGURE 20	Peak Gain is -2.2dBi Average Gain is -7.9dBi

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 give an idea of the efficiency of the DUT antenna, in comparison to a reference antenna.

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

α=360°/601
tan(α)=Y(segment)/X(segment)
Power volume of one segment is (X*Y)/2

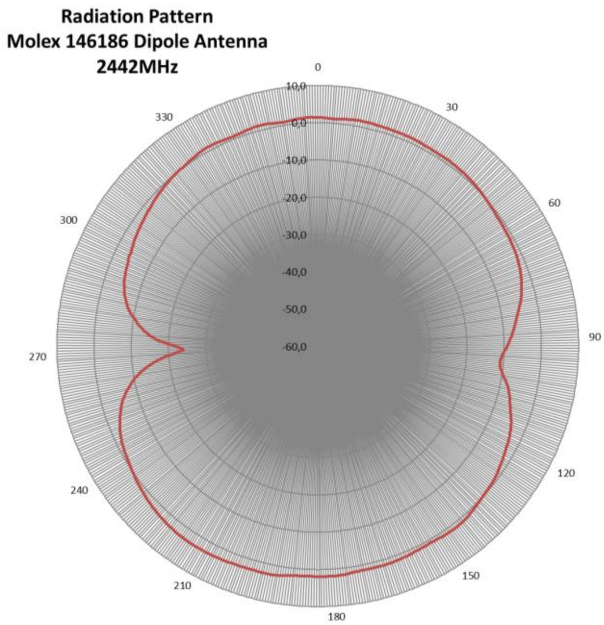


FIGURE 21

Reference Antenna
Peak Gain is 3.0dBi
Average Gain is -1.7dBi

Power enclosed, using formula above, is 3.9 (linear)

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

Efficiency of the Reference Antenna is specified to be >70% i.e. 0.7 or -1.55dB
Reference Antenna Pradiated measured =3.9 -> Pin_antenna =5.6

DUT Antenna Pradiated Measured =0.77 (Total average power in radiation patterns of figure 4,7,10,13,16,19)
Efficiency DUT Antenna is greater than 0.77/5.6 =0.137 i.e. 13.7% or -8.6dB

6. Antenna Drawing

The pcb-trace antenna

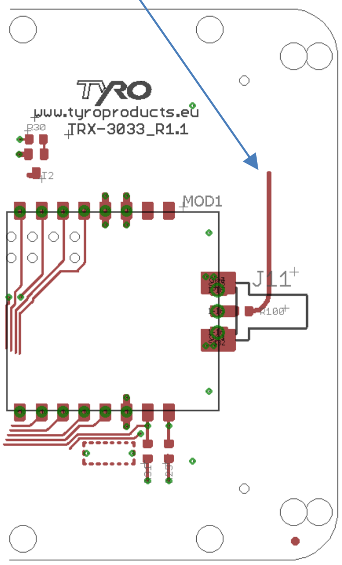


FIGURE 22

Antenna trace cut to 18.05mm (measured with function 'Length' in Eagle CAD)
The cut part removed from the printed circuit board.

7. Test results

- The Antenna Peak Gain is 2.9dBi at midband frequency
- The Antenna Average Gain is -1.8dBi at midband frequency
- Efficiency calculated using the radiated power measurement gives 13.7%

8. Conclusion

The Antenna performance is in line with our expectation.
If the remote control is held horizontally and the base station antenna has vertical polarization, which is often the case, then some weak spots are present. See figure 6,7 and 8. If the remote control is held vertically and the base station antenna has vertical polarization, then the radiation patterns in figures 18, 19 and 20 show a nice nearly omni-directional pattern. I cases where the base station antenna has horizontal polarization then the radiation patterns are nearly omni-directional if the handheld is used in horizontal position. See figures 3, 4 and 5.

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