www.ti.com **Texas Instruments – Low Power Connectivity** Address: Hoffsveien 77C 0377 Oslo Phone: Fax: E-mail: Web: www.ti.com Enterprise No: 980 499 480	Measurement result
	Title: **LEGO Hub No. 19 EMC test report**
	Project number: XXX / Project name: XXX
	Author: Zack Costello
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Rev	
A	Initial version

Contents

1 Test Setup

1.1 Information

Hardware	R&S® TS8991 OTA (Over The Air) performance test system. Additional RSE (Radiated Spurious Emission) test capability with additional filter/LNA support for spurious emissions measurements.
Software	R&S® EMC32 measurement software for Automation for EMC compliance and pre-compliance.
Table of Calibrated Instruments	PM8 R&S® NRP-Z11 Power Sensor Calibration due: 14th September 2024
Test Site Information	TI Norway, Validation Lab, Hoffsveien 70C, 0377 Oslo
Completed Test Date(s)	31st October 2023
Test Personnel	Zack Costello

1.2 Test Setup Photos

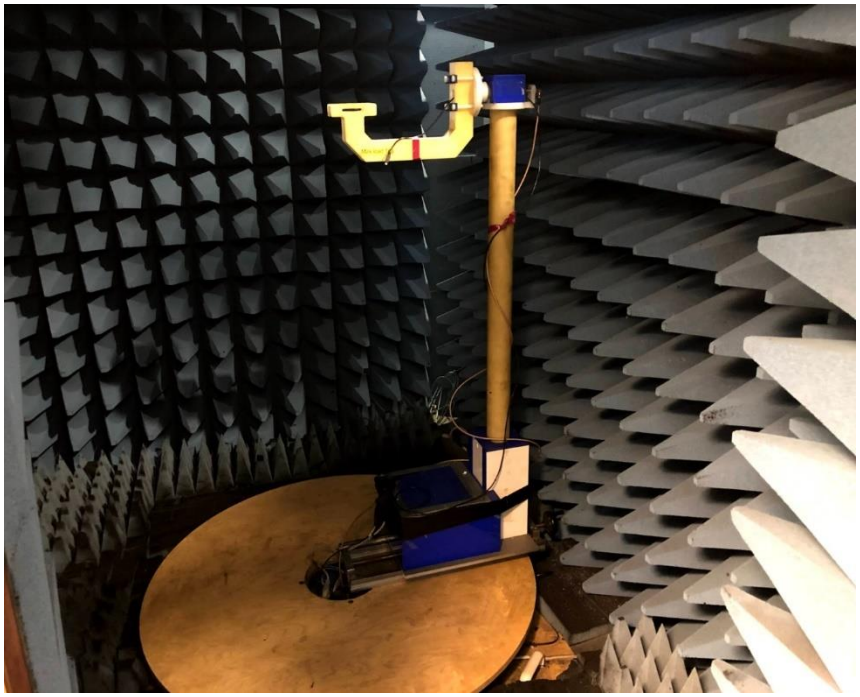


Figure 1: Turn arm in chamber

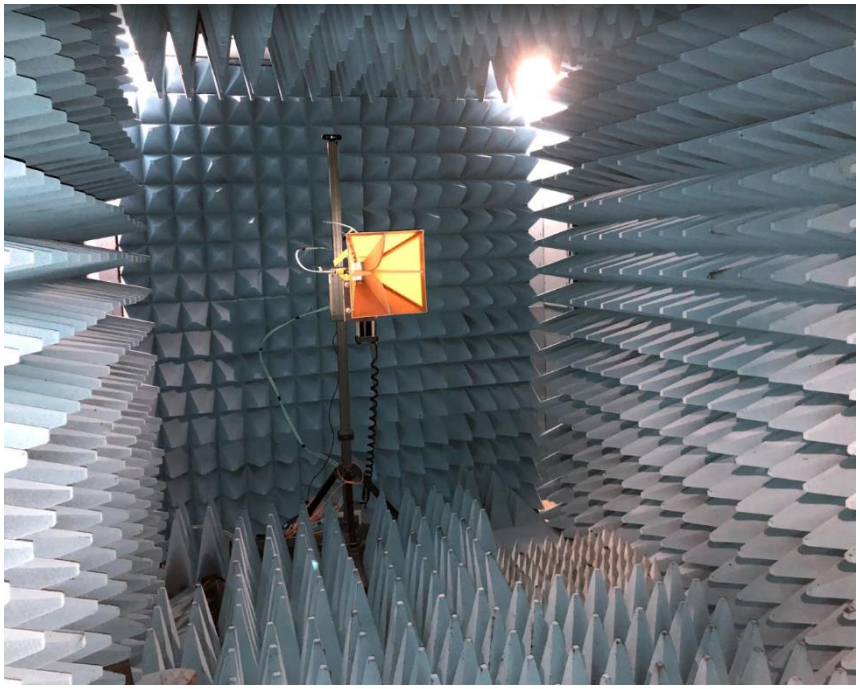


Figure 2: Receiving antenna in chamber

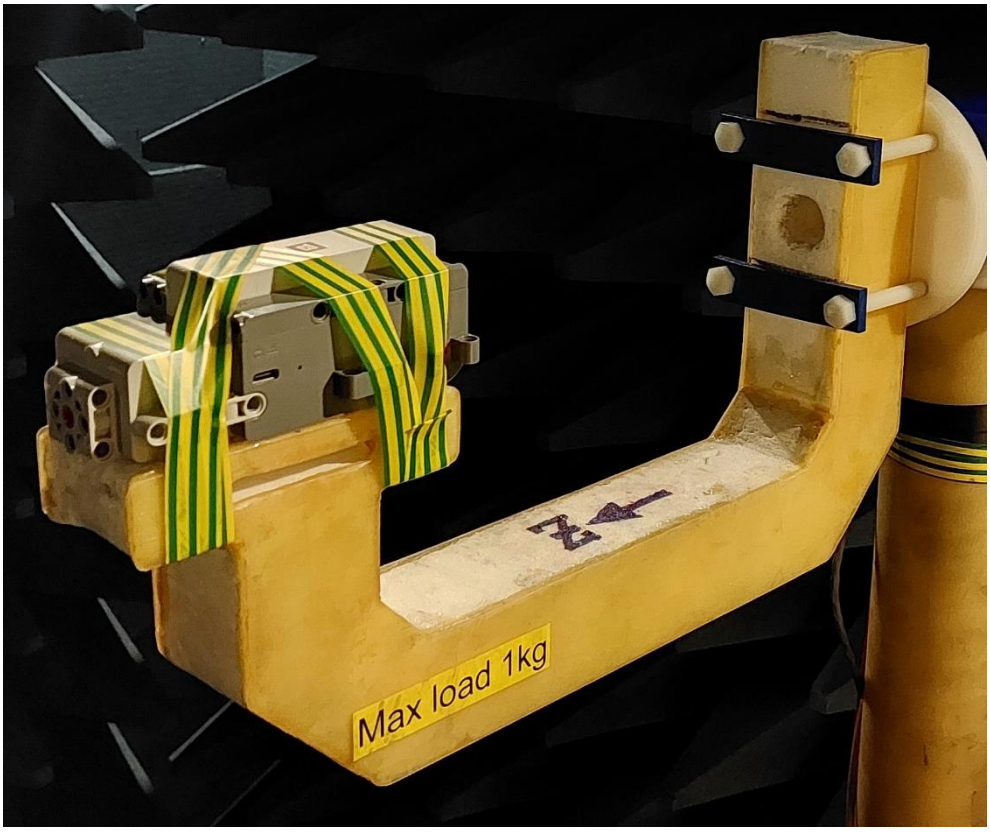


Figure 3: Placement of AUT on turn arm in chamber showing Z-axis

2 +0 dBm, 2440 MHz

2.1 Setup

ATM mode 2.

2.2 Summary

The calculations for this section are detailed in Section 3.

Total Radiated Power	-2.80 dBm
Peak EIRP	0.05 dBm
Antenna directivity	2.85 dBm
Antenna efficiency	-2.80 dB
Antenna gain	**0.05 dBi**
2nd Harmonic	Noise floor of EMC chamber
3rd Harmonic	Noise floor of EMC chamber
4th Harmonic	Noise floor of EMC chamber

2.3 Radiated Spurious Emissions (RSE) Plot

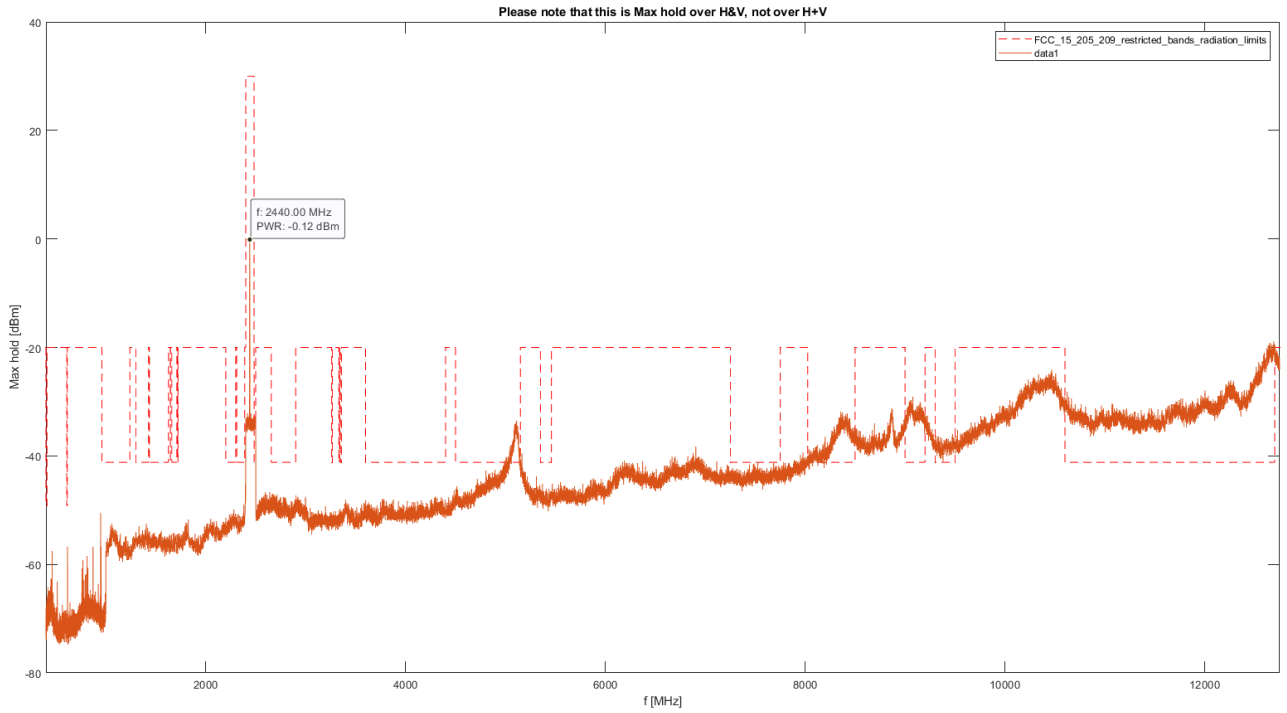


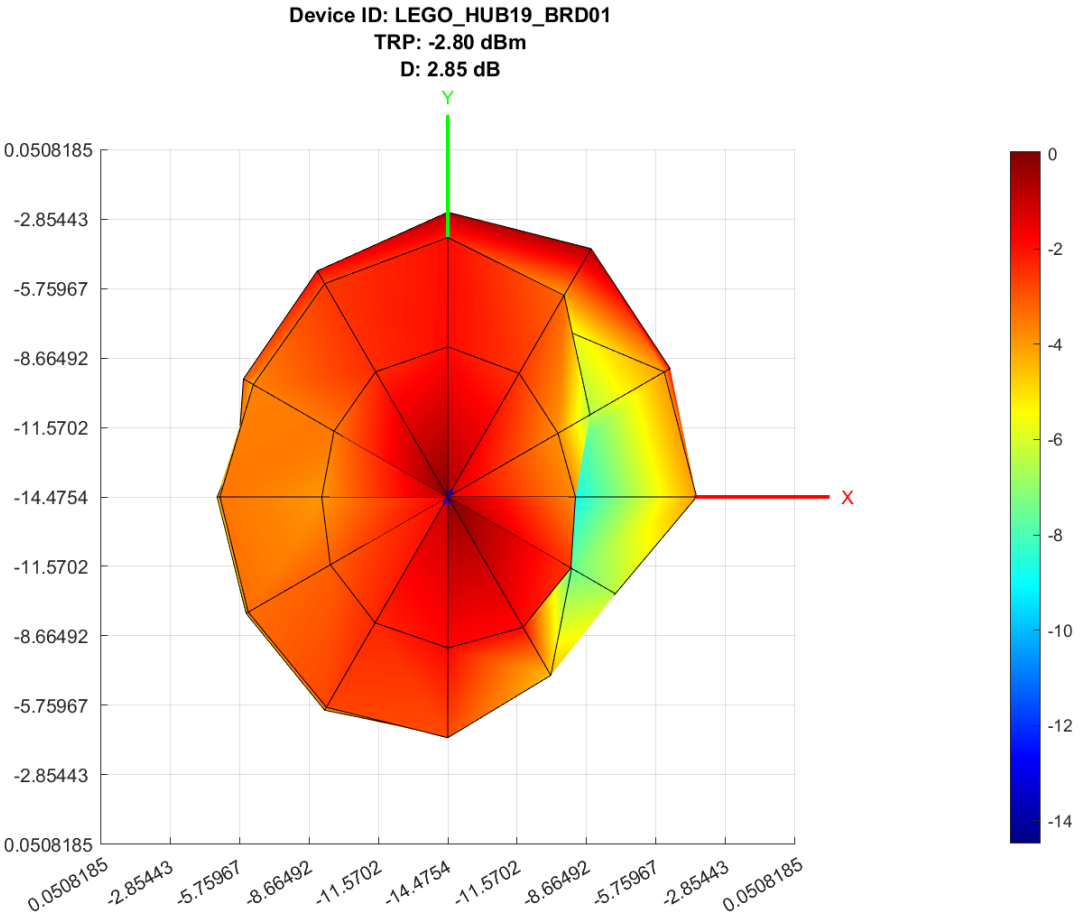
Figure 5: Spectrum sweep from 0.4 GHz to 12.75 GHz

Note: The spurs below 1 GHz and at approx. 5.5 GHz is a limitation of the EMC chamber and is not caused by the DUT. The high noise floor for frequencies above 6 GHz is also a limitation of the EMC chamber.

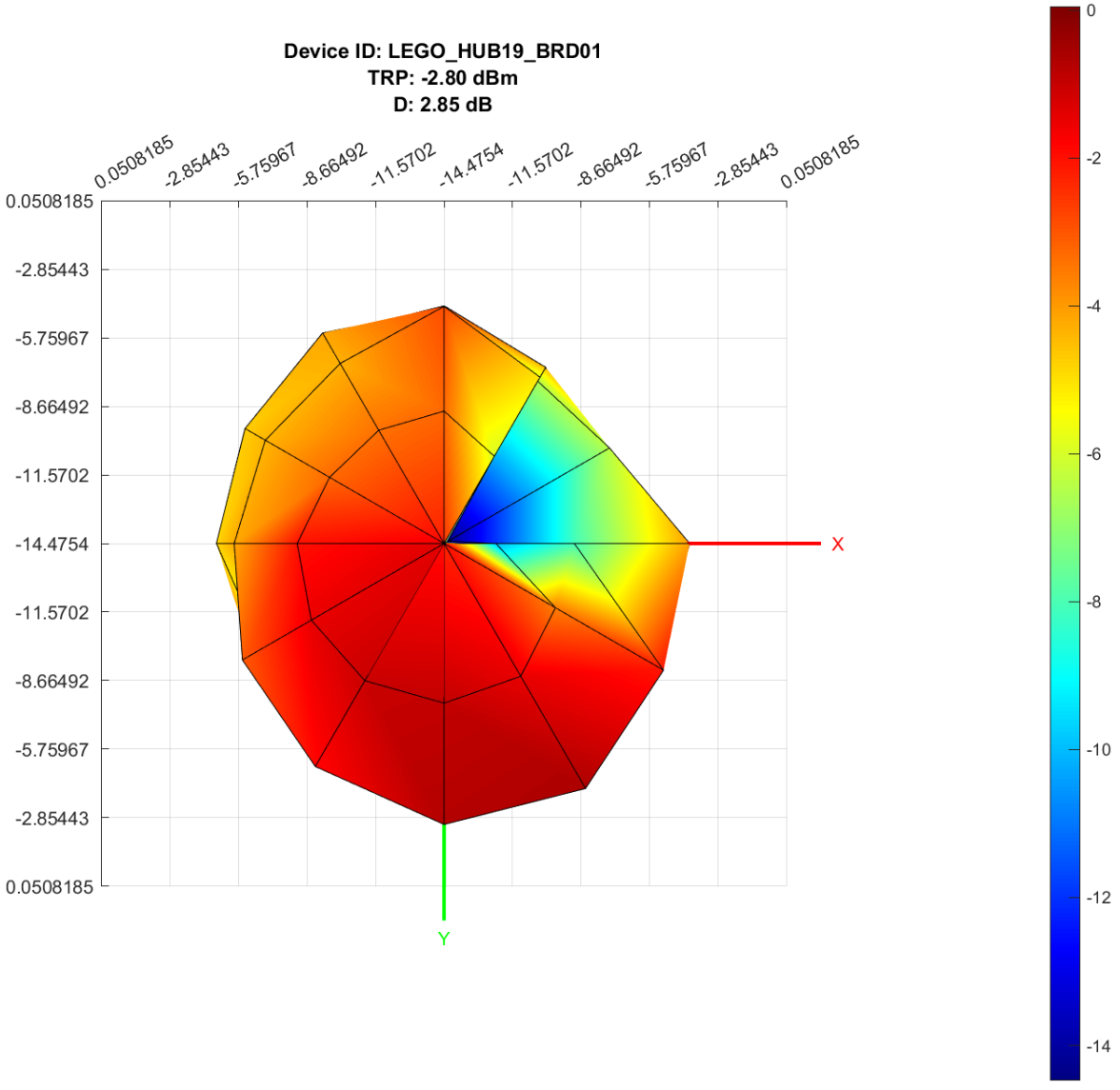
The noise floor of the EMC chamber at the 3rd harmonic of 2.44 GHz (7.32 GHz) is below the FCC 15.205.209 spectral mask limit of -41.2 dBm, meaning that spurious emissions that violate the -41.2 dBm limit will be visible.

2.4 Radiation Pattern

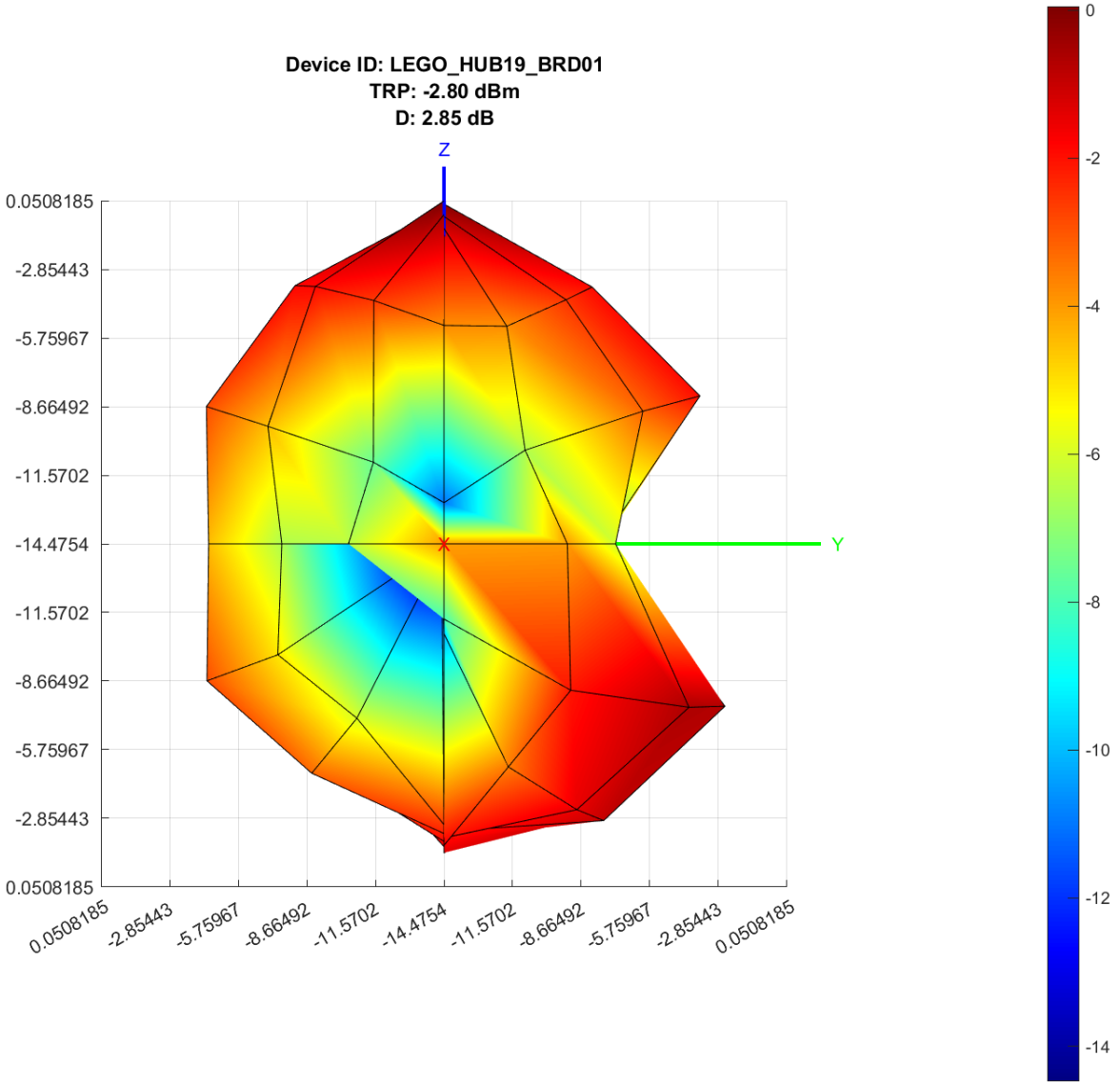
2.4.1 Theta = 0, Phi = 0



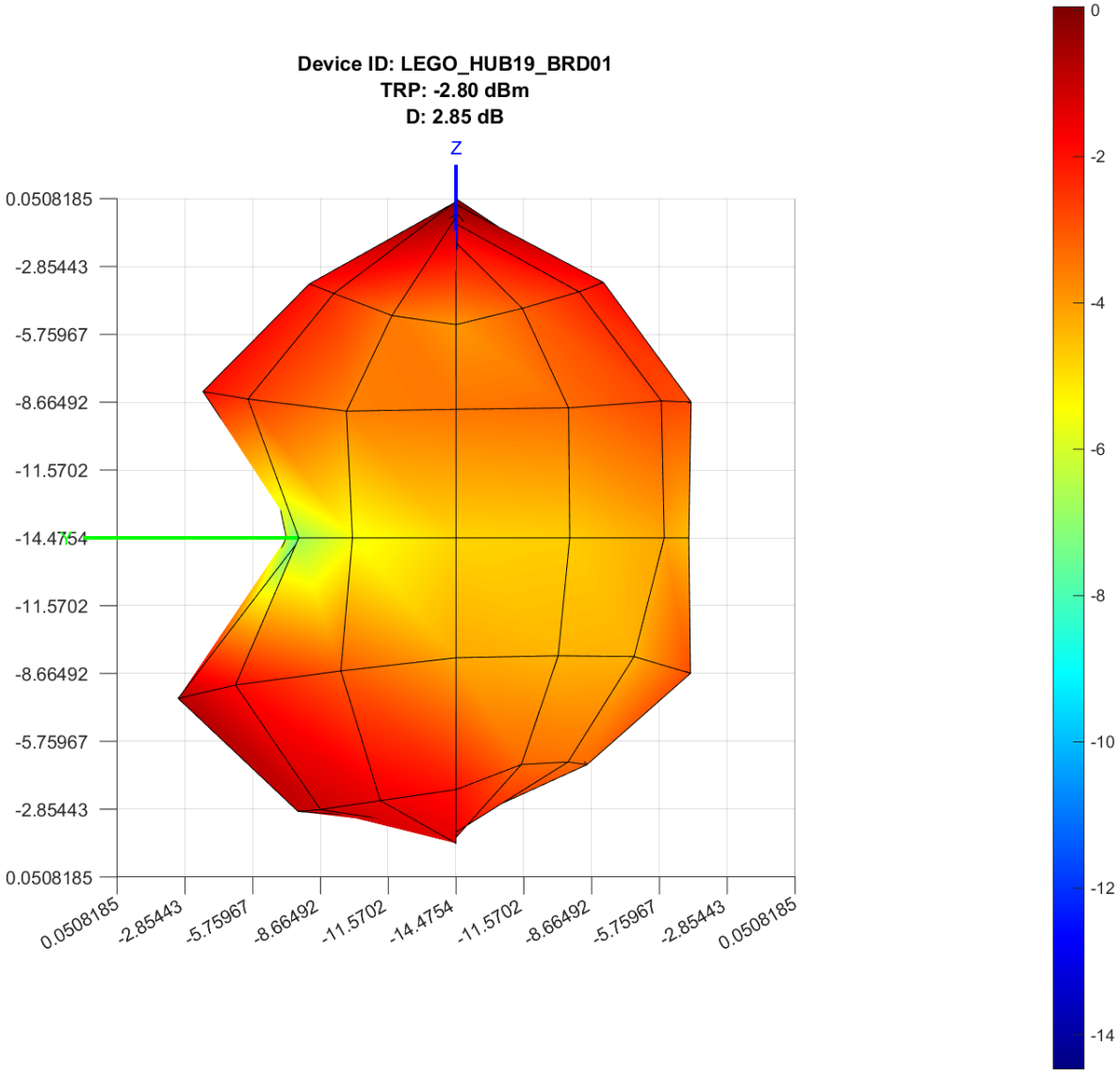
2.4.2 Theta = 180, Phi = 0



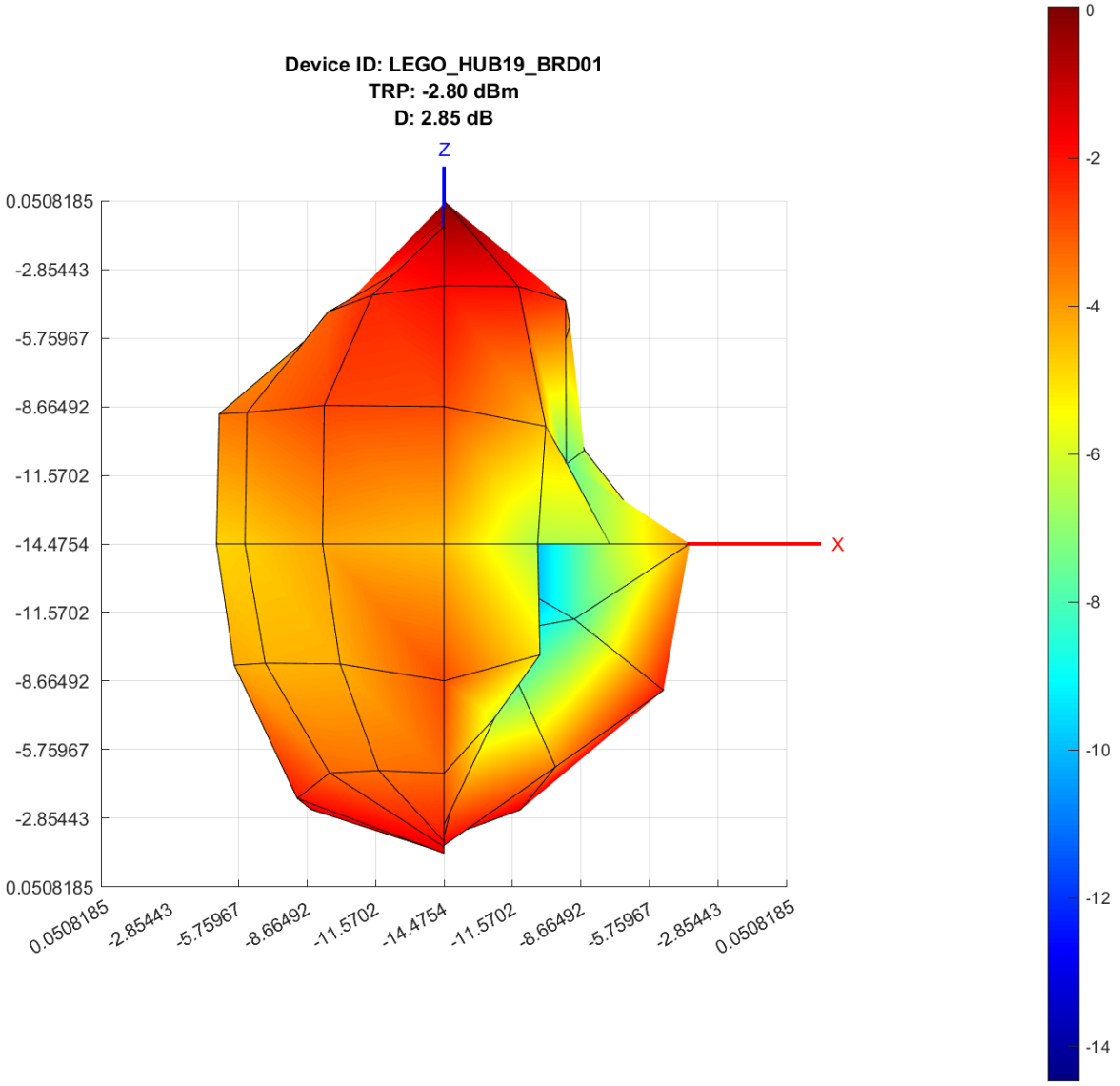
2.4.3 Theta = 90, Phi = 0



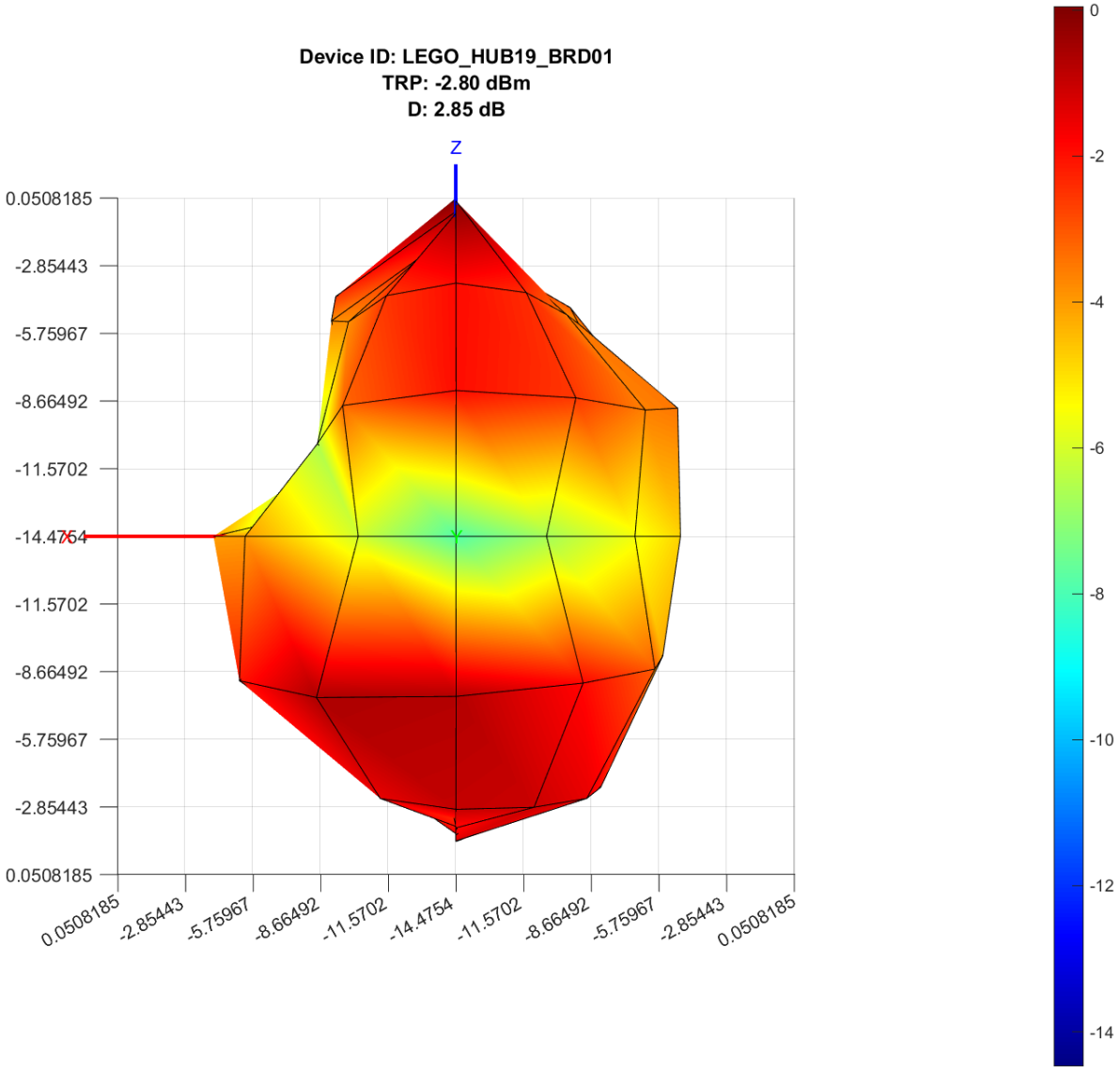
2.4.4 Theta = 90, Phi = 180



2.4.5 Theta = 90, Phi = 270



2.4.6 Theta = 90, Phi = 90



3 Antenna Gain Calculation

3.1 Measured Data

3.1.1 Horizontal Power (dBm)

θ (degrees) \ φ (degrees)	0	30	60	90	120	150	180
0	-1.6400	-4.9600	-15.7300	-5.2100	-14.0300	-13.6600	-3.3000
30	-3.2500	-6.9700	-14.0400	-6.4200	-18.6800	-20.5100	-3.5000
60	-8.1600	-13.8900	-18.0300	-13.2700	-12.5900	-12.1100	-5.1000
90	-18.4900	-19.4300	-11.2500	-10.7600	-7.3800	-6.4400	-6.9900
120	-7.3700	-7.9600	-6.1100	-5.7000	-5.9500	-4.5200	-6.4900
150	-3.0300	-4.6900	-3.9500	-4.8800	-4.5600	-4.1100	-4.1800
180	-1.7400	-4.2800	-3.5300	-4.9300	-4.3700	-2.4700	-2.8500
210	-2.6900	-6.4800	-4.7600	-5.6200	-3.4400	-2.1800	-3.0900
240	-6.7800	-12.1200	-6.0300	-6.9200	-2.7000	-2.5200	-5.8200
270	-20.8300	-13.8900	-7.1900	-10.8800	-2.7800	-3.1800	-11.1900
300	-8.6100	-7.6500	-10.2100	-16.4200	-4.6800	-5.1100	-10.3000
330	-3.2200	-5.2300	-20.3900	-9.3600	-9.0300	-8.1600	-5.7600
360							

3.1.2 Vertical Power (dBm)

		φ (degrees)						
		0	30	60	90	120	150	180
θ (degrees)	0	-14.0400	-10.0700	-12.7700	-10.4200	-9.3800	-12.5900	-8.1900
	30	-3.8500	-4.5400	-8.6700	-26.6500	-16.5500	-15.2000	-9.5400
	60	-0.6600	-2.1700	-4.7200	-7.5700	-5.9300	-7.1500	-6.1500
	90	-0.2700	-1.9200	-3.5200	-5.6700	-4.7700	-6.1000	-3.9600
	120	-2.1700	-3.6900	-5.4300	-9.4600	-9.3100	-9.8000	-3.7100
	150	-8.0300	-8.3200	-12.1900	-19.5100	-18.0800	-10.8100	-5.1900
	180	-19.4100	-15.0700	-21.9900	-21.0600	-18.5100	-12.1700	-6.7500
	210	-5.1800	-6.5100	-10.0100	-27.9600	-14.0400	-9.7600	-6.3000
	240	-1.1000	-2.8800	-5.2000	-19.6400	-9.4700	-6.4400	-4.2500
	270	-0.1200	-2.2000	-3.4900	-10.8100	-4.9600	-4.8900	-2.9000
	300	-1.3600	-4.1400	-4.2100	-6.5000	-2.8000	-3.9400	-2.7200
	330	-5.2900	-9.4400	-6.7200	-5.5200	-3.0500	-5.4200	-3.8800
	360							

3.1.3 Total Power (dBm)

$$P_{dBm} = 10\log(10^{P_{hor}/10} + 10^{P_{ver}/10})$$

θ (degrees) \ φ (degrees)	0	30	60	90	120	150	180
0	-1.3970	-3.7929	-10.9923	-4.0662	-8.1000	-10.0818	-2.0800
30	-0.5293	-2.5769	-7.5627	-6.3790	-14.4754	-14.0792	-2.5348
60	0.0508	-1.8871	-4.5219	-6.5349	-5.0815	-5.9470	-2.5830
90	-0.2051	-1.8436	-2.8431	-4.4981	-2.8715	-3.2564	-2.2056
120	-1.0239	-2.3098	-2.7464	-4.1749	-4.3026	-3.3923	-1.8710
150	-1.8367	-3.1260	-3.3431	-4.7330	-4.3711	-3.2685	-1.6454
180	-1.6664	-3.9322	-3.4685	-4.8254	-4.2057	-2.0279	-1.3659
210	-0.7486	-3.4847	-3.6255	-5.5947	-3.0773	-1.4812	-1.3946
240	-0.0606	-2.3912	-2.5849	-6.6938	-1.8708	-1.0417	-1.9541
270	-0.0833	-1.9152	-1.9470	-7.8346	-0.7243	-0.9411	-2.2996
300	-0.6105	-2.5393	-3.2368	-6.0787	-0.6288	-1.4754	-2.0212
330	-1.1225	-3.8334	-6.5373	-4.0184	-2.0727	-3.5671	-1.7088
360							

3.1.4 Total Power (mW)

$$P_{mW} = 10^{P_{dBm}/10}$$

θ (degrees) \ φ (degrees)	0	30	60	90	120	150	180
0	0.7249	0.4176	0.0796	0.3921	0.1549	0.0981	0.6194
30	0.8852	0.5525	0.1753	0.2302	0.0357	0.0391	0.5579
60	1.0118	0.6476	0.3530	0.2221	0.3104	0.2543	0.5517
90	0.9539	0.6541	0.5196	0.3550	0.5162	0.4725	0.6018
120	0.7900	0.5875	0.5313	0.3824	0.3713	0.4579	0.6500
150	0.6551	0.4869	0.4631	0.3363	0.3655	0.4711	0.6846
180	0.6813	0.4044	0.4499	0.3292	0.3797	0.6269	0.7301
210	0.8417	0.4483	0.4340	0.2758	0.4923	0.7110	0.7253
240	0.9861	0.5766	0.5515	0.2141	0.6500	0.7867	0.6377
270	0.9810	0.6434	0.6387	0.1646	0.8464	0.8052	0.5889
300	0.8689	0.5573	0.4746	0.2467	0.8652	0.7120	0.6279
330	0.7722	0.4137	0.2220	0.3964	0.6205	0.4398	0.6747
360							

3.2 Calculation of Antenna Parameters

3.2.1 TRP (dBm)

Calculation of the Total Radiated Power (TRP) was made according to: Test Plan for Wireless Device Over-the-Air Performance, CTIA 01.90, Version 4.0.0:

$$TRP_{mW} \cong \frac{1}{NM}\sum_{i=0}^{N-1}\sum_{j=0}^{M-1} EIRP(i,j)$$

Where N and M define the number of angular intervals in theta, θ and phi, φ, respectively:

$$N = 12$$

$$M = 7$$

The final result is then converted to dBm:

$$TRP_{dBm} = 10\log_{10}(TRP_{mW})$$

3.2.2 Peak EIRP (dBm)

The peak EIRP, $EIRP_{PEAK}$ is the largest value calculated in Section 3.1.3.

3.2.3 Directivity (dBm)

$$D = EIRP_{PEAK} - TRP_{dBm}$$

3.2.4 Efficiency (dB)

The antenna efficiency, Eff_{dB} is calculated using:

$$Eff_{dB} = TRP_{dBm} - P_{cond}$$

Where P_{cond} is the measured conducted output power in dBm:

$$P_{cond} = 0\ dBm$$

3.2.5 Gain (dBi)

The antenna gain, G is calculated using:

$$G = D + Eff_{dB}$$