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LEGO Hub No. 16 EMC test report

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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, Hoffsvein 70C, 0377 Oslo
Completed Test Date(s)	18th September 2023
Test Personnel	Zack Costello

1.2 Test Setup Photos

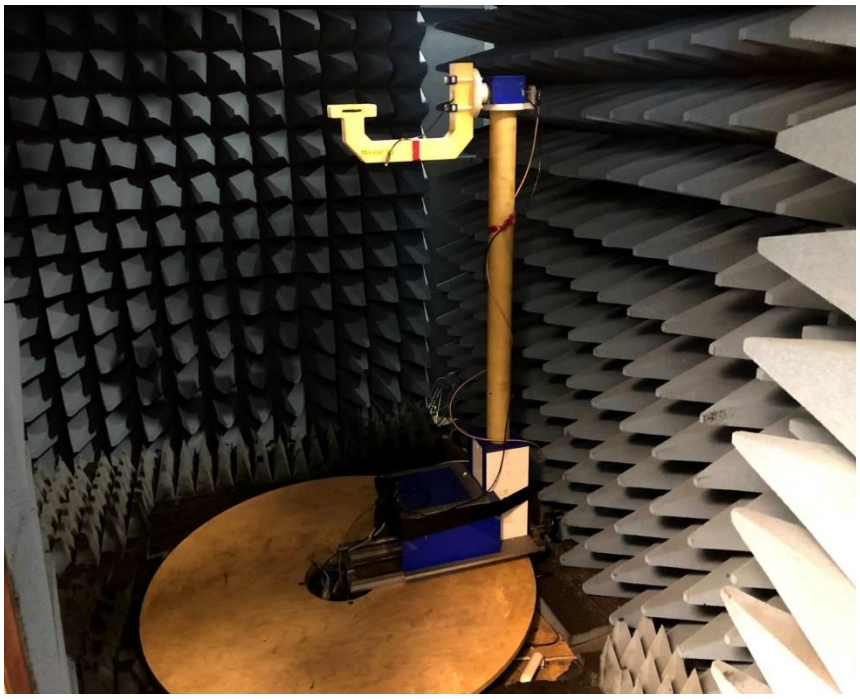


Figure 1: Turn arm in chamber

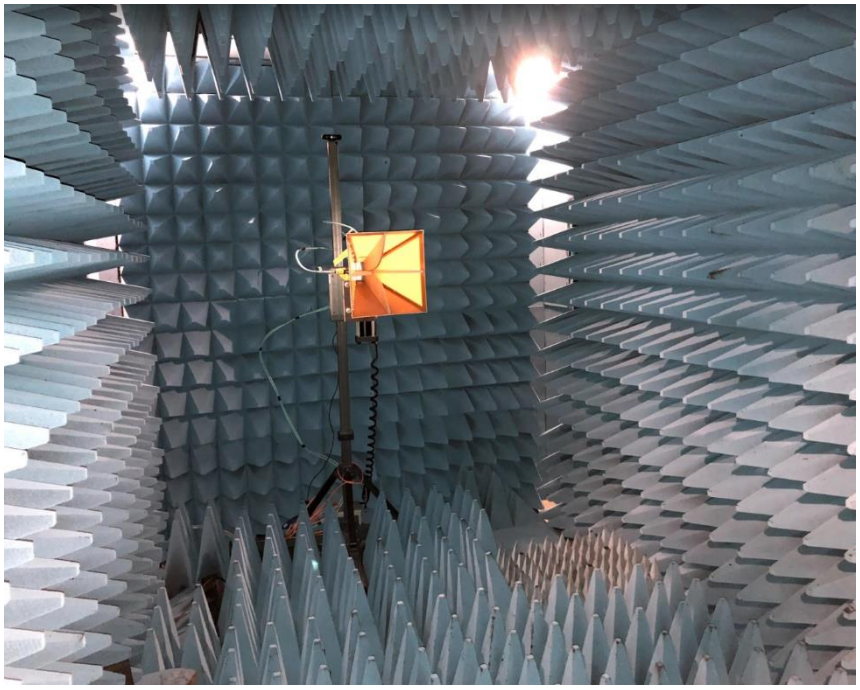


Figure 2: Receiving antenna in chamber

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

Figure 4: Placement of AUT on turn arm in chamber (additional view)

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	-5.10 dBm
Peak EIRP	0.20 dBm
Antenna directivity	5.30 dBm
Antenna efficiency	-3.70 dB
Antenna gain	**1.60 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

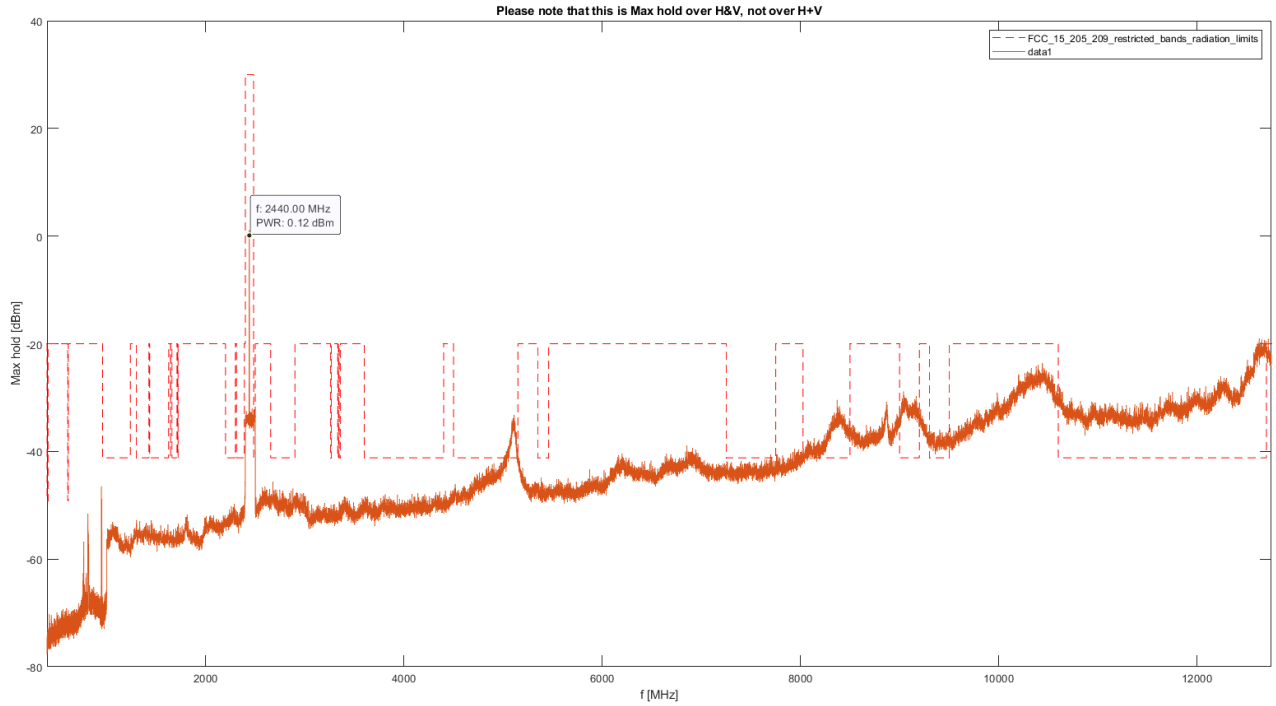


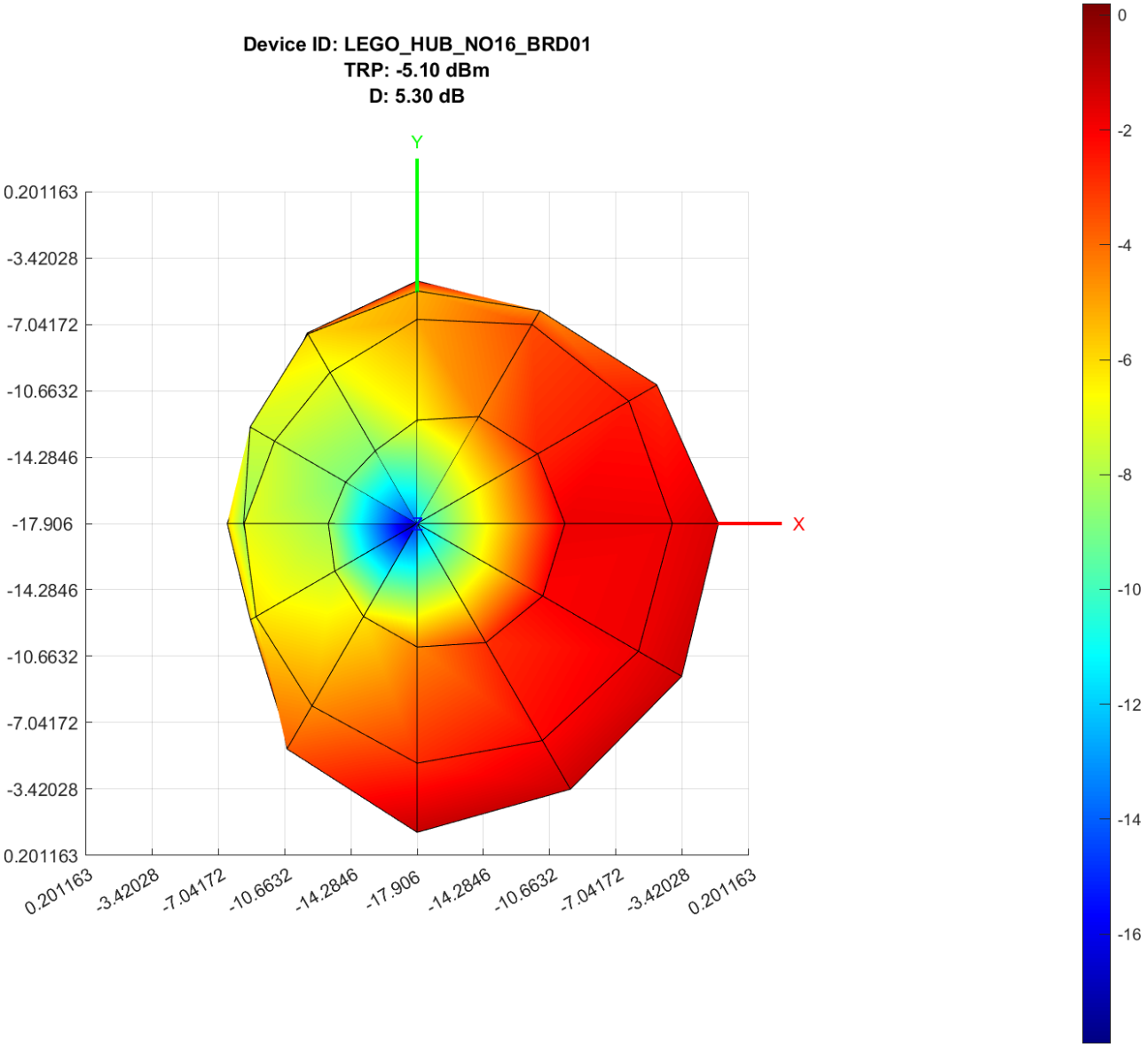
Figure 5: Spectrum sweep from 0.4 GHz to 12.75 GHz

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.

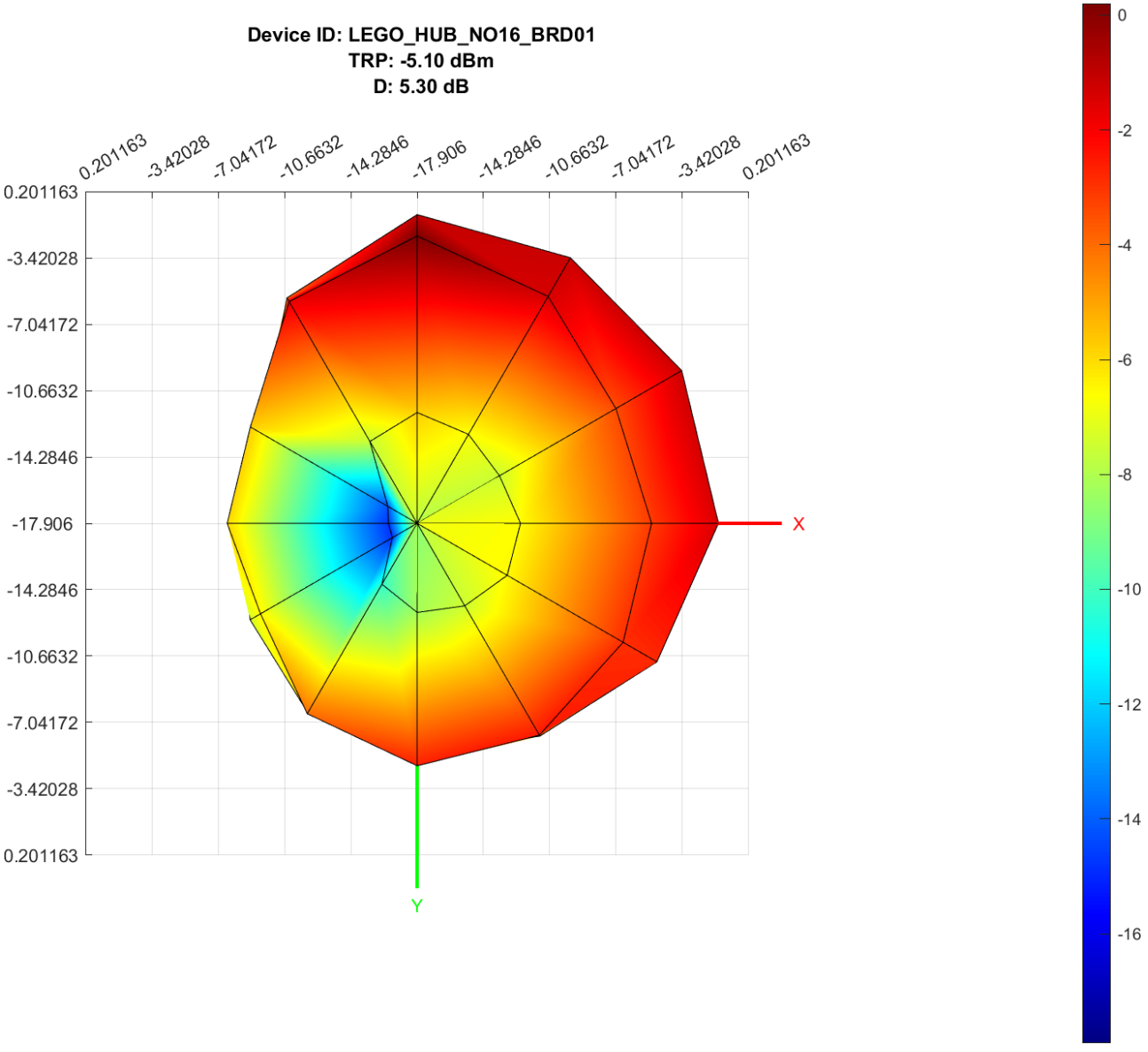
The noise floor of the EMC chamber at the 3rd harmonic of 2.44 GHz (7.32 GHz) is below the FCC 15.205.209 spectral mask limit of -41.2 dBm, meaning that spurious emissions that violate the -41.2 dBm limit will be visible.

2.4 Radiation Pattern

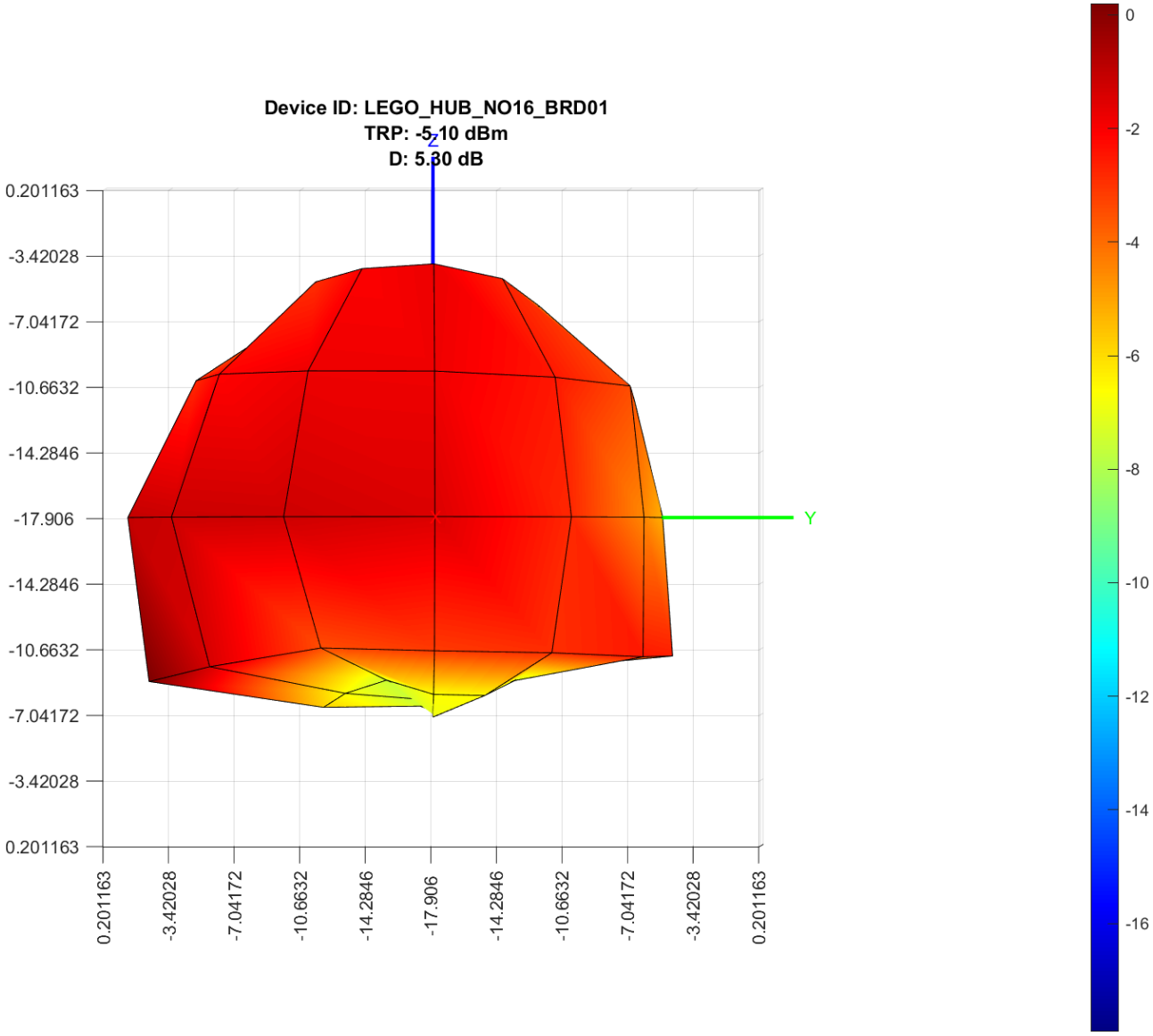
2.4.1 Theta = 0, Phi = 0



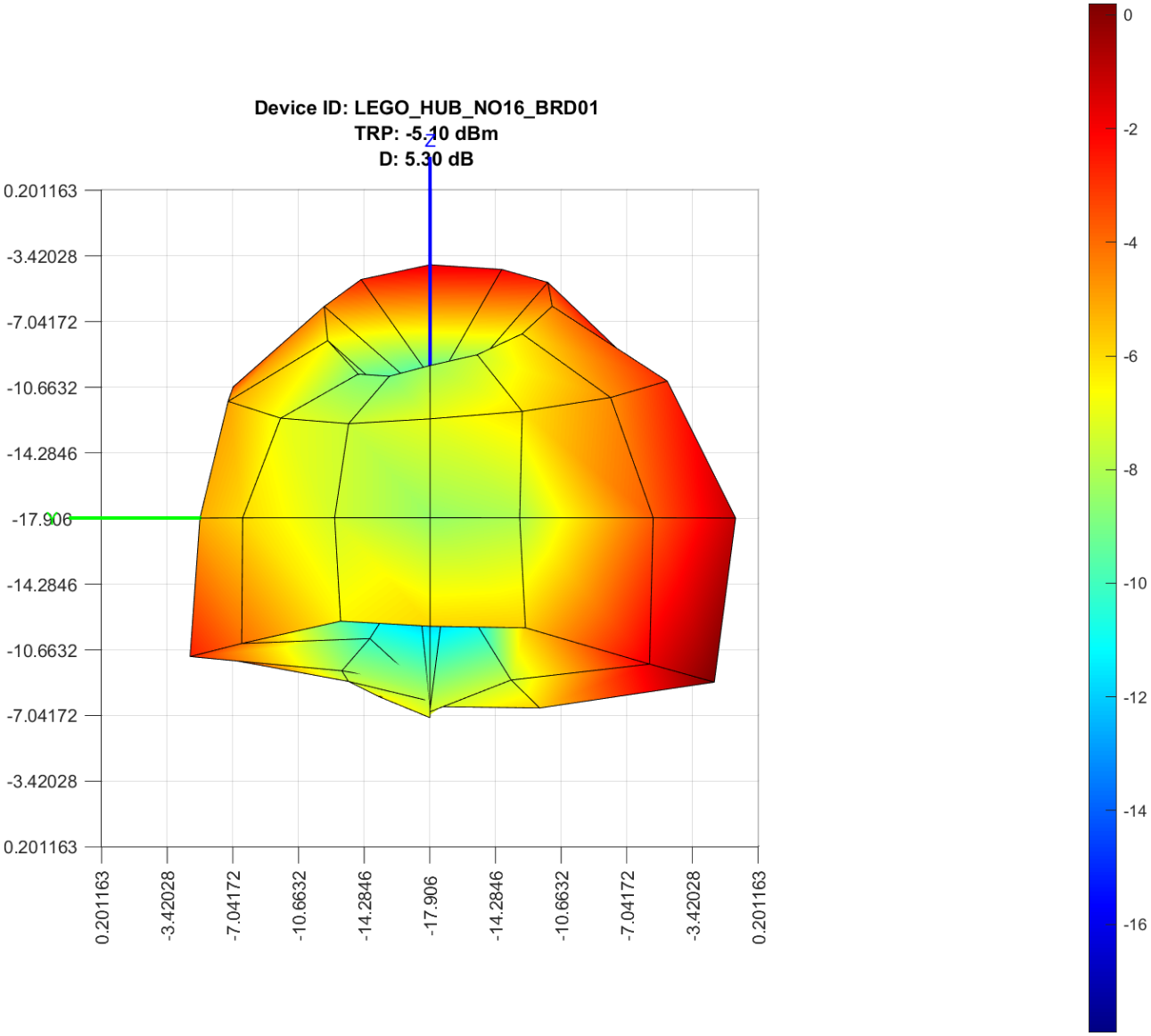
2.4.2 Theta = 180, Phi = 0



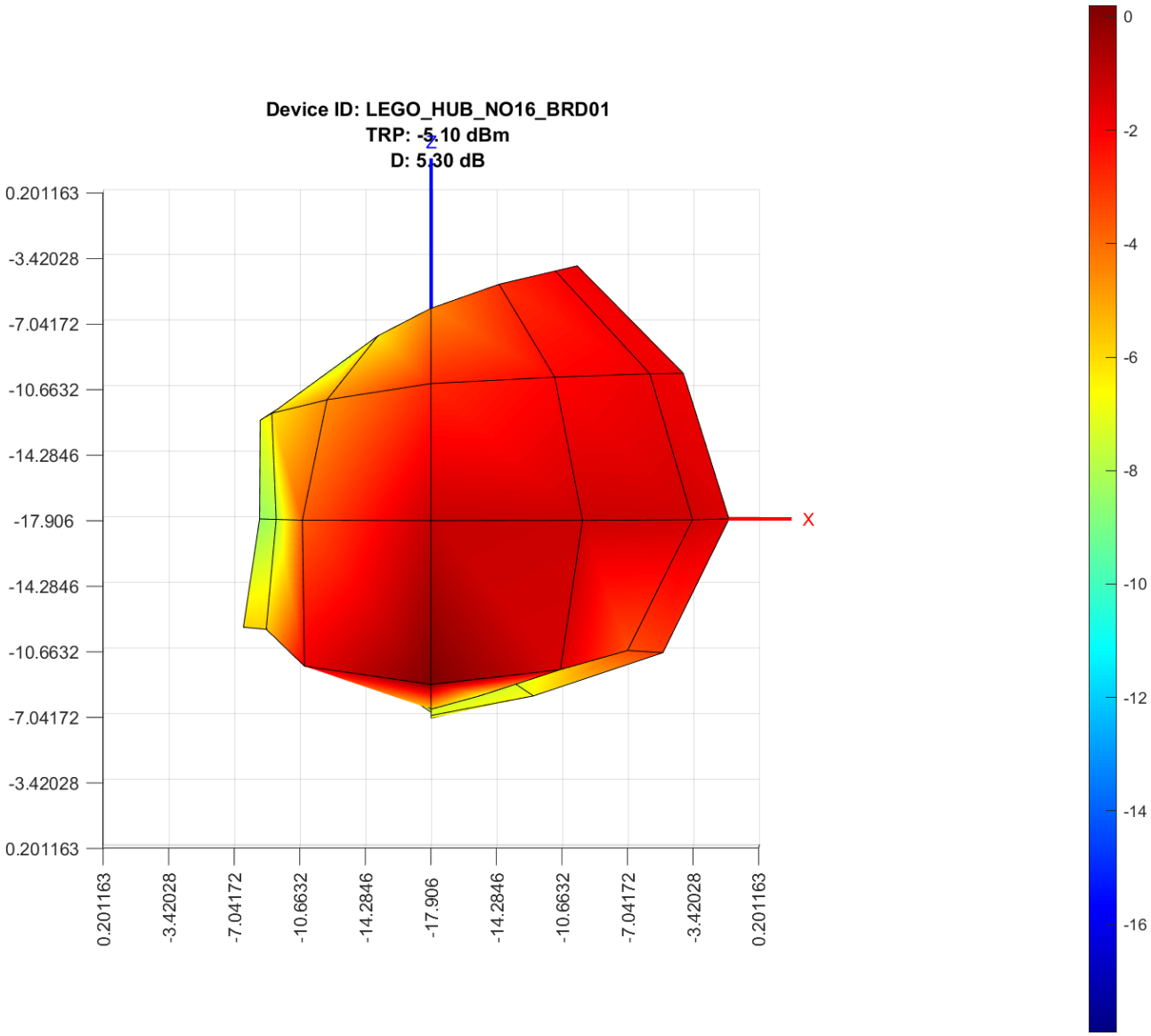
2.4.3 Theta = 90, Phi = 0



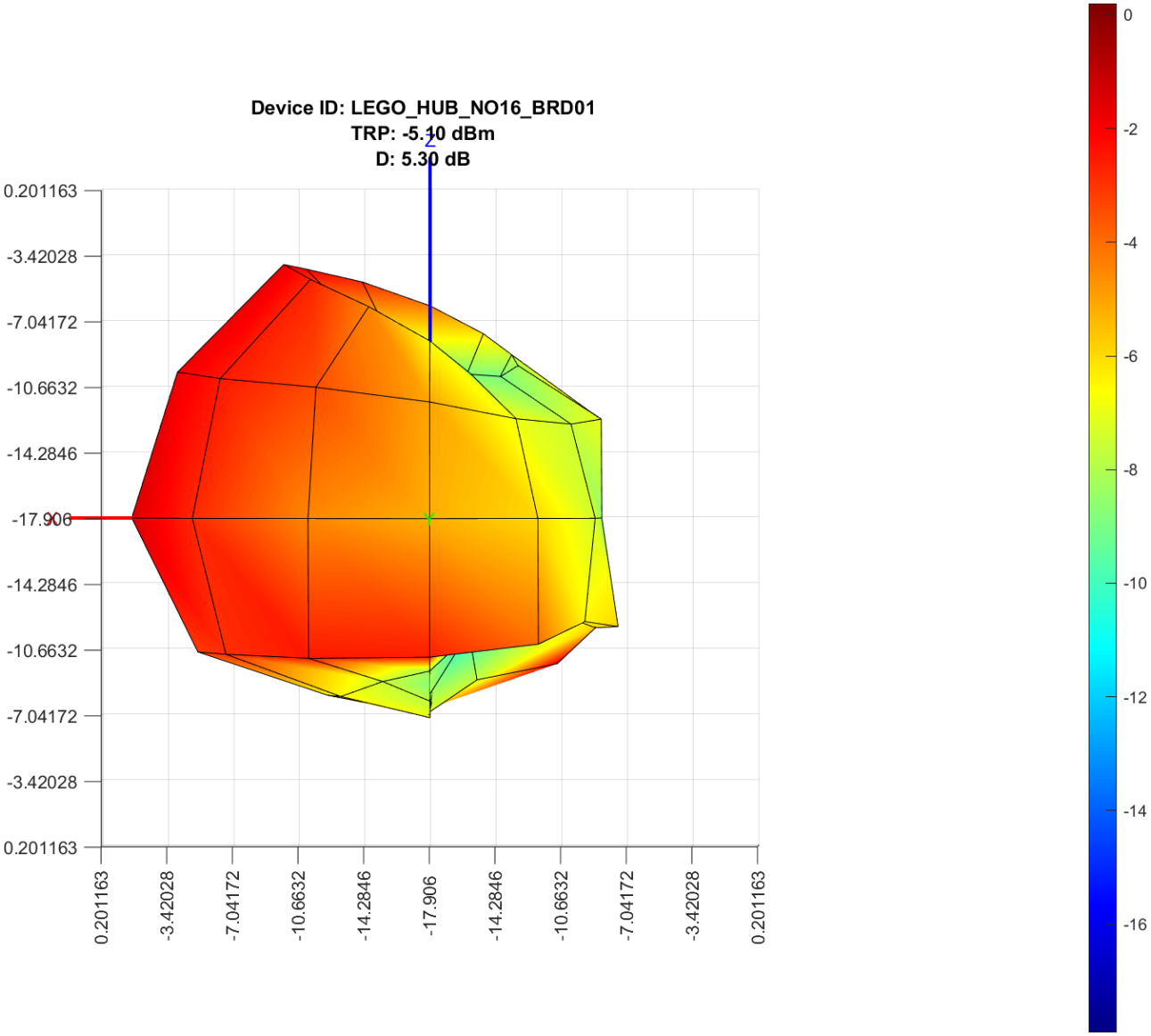
2.4.4 Theta = 90, Phi = 180



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	-10.7723	-1.91574	-2.00489	-1.80138	-3.3199	-6.72382	-7.97389
30	-11.3438	-2.25299	-2.09903	-1.53388	-3.47188	-7.78048	-8.01004
60	-14.366	-3.28023	-2.26829	-1.22741	-1.44963	-7.14822	-10.4577
90	-19.2334	-4.9855	-2.90532	-1.15972	0.120014	-6.4726	-17.6946
120	-26.219	-7.00508	-5.53434	-4.1965	-2.06055	-8.62042	-20.2658
150	-24.2751	-7.8496	-6.93333	-8.52438	-5.93989	-15.2734	-11.3048
180	-19.8182	-8.35924	-7.46695	-8.60511	-5.9568	-19.6376	-8.09113
210	-17.4777	-9.39325	-7.97006	-7.90795	-7.56407	-19.9306	-7.65511
240	-17.5035	-9.26457	-7.06505	-7.13794	-5.42788	-19.1752	-9.71921
270	-22.6353	-8.29662	-5.80906	-6.46289	-3.90996	-15.2363	-15.9762
300	-19.685	-6.34997	-4.18547	-5.11619	-3.39492	-11.2357	-23.2712
330	-12.6087	-3.86833	-2.88437	-3.06555	-3.3261	-8.40282	-12.4924
360	-10.7723	-1.91574	-2.00489	-1.80138	-3.3199	-6.72382	-7.97389

3.1.2 Vertical Power (dBm)

		φ (degrees)						
		0	30	60	90	120	150	180
θ (degrees)	0	-22.3533	-16.3727	-15.5871	-12.5436	-16.6087	-22.5985	-14.2049
	30	-23.7008	-15.7793	-13.428	-12.8135	-24.0702	-19.9214	-23.1777
	60	-16.7448	-13.6029	-16.7835	-19.5743	-20.2611	-16.6665	-11.2348
	90	-14.3888	-13.5861	-19.0203	-17.1595	-17.1243	-14.2794	-7.94132
	120	-15.3076	-13.8358	-11.9132	-13.3231	-13.5975	-14.3203	-7.44245
	150	-18.4676	-18.882	-14.1331	-17.6713	-19.7595	-20.8024	-9.56901
	180	-22.3897	-22.7304	-16.9161	-22.4562	-27.8073	-16.4884	-15.6912
	210	-23.5083	-18.4808	-17.6219	-16.7339	-13.1379	-16.3725	-23.9815
	240	-17.8311	-18.2477	-21.5494	-12.2279	-9.6997	-10.8177	-13.529
	270	-13.6592	-11.5397	-12.9724	-11.238	-8.5268	-9.12589	-9.57334
	300	-12.0322	-8.89669	-11.3849	-13.2539	-9.75553	-9.89626	-7.92834
	330	-13.7207	-9.00057	-13.1375	-14.8494	-13.2783	-11.135	-8.28912
	360	-22.3533	-16.3727	-15.5871	-12.5436	-16.6087	-22.5985	-14.2049

3.1.3 Total Power (dBm)

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

		φ (degrees)						
		0	30	60	90	120	150	180
θ (degrees)	0	-10.4805	-1.76283	-1.81859	-1.44993	-3.12087	-6.61297	-7.04606
	30	-11.0985	-2.06433	-1.79045	-1.22189	-3.4342	-7.52299	-7.87987
	60	-12.3842	-2.89467	-2.11739	-1.16432	-1.39291	-6.68822	-7.81857
	90	-13.1577	-4.42401	-2.80036	-1.05197	0.201163	-5.80674	-7.50437
	120	-14.9691	-6.18636	-4.63457	-3.69551	-1.76592	-7.58526	-7.22147
	150	-17.455	-7.52002	-6.17583	-8.0256	-5.7633	-14.2014	-7.34044
	180	-17.906	-8.20334	-6.99995	-8.42977	-5.92853	-14.7733	-7.39528
	210	-16.5106	-8.88799	-7.5233	-7.37317	-6.50187	-14.7866	-7.55508
	240	-14.6539	-8.74771	-6.91309	-5.96606	-4.04815	-10.226	-8.20878
	270	-13.1415	-6.61193	-5.04571	-5.21448	-2.62146	-8.17461	-8.67805
	300	-11.3441	-4.42897	-3.42792	-4.49586	-2.49173	-7.50423	-7.80325
	330	-10.1189	-2.70643	-2.49286	-2.78669	-2.9078	-6.54721	-6.89063
	360	-10.4805	-1.76283	-1.81859	-1.44993	-3.12087	-6.61297	-7.04606

3.1.4 Total Power (mW)

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

		φ (degrees)						
		0	30	60	90	120	150	180
θ (degrees)	0	0.089525	0.666372	0.657872	0.716155	0.487431	0.218124	0.197421
	30	0.077652	0.62168	0.662148	0.754763	0.453503	0.176889	0.162934
	60	0.057753	0.513492	0.614131	0.764836	0.72562	0.214377	0.165251
	90	0.048332	0.361076	0.524764	0.784879	1.047409	0.262619	0.177649
	120	0.031849	0.240638	0.343988	0.427021	0.665898	0.174371	0.189606
	150	0.017968	0.17701	0.241222	0.157558	0.265259	0.038007	0.184483
	180	0.016196	0.15124	0.199528	0.143556	0.255357	0.033317	0.182168
	210	0.022333	0.129182	0.176876	0.183098	0.223776	0.033215	0.175587
	240	0.034246	0.133422	0.203559	0.253159	0.393717	0.094929	0.15105
	270	0.048512	0.218176	0.312917	0.30099	0.546832	0.152243	0.13558
	300	0.073381	0.360664	0.454159	0.355152	0.563413	0.177655	0.165835
	330	0.0973	0.536238	0.563267	0.526418	0.511941	0.221452	0.204615
	360	0.089525	0.666372	0.657872	0.716155	0.487431	0.218124	0.197421

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:

$$N = 13$$

$$M = 7$$

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:

$$P_{cond} = -1.4\ dBm$$

3.2.5 Gain (dBi)

The antenna gain, G is calculated using:

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