InterLab®

Antenna Characterization Test Report

Test Report Reference: MUS_HARMAN_192211#FCAINT

Date: 2025-02-12

Test Laboratory:
Bureau Veritas CPS Inc.
1293 Anvilwood Ave
Sunnyvale, CA 94089
USA

A2LA ACCREDITED
Cert# 3699.01
Cert# 3699.02

ctia Authorized™ Test Lab
Lab Code: 20011202-00
20131001-00

RELEASE CONTROL RECORD

REPORT NO.	REASON FOR CHANGE	DATE ISSUED
MUS_HARMAN_192211	Initial release	10.28.2019
MUS_HARMAN_192211_REV1	Updated missing antenna description in section 2.1	05/16/2022
MUS_HARMAN_192211_REV2	Updated Model Number and Antenna Manufacturer in section 2.1	02/12/2025

1 Administrative Data

1.1 Project Data

Responsible for testing and report:	Alberto Saldivar
Receipt of OUT:	2019-10-15
Date of first test:	2019-10-17
Date of last test:	2019-10-18
Date of Report:	2025-02-12

1.2 Applicant Data

Company Name:	Harman International Industries, Inc.
Address:	30001 Cabot Drive Novi, MI 48377 USA
Contact Person:	Mark Bowman Phone: +1 (248) 633 5481 email: mark.bowman@harman.com

1.3 Testing Laboratory

Company Name:	Bureau Veritas CPS Inc.
Street:	1293 Anvilwood Ave
City:	Sunnyvale, CA 94089
Country:	USA
Contact Person:	Jenil Nathwani
Phone:	+1-949-716-6512
Email:	Jenil.nathwani@us.bureauveritas.com

Laboratory Details

Identification:	OTA 3 Chamber
Responsible:	Felix Huang

*Details of the laboratory equipment available upon request.

1.4 Signature of responsible for testing

Jenil Nathwani

1.5 Signature of responsible for accreditation scope

Eddie Parsons

2 Object Under Test Data

2.1 General SocketGate Description

Manufacturer	Harman
Model	FCA R1 INT
Serial Number/IMEI	P68306857AA
Hardware Version	N/A
Software Version	N/A

Antenna Manufacturer	Antenna Type	Connector	Brand	Model Number
Harman	PCB Trace	PCB Trace	Integral	4010 MAIN, 9090 FRONT

2.2 Test Equipment List

Type of Equipment	Model Number	Serial Number	Calibration Due Date
Vector Network Anaylzer	Keysight E5071C	MY46525119	05/06/2020

2.3 Description of Testing

7layers has been tasked to perform passive antenna characterization for Harman antennas to evaluate the performance (efficiency, Return Loss, Peak Gain, 2D-3D Radiation Patterns).

3 Introduction

This package is for customers who want to identify the most suitable off-the-self antenna for their device in terms of performance. This testing should provide key metrics to indicate if the selected antenna would meet the required performance when paired with the device. The test will be performed in an accredited OTA chamber, producing reliable results to be analysed by our Sr. RF Engineer. This package is also included in the *"Product Review Package"* and does not include antenna matching services.

The services performed will include:

- Testing each antenna in an accredited test environment, providing the characteristics of the antenna.

Deliverables:

- Report detailing the results of each antenna includes radiation pattern, efficiency, return loss and peak gain of each antenna.

Requirements:

- Sample prototype to be tested (if applicable)
- sample of each antenna to be tested

4 Objectives and Summary of Tests to be Performed

- Measure the Return Loss and VSWR of the antennas.
- Measure the efficiency, radiation patterns and peak gain of the antenna.

5 Passive testing

5.1 Test set up

Figure 1 shows the Return Loss test set up with the VNA, the antenna is connected to the VNA using a low loss coaxial cable, the reference plane of the VNA was move it until the end of the low loss coaxial cable in order to measure accurately the Return Loss the antenna.

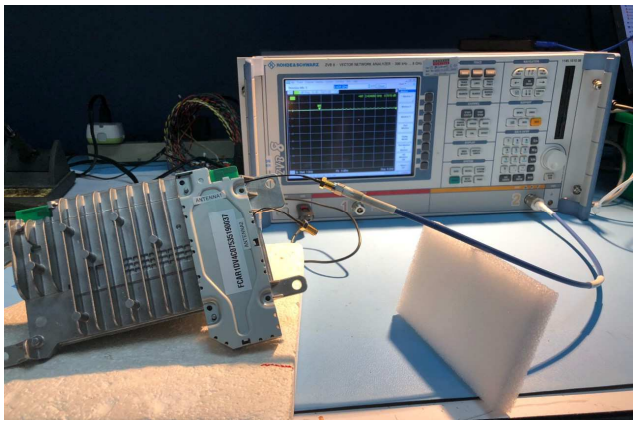


Figure 1. *Return Loss and VSWR test set up*

Figure 2 shows the OTA test set up for Efficiency and Peak Gain testing, an RF signal is injected to the antenna, and most of this RF signal is radiated by the antenna and measured.

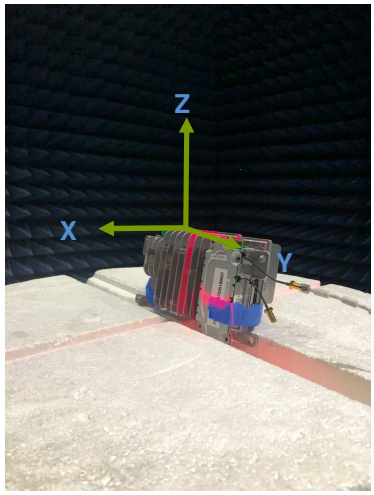


Figure 2. *OTA test set up.*

5.2 Antenna Return Loss

The following figure shows the antenna Return Loss.

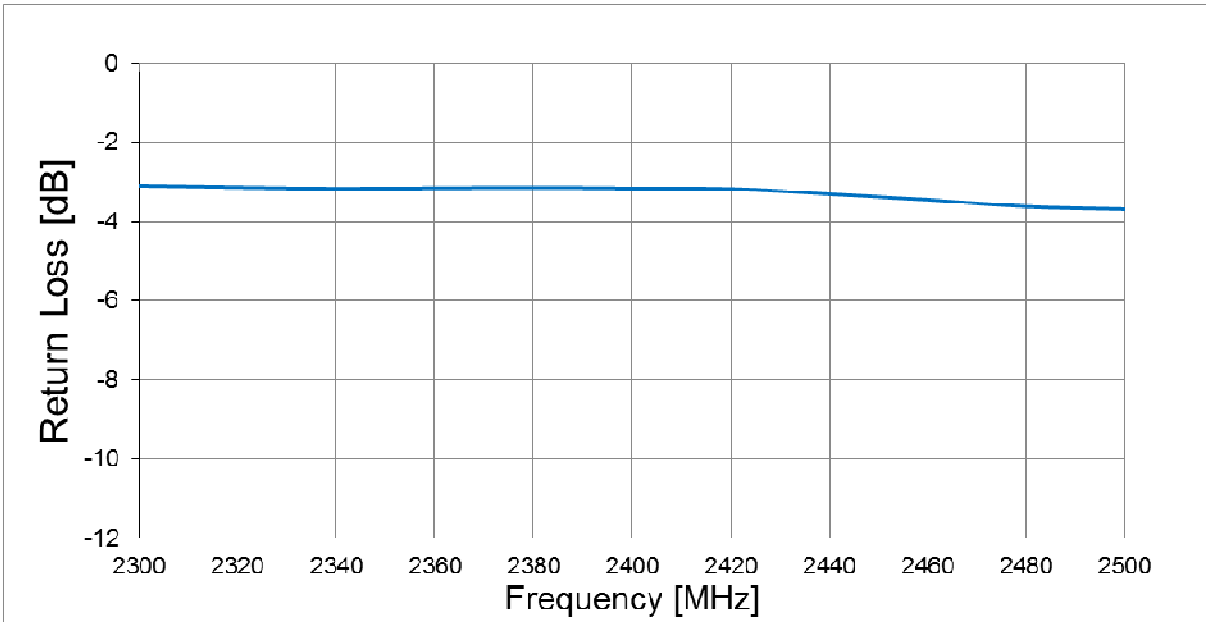


Figure 3. *Antenna Return Loss at 2.4GHz Port1.*

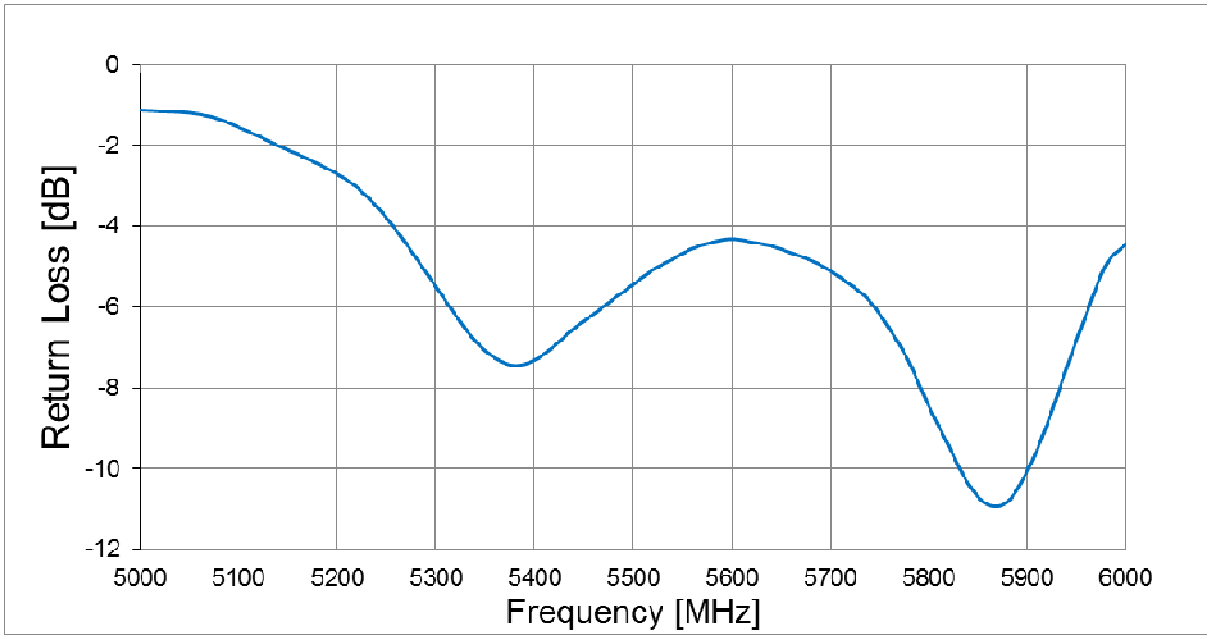


Figure 4. *Antenna Return Loss at 5.0GHz Port1.*

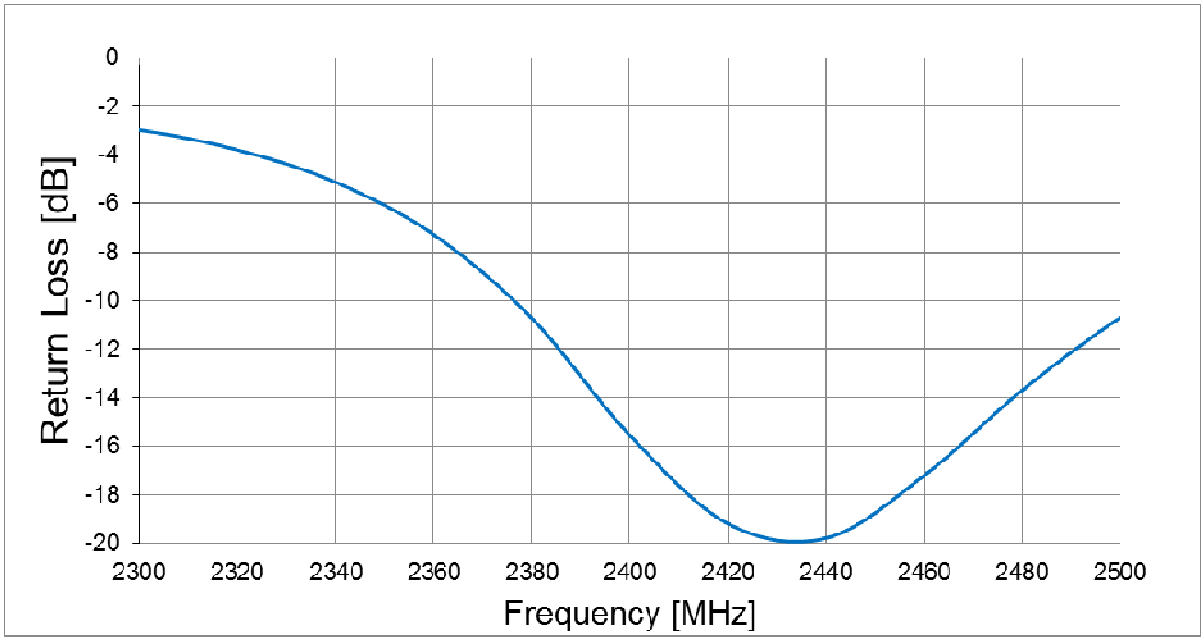


Figure 5. *Antenna Return Loss at 2.4GHz Port2.*

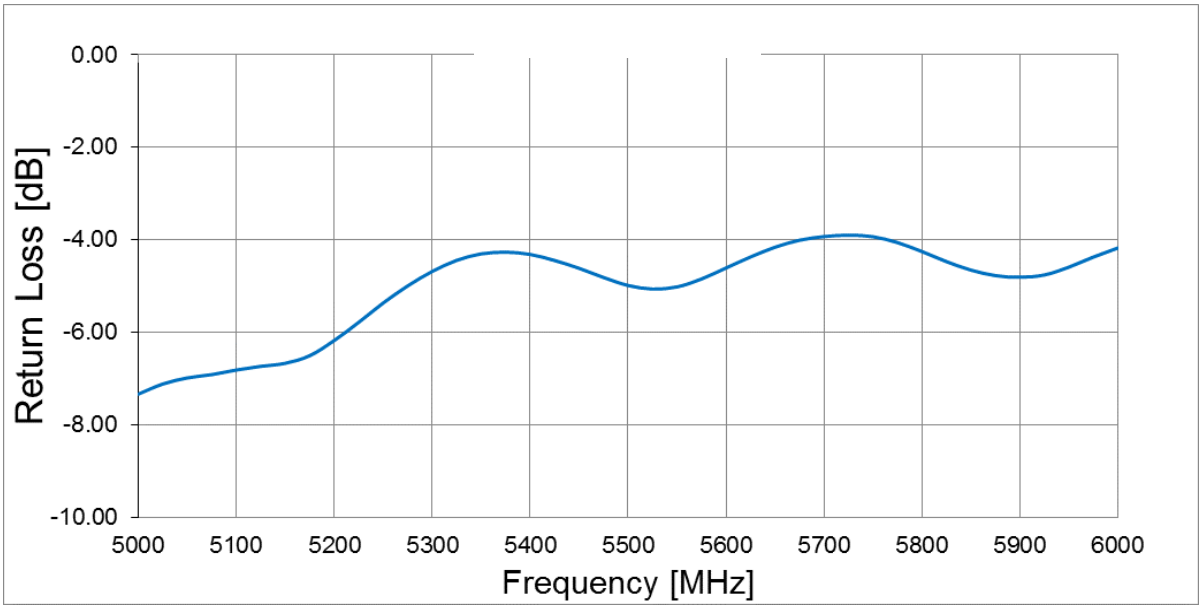


Figure 6. *Antenna Return Loss at 5.0GHz Port2.*

5.3 Antenna VSWR

The following figure shows the Antenna VSWR.

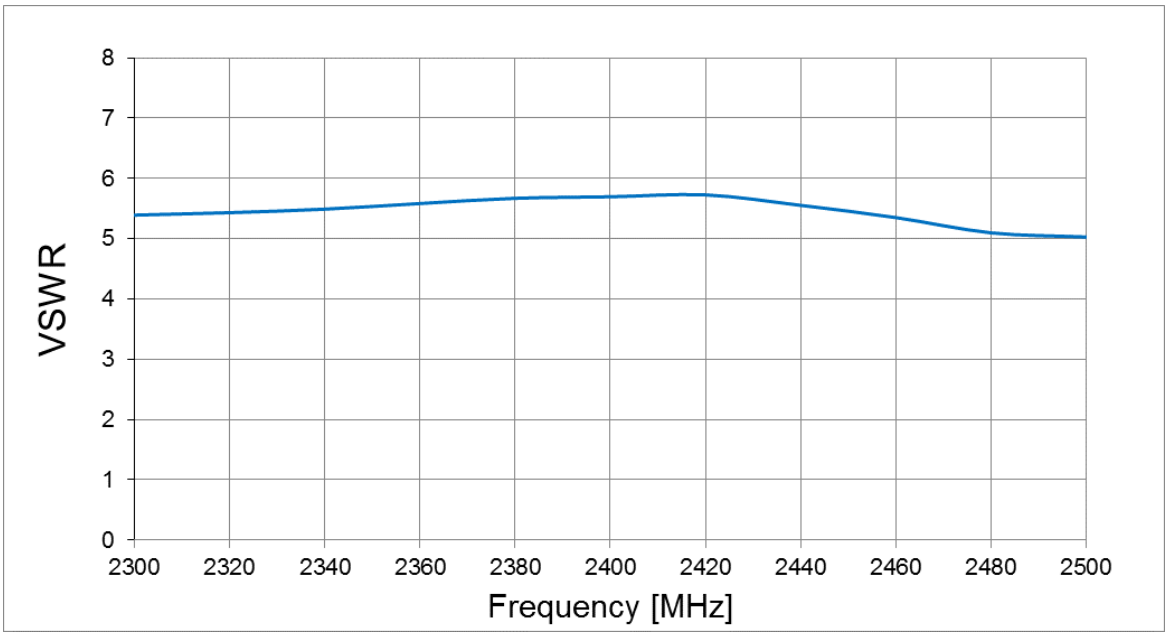


Figure 7. *Antenna VSWR at 2.4GHz PORT1.*

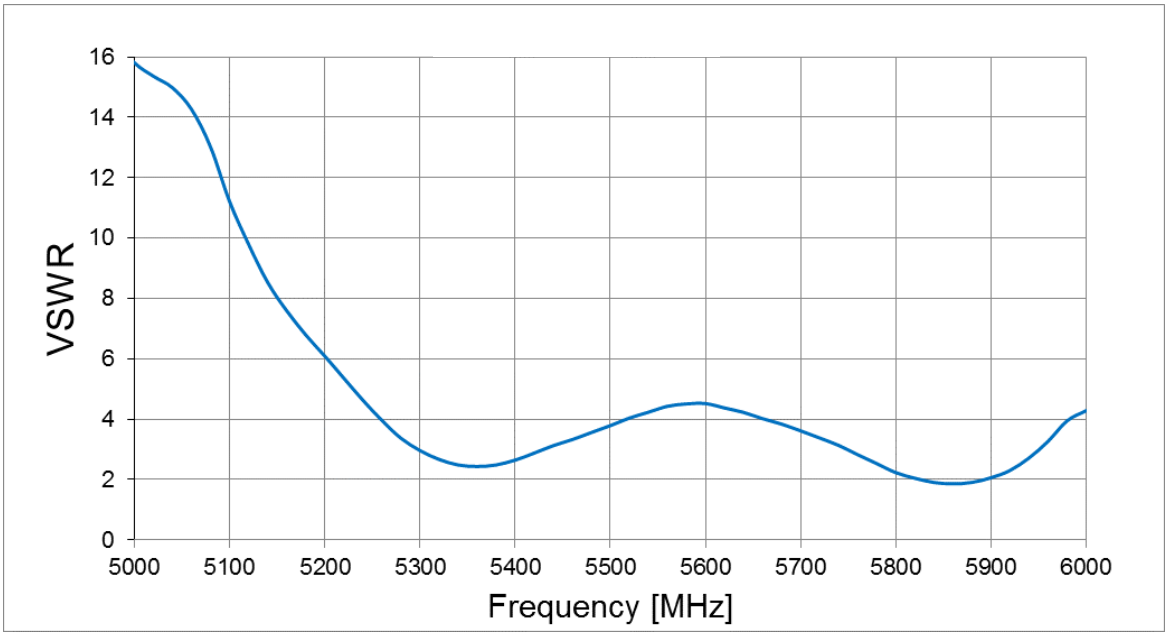


Figure 8. *Antenna VSWR at 5.0GHz PORT1.*

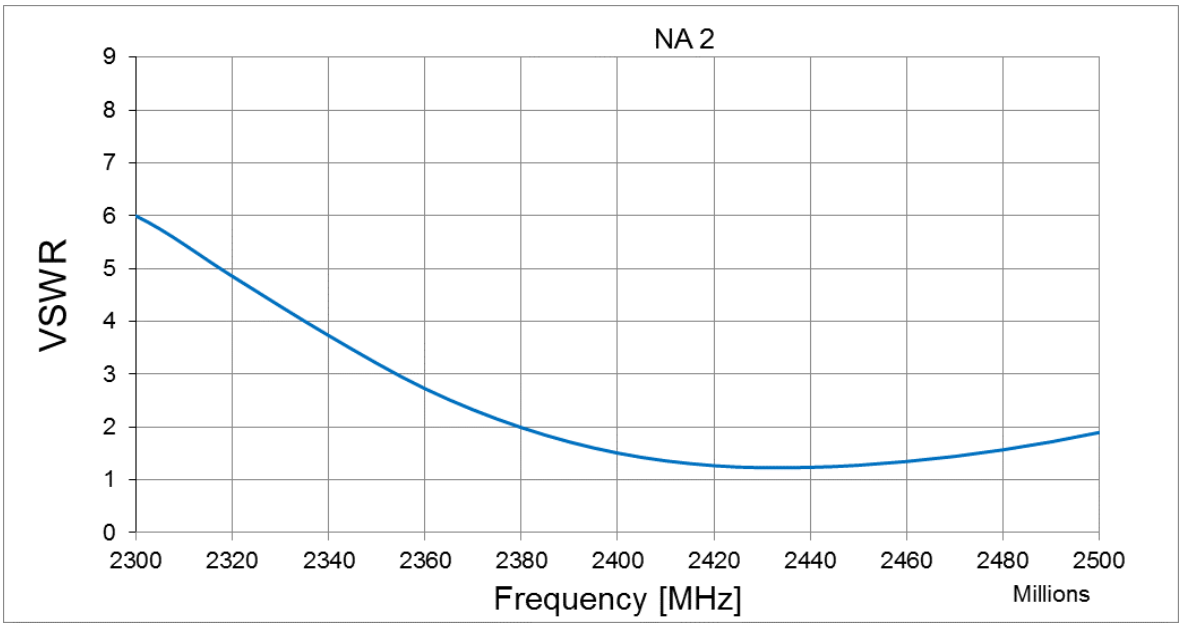


Figure 9. *Antenna VSWR at 2.4GHz Port2.*

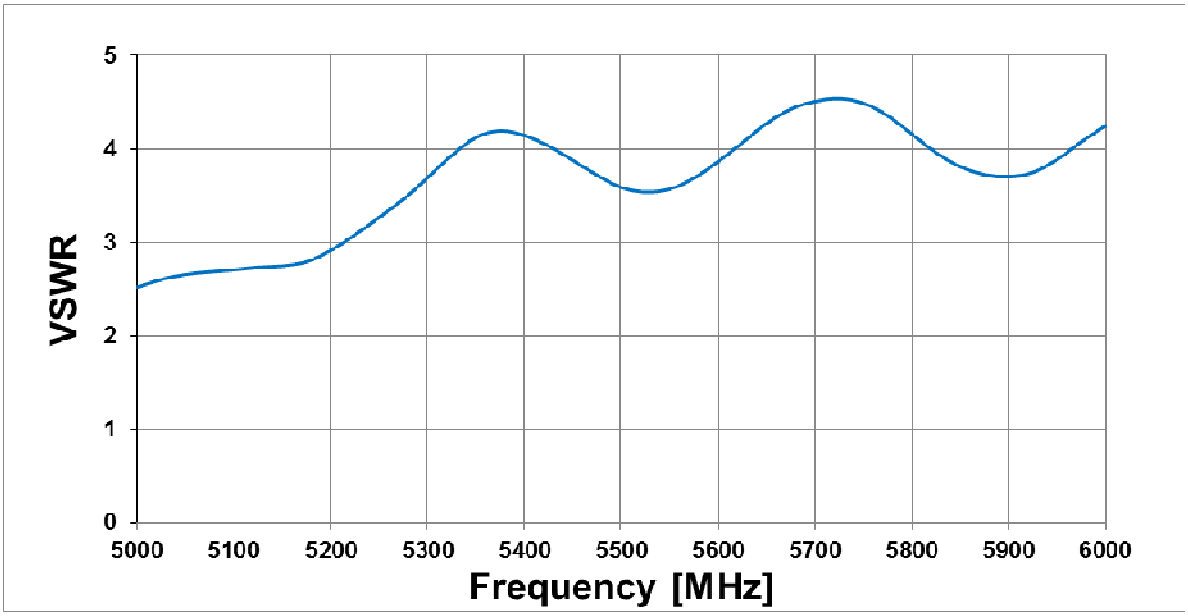


Figure 10. *Antenna VSWR at 5.0GHz Port2.*

5.4 Antenna Efficiency

The following figure shows the efficiency of the device.

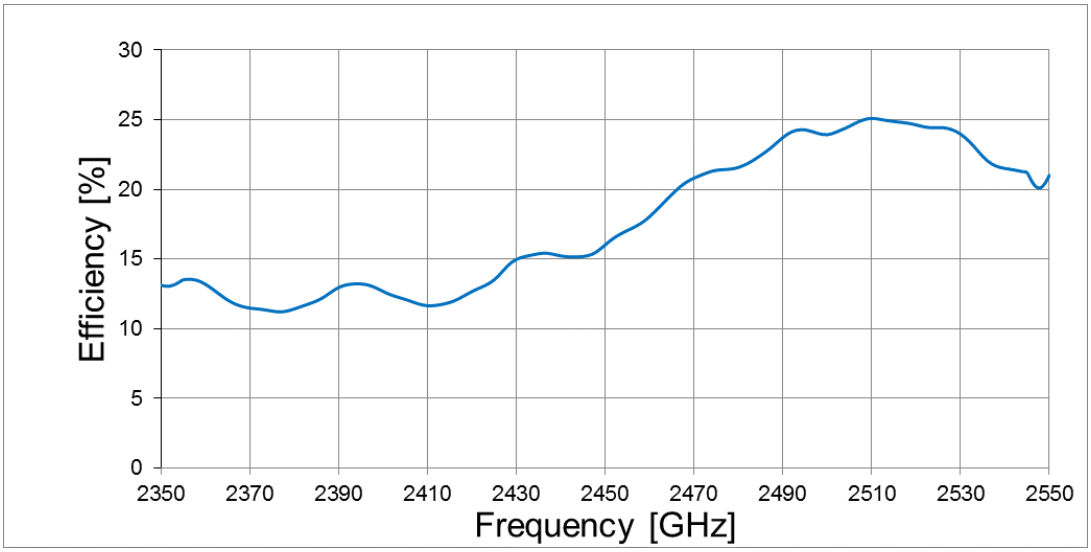


Figure 11. *Antenna Efficiency at 2.4GHz Port1.*

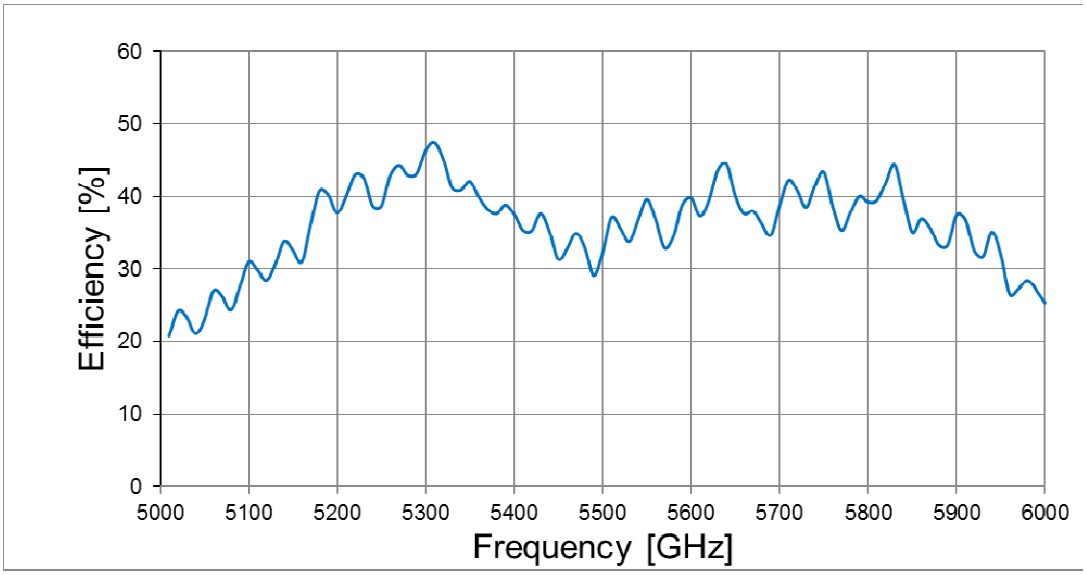


Figure 12. *Antenna Efficiency at 5.0GHz Port1.*

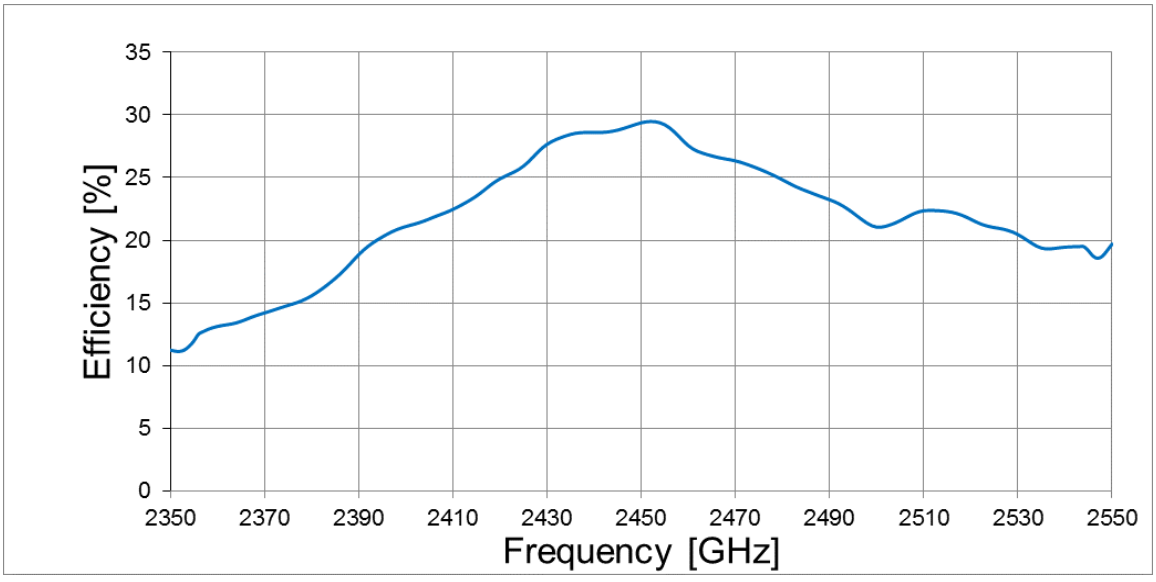


Figure 13. *Antenna Efficiency at 2.4GHz Port2.*

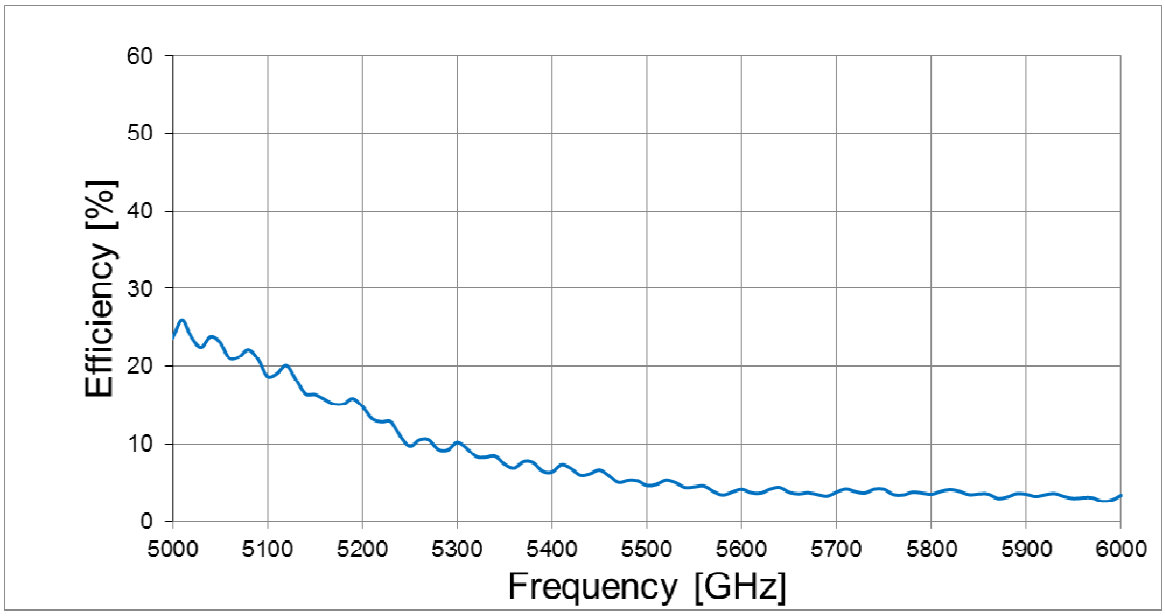


Figure 14. *Antenna Efficiency at 5.0GHz Port2.*

5.5 Antenna Peak Gain

The following figure shows the peak gain of the device.

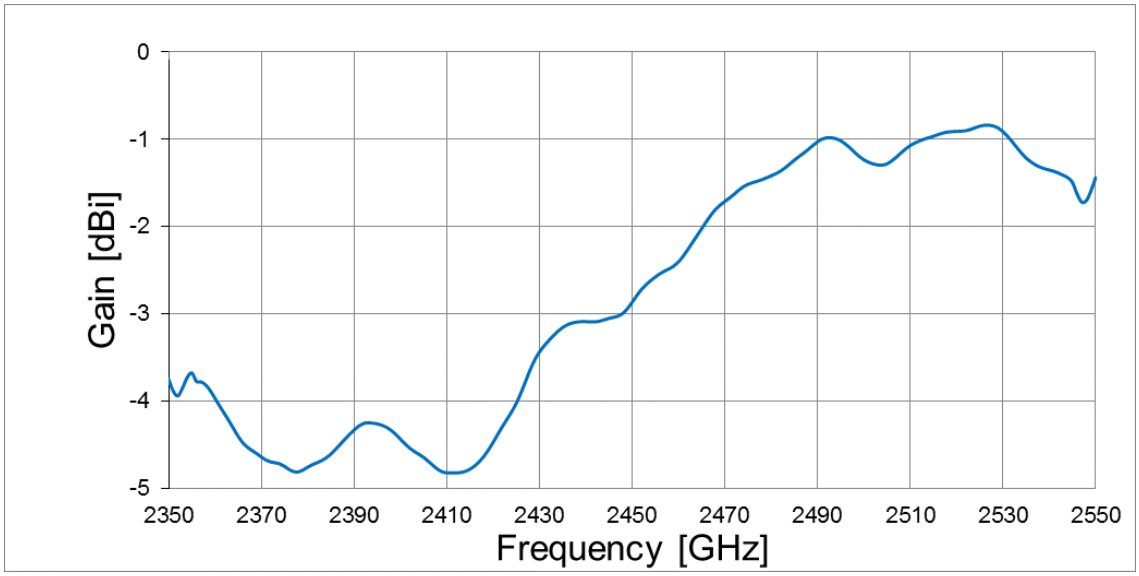


Figure 15. *Antenna Peak Gain at 2.4GHz Port1.*

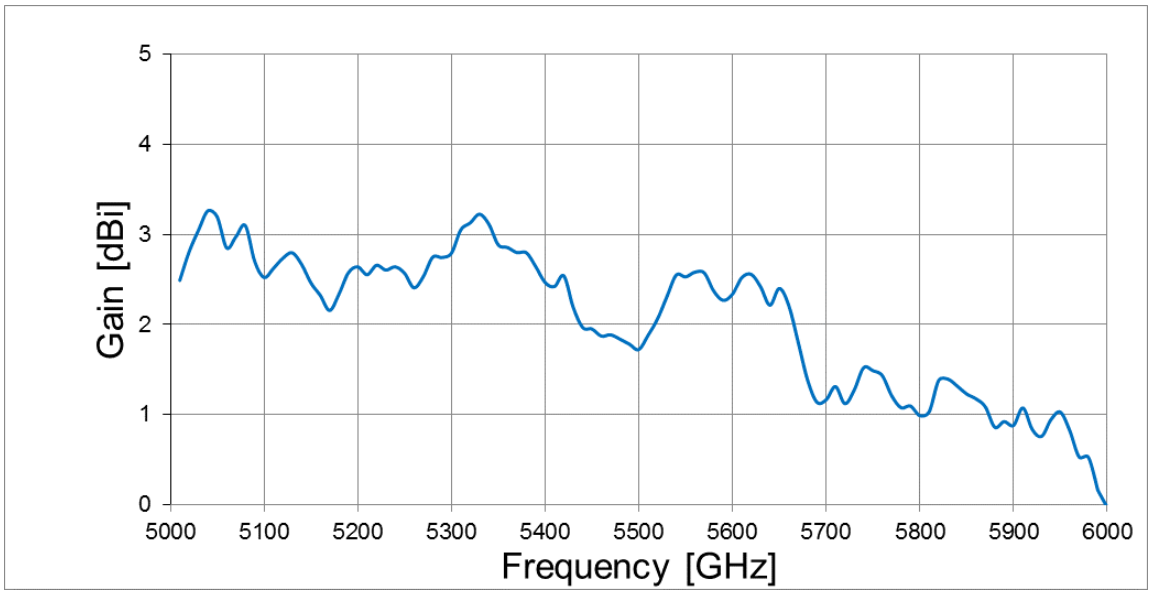


Figure 16. *Antenna Peak Gain at 5.0GHz Port1.*

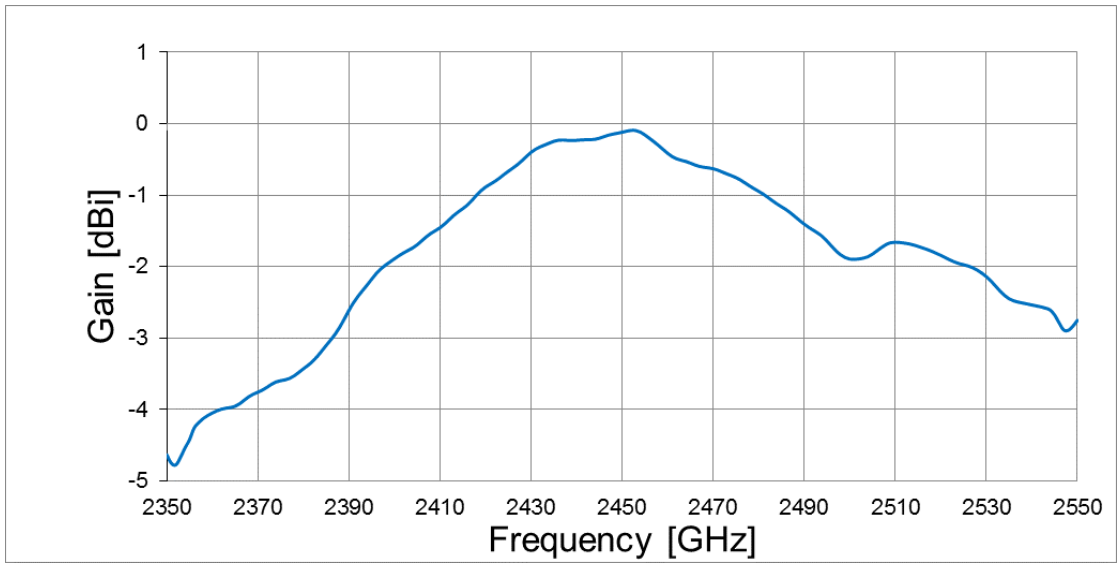


Figure 17. *Antenna Peak Gain at 2.4GHz Port2.*

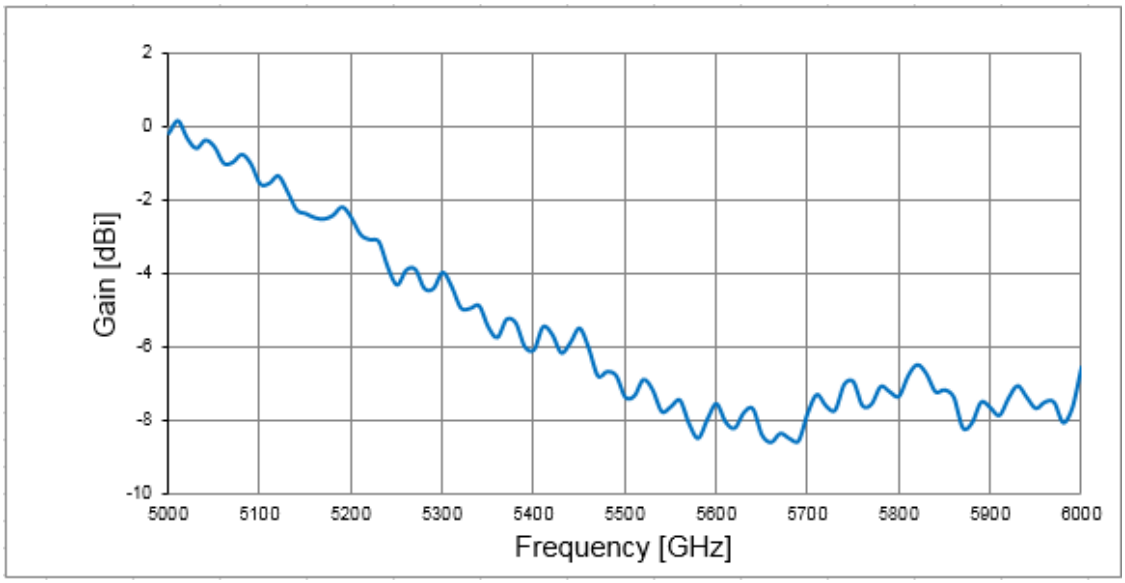


Figure 18. *Antenna Peak Gain at 5.0GHz Port2.*

5.6 Antenna Average Gain

The following figure shows the peak gain of the device.

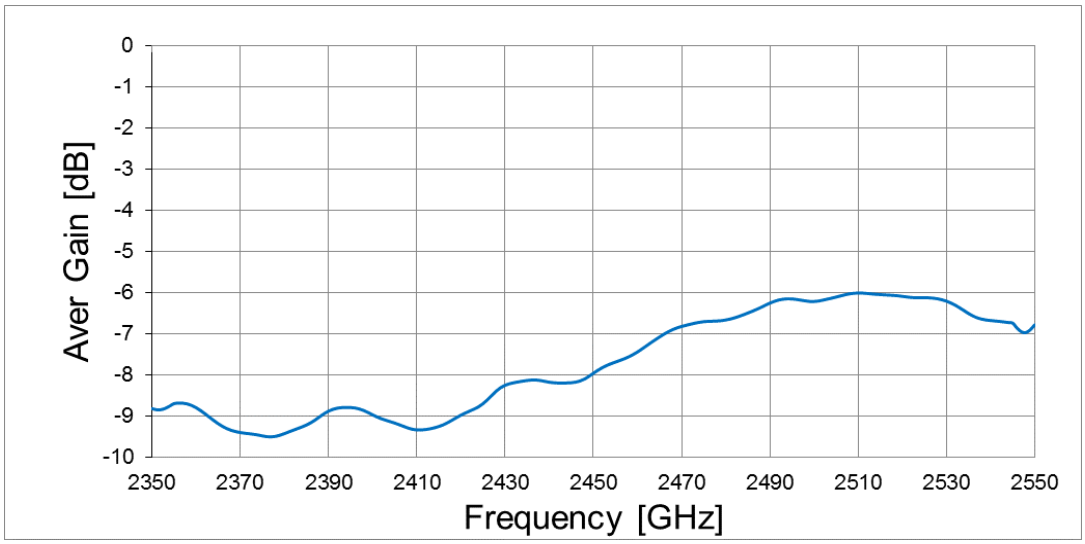


Figure 19. *Antenna Average Gain at 2.4GHz Port1.*

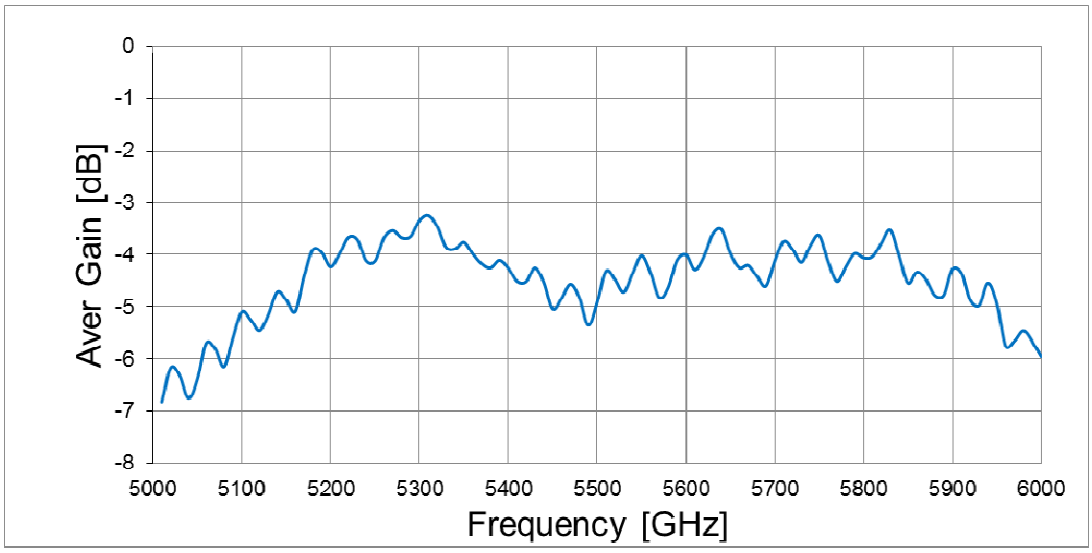


Figure 20. *Antenna Average Gain at 5.0GHz Port1.*

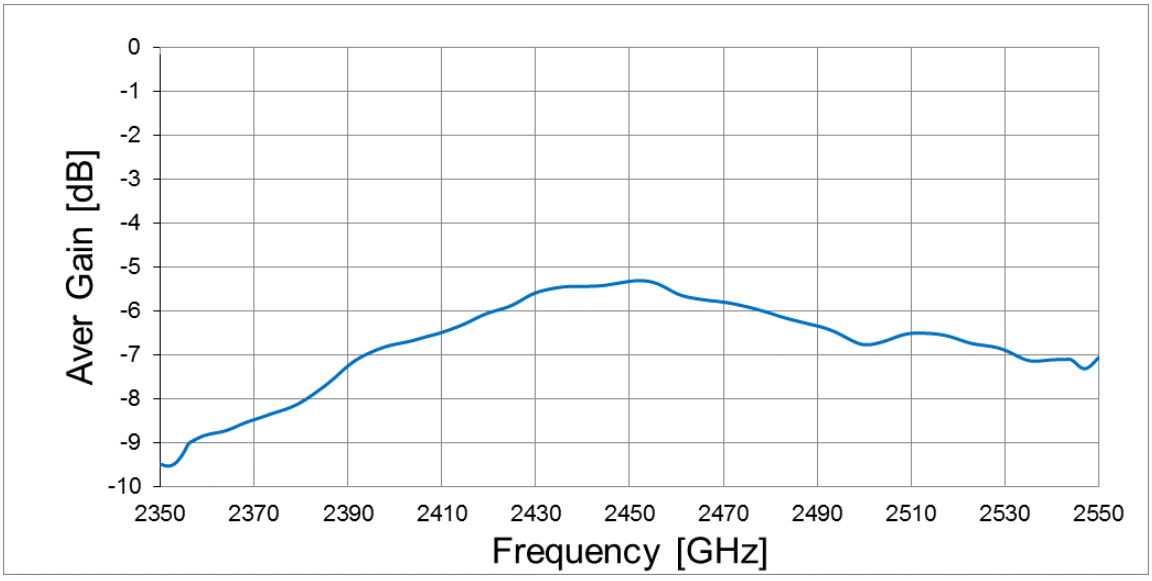


Figure 21. *Antenna Average Gain at 2.4GHz Port2.*

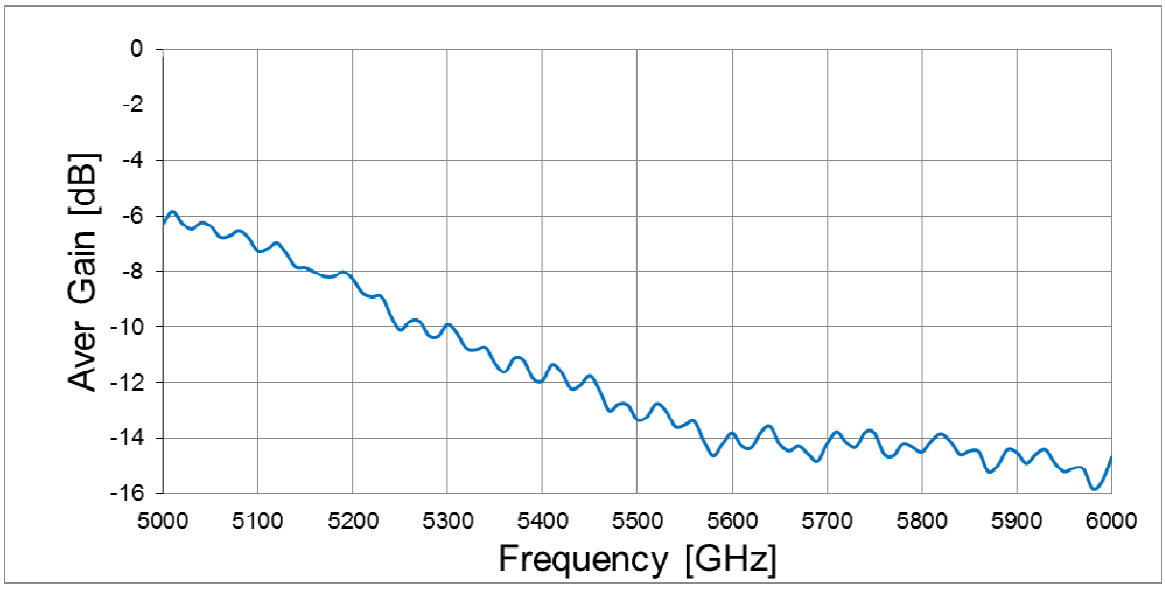


Figure 22. *Antenna Average Gain at 5.0GHz Port2.*

Table 1, shows the antenna characteristics at 2.4GHz Port1.

Frequency	*Efficiency [%]*	*Peak Gain [dBi]*	*Efficiency [dB]*
2400	12.6841	-4.43203	-8.967403427
2402	12.4096	-4.53494	-9.062422169
2405	12.1109	-4.64141	-9.168235818
2410	11.6569	-4.81843	-9.334169292
2415	11.8819	-4.77751	-9.25114107
2420	12.6639	-4.47042	-8.974325275
2425	13.5019	-4.02226	-8.696051129
2430	14.9688	-3.435	-8.248130142
2435	15.3794	-3.15485	-8.130606074
2440	15.2305	-3.08777	-8.17285839
2441	15.1834	-3.09085	-8.186309665

2445	15.1864	-3.05052	-8.185451653
2450	16.0073	-2.8661	-7.956819157
2455	17.0455	-2.576	-7.68390255
2460	18.0375	-2.40371	-7.438236559
2462	18.6565	-2.2638	-7.291698275
2465	19.6169	-2.02481	-7.073696218
2470	20.8015	-1.71184	-6.819053469
2475	21.3634	-1.51466	-6.703296279
2480	21.5712	-1.41827	-6.661256945
2485	22.4293	-1.23837	-6.491842802
2490	23.7074	-1.02826	-6.251160727
2495	24.267	-1.01639	-6.149839099
2500	23.9213	-1.23558	-6.212152224

Table 2, shows the antenna characteristics at 5.0 GHz Port1.

Frequency	*Efficiency [%]*	*Peak Gain [dBi]*	*Efficiency [dB]*
5000	20.7396	2.49	-6.83199624
5020	24.1644	2.80735	-6.168239839
5040	21.0863	3.26252	-6.75999619
5060	26.9571	2.85167	-5.693268303
5080	24.2839	3.0976	-6.146815642
5100	30.928	2.52252	-5.096481633
5120	28.4627	2.73464	-5.457239047
5140	33.8008	2.6683	-4.710730207
5160	30.963	2.32271	-5.091569672
5180	40.7305	2.33849	-3.900802586
5200	37.7684	2.63976	-4.22871413

5220	42.9778	2.65749	-3.667558195
5240	38.7585	2.64007	-4.11633039
5260	42.8974	2.40783	-3.675690295
5280	42.9166	2.74708	-3.673746916
5300	46.3395	2.79165	-3.340486565
5320	45.1299	3.12785	-3.455356288
5340	40.8771	3.11373	-3.885199225
5360	39.9357	2.85483	-3.986386988
5380	37.5907	2.79679	-4.249195869
5400	37.5421	2.46658	-4.254814378
5420	35.311	2.5401	-4.520899831
5440	35.171	1.96765	-4.538152834
5460	32.8472	1.87138	-4.835016452
5480	32.9131	1.83684	-4.826312107
5500	32.2432	1.72203	-4.915618629

Frequency	*Efficiency [%]*	*Peak Gain [dBi]*	*Efficiency [dB]*
5520	35.6435	2.06189	-4.480196572
5540	36.6793	2.54909	-4.355789611
5560	36.799	2.58147	-4.34163983
5580	34.465	2.37219	-4.626217172
5600	39.8009	2.33702	-4.001071073
5620	39.4107	2.55674	-4.043858513
5640	44.478	2.21478	-3.518547495
5660	37.6123	2.21449	-4.246701086
5680	36.1674	1.38851	-4.416827107
5700	38.7232	1.16338	-4.120287607
5720	40.7951	1.12045	-3.89391998

5740	41.4829	1.51934	-3.821308904
5760	38.6359	1.43073	-4.130089667
5780	37.7821	1.07573	-4.227139068
5800	39.2644	0.987563	-4.060010346
5820	41.9328	1.37659	-3.774461373
5840	39.5542	1.31506	-4.028073948
5860	36.8916	1.17386	-4.330725089
5880	33.2982	0.859185	-4.775792425
5900	37.4132	0.878981	-4.269751444
5920	32.5703	0.833726	-4.871782412
5940	35.106	0.943249	-4.546186515
5960	26.5326	0.822329	-5.762201903
5980	28.4592	0.523727	-5.457773123
6000	25.3768	-0.0301562	-5.955631431

Table 3, shows the antenna characteristics at 2.4GHz Port2.

Frequency	*Efficiency [%]*	*Peak Gain [dBi]*	*Efficiency [dB]*
2400	21.1028	-1.89108	-6.75659917
2402	21.3087	-1.80817	-6.714430449
2405	21.7024	-1.69444	-6.634922362
2410	22.4627	-1.45679	-6.485380431
2415	23.5272	-1.19069	-6.284297557
2420	24.8961	-0.888635	-6.038686803
2425	25.9135	-0.666713	-5.864739252
2430	27.6513	-0.402833	-5.582844459
2435	28.4421	-0.248257	-5.46038341
2440	28.5963	-0.23351	-5.436901555

2441	28.5986	-0.227997	-5.436552266
2445	28.7881	-0.204437	-5.407869974
2450	29.3659	-0.121561	-5.321566845
2455	29.2183	-0.157746	-5.343450561
2460	27.5568	-0.414925	-5.597712158
2462	27.0979	-0.492359	-5.670643642
2465	26.7341	-0.551822	-5.729344318
2470	26.3391	-0.630419	-5.793990688
2475	25.698	-0.753767	-5.901006752
2480	24.835	-0.946181	-6.049358357
2485	23.9479	-1.1618	-6.20732564
2490	23.2426	-1.4048	-6.337152918
2495	22.1956	-1.64151	-6.537331105
2500	21.0521	-1.89443	-6.767045757

Table 4, shows the antenna characteristics at 5.0 GHz Port2.

Frequency	*Efficiency [%]*	*Peak Gain [dBi]*	*Efficiency [dB]*
5000	23.5836	-0.17684	-6.273898998
5020	23.6796	-0.31456	-6.256256381
5040	23.7653	-0.36889	-6.24056699
5060	21.0665	-0.996538	-6.764076123
5080	22.1685	-0.75534	-6.542636918
5100	20.9405	-1.01789	-6.790129528
5120	18.7256	-1.55726	-7.275642579
5140	19.0831	-1.54082	-7.193510739
5160	15.7731	-2.47744	-8.020829433
5180	15.1675	-2.51046	-8.190859964
5200	15.1593	-2.40838	-8.193208523

5220	15.8465	-2.18235	-8.00066645
5240	14.8351	-2.47791	-8.287095219
5260	10.4908	-3.90085	-9.791913924
5280	10.5213	-3.87852	-9.779305959
5300	9.32124	-4.39817	-10.3052631
5320	9.25034	-4.39608	-10.33842304
5340	10.1951	-3.96432	-9.9160851
5360	9.46703	-4.35576	-10.23786247
5380	8.34686	-4.93074	-10.78476871
5400	8.25203	-4.94226	-10.83439202
5420	8.40578	-4.87074	-10.75421981
5440	7.38538	-5.4468	-11.31627154
5460	6.88547	-5.72962	-11.6206641
5480	7.70186	-5.2357	-11.1340438
5500	7.58494	-5.33187	-11.2004785

Frequency	*Efficiency [%]*	*Peak Gain [dBi]*	*Efficiency [dB]*
5520	5.28297	-6.87373	-12.77121856
5540	4.99305	-7.14983	-13.01634085
5560	4.37391	-7.74184	-13.59130157
5580	4.4359	-7.6136	-13.53018253
5600	4.56636	-7.43681	-13.40429853
5620	3.88976	-8.07857	-14.10077194
5640	3.4333	-8.46753	-14.64288246
5660	3.80995	-7.95556	-14.19080724
5680	4.15599	-7.53256	-13.81325506
5700	3.72578	-8.02531	-14.28782793
5720	3.66984	-8.19226	-14.3535287
5740	4.16887	-7.77312	-13.79981647

5760	4.37975	-7.67156	-13.58550679
5780	3.7793	-8.38766	-14.22588633
5800	3.5785	-8.57833	-14.46298978
5820	3.72268	-8.33668	-14.29144294
5840	3.48566	-8.47604	-14.57714977
5860	3.29555	-8.539	-14.82072095
5880	3.80267	-7.78316	-14.19911362
5900	4.19115	-7.28536	-13.77666796
5920	3.84667	-7.58857	-14.1491507
5940	3.69051	-7.70342	-14.32913614
5960	4.1757	-7.00503	-13.7927071
5980	4.15007	-6.92997	-13.81944578
6000	3.48811	-7.58551	-14.57409828

5.7 Radiattion Patterns

5.7.1 Reference coordinate system

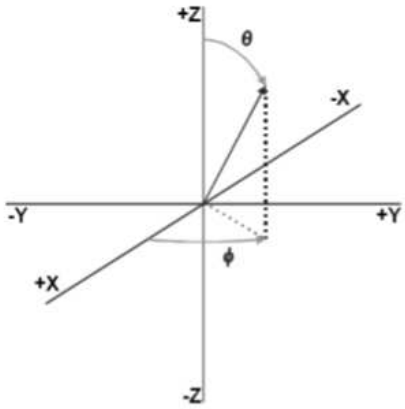


Figure 23. Reference coordinate system

X-axis: Theta =+90° / Phi=0°
Y axis: Theta=+90 and Phi =+90
Z axis: Theta=0

5.7.2 EUT Orientation

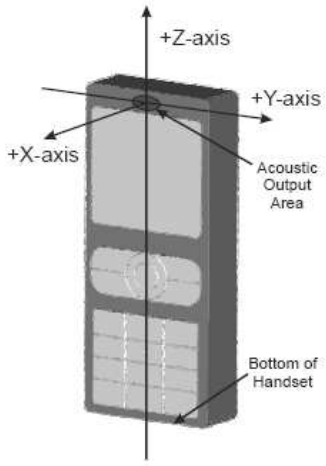


Figure 24. OUT orientation

5.7.3 3D Radiation Patterns

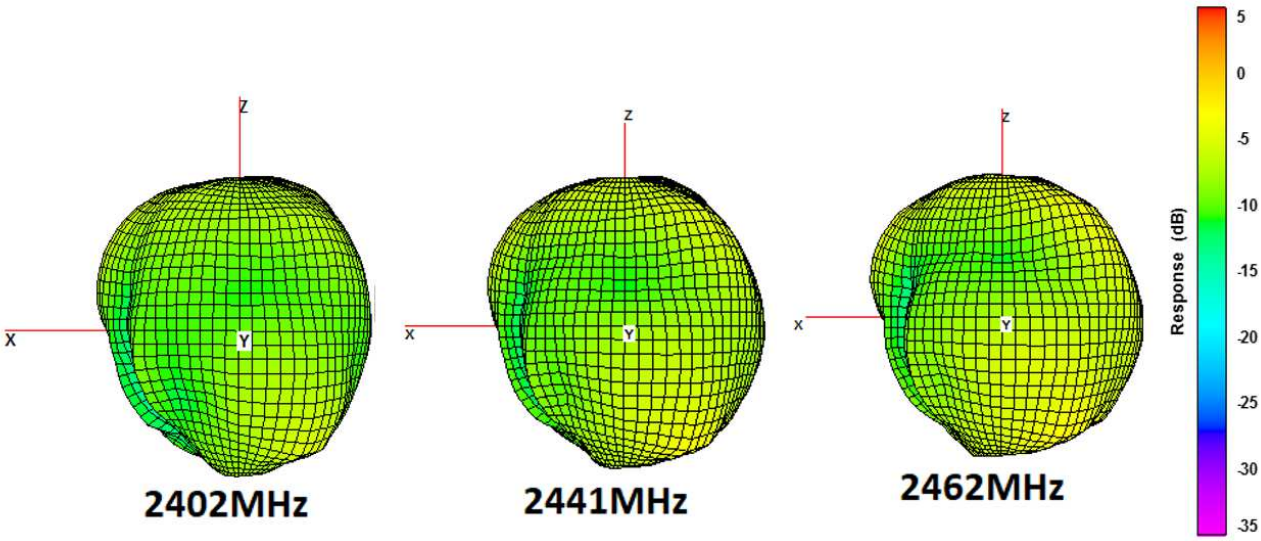


Figure 25. *3D radiation patterns at 2.4GHz Port1.*

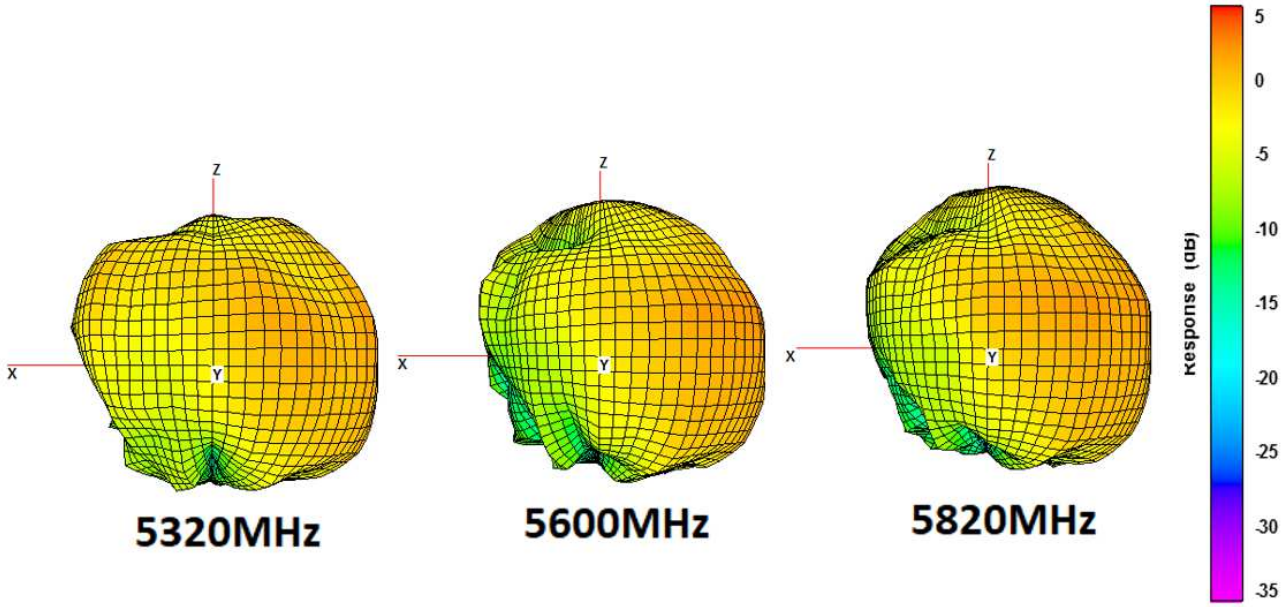


Figure 26. *3D radiation patterns at 5.0GHz Port1.*

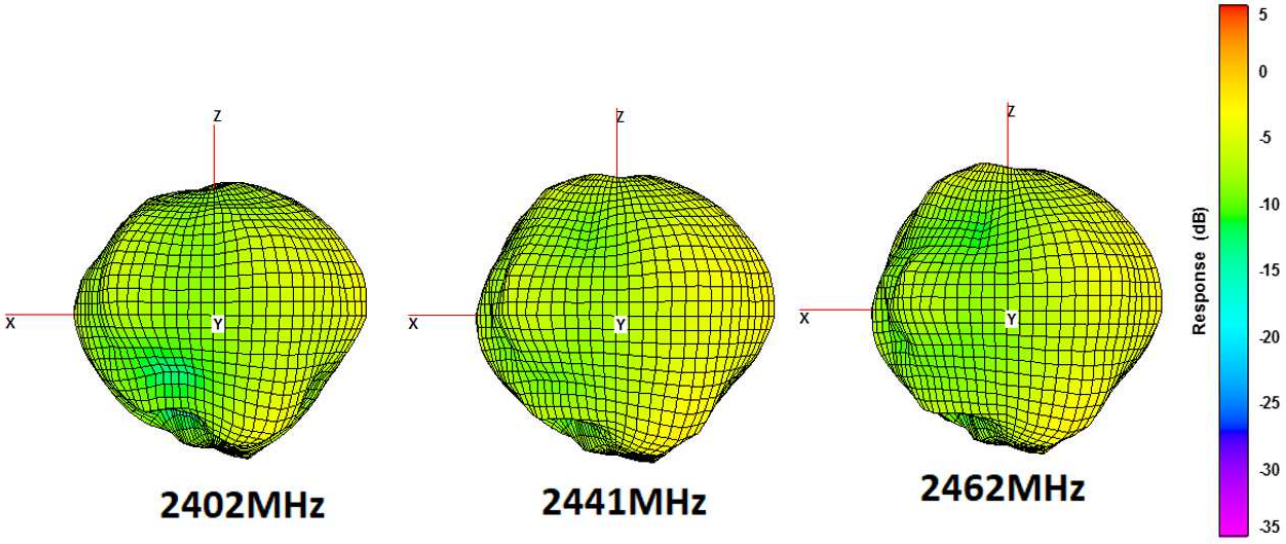


Figure 27. *3D radiation patterns at 2.4GHz Port2.*

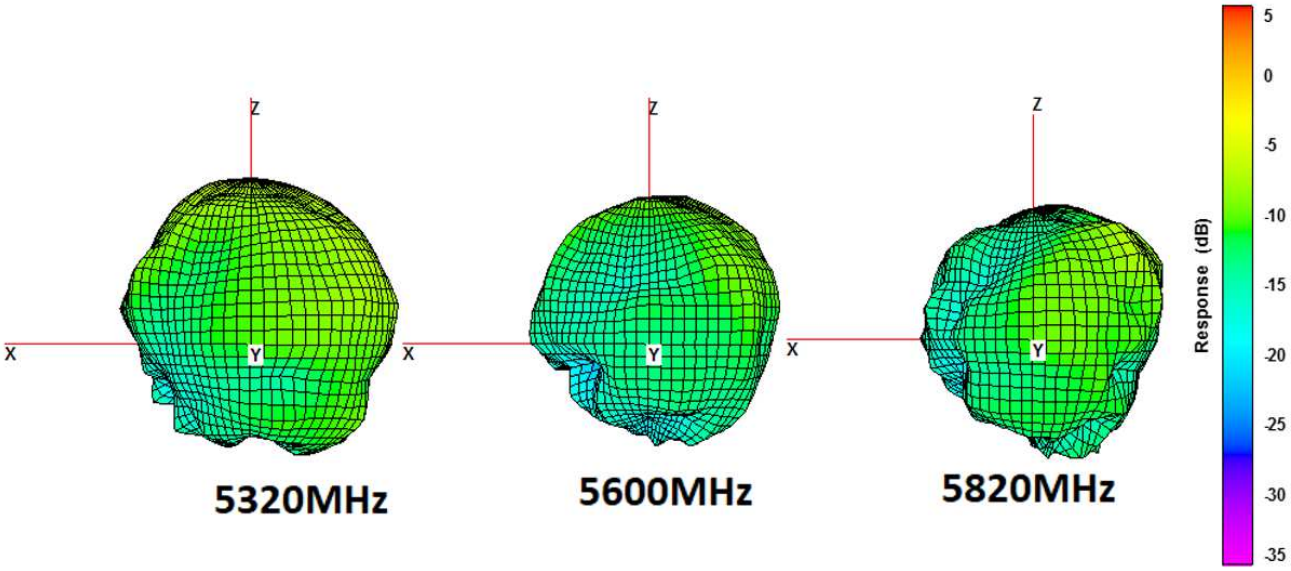


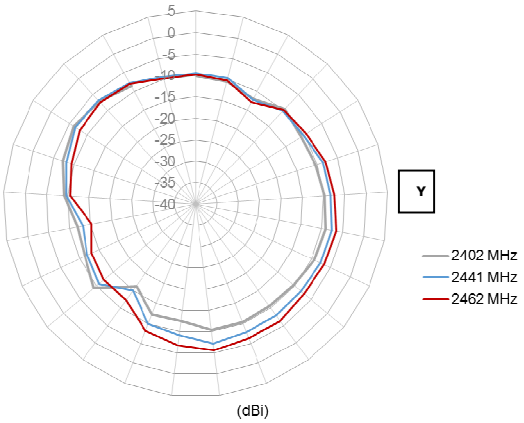
Figure 28. *3D radiation patterns at 5.0GHz Port2.*

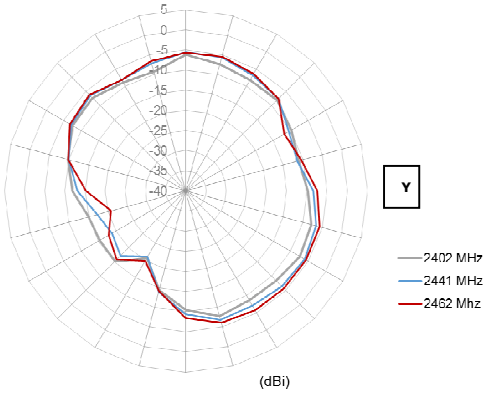
5.7.4 2D Radiation Patterns

Figure 29, 30, 31 and 32 shows the 2D radiation patterns of the antenna at three different frequencies.

x

z





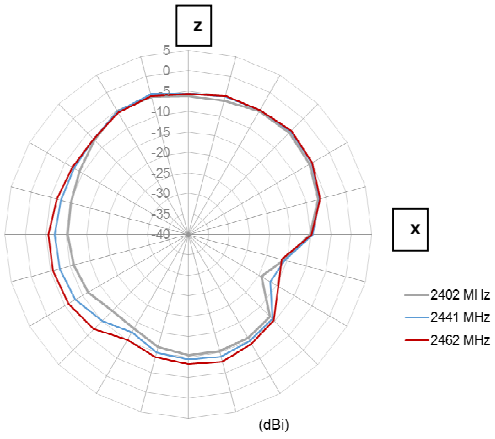


Figure 29. *2D radiation patterns WLAN at 2.4GHz Port 1.*

X

Z