FXUB.71 MIMO LTE Antenna U-Shape / L-Shape Bend Study

VERSION	DATE	PAGE	DESCRIPTION	CENTRE	DESIGNED	APPROVED
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1 Introduction

Evaluation of the different U-Shape and L-Shape bending influence on the Taoglas FXUB.71 MIMO LTE antenna parameters (when mounted on 2mm ABS plastic) will be reported on in this document.

First the isolation will be studied for number of separation distances between the curves by subsequently shortening the distance between the U-Shape legs at the antenna operation frequency range from 698MHz to 3.4GHz.

Next, an evaluation of antenna efficiency and radiation pattern for U-Shape 9cm-6cm-9cm and also a complete 90° bend shape (L-Shape) for the FXUB.71 antenna will be done.

Equipment Used:

- Copper Mountain Planar 804/1
- ETS-Lindgren Anechoic Chamber
- 2mm ABS Plastic Sheet

The FXUB.71 MIMO LTE antennas come from batch number T0305045.

2 Prerequisite: Performance Evaluation

First starting point is the performance evaluation of the FXUB.71 MIMO LTE antenna on a 2mm ABS sheet and comparison to the data sheet. This is done for return loss and efficiency, as other performance figures (VSWR, peak and average gain) are strongly correlated.

2.1 Test Setup

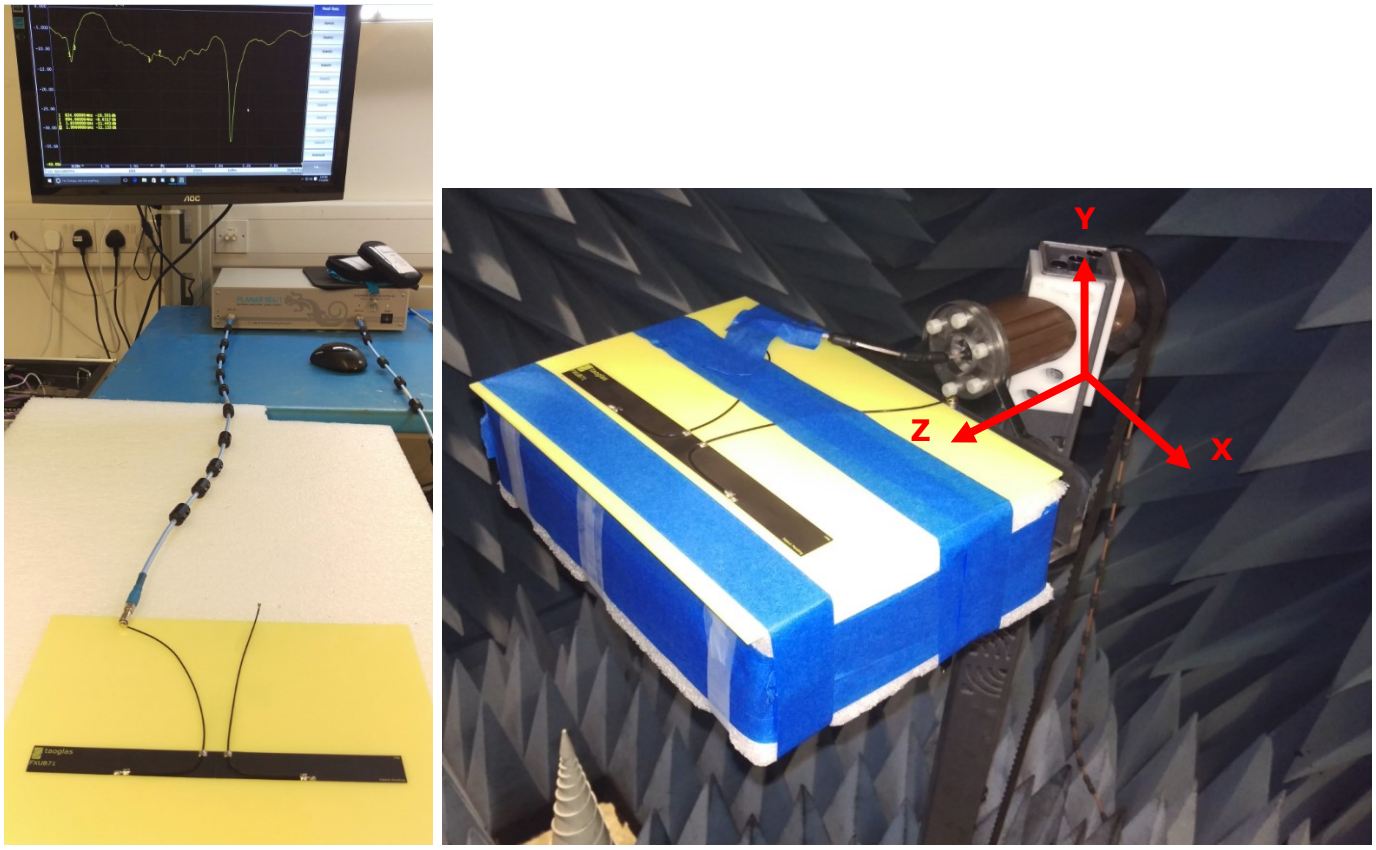


Figure 1. Left: S_{11} Setup Measurement Flat on 2mm ABS; Right: OTA ETS Lindgren Chamber Setup

2.2 Return Loss and Efficiency

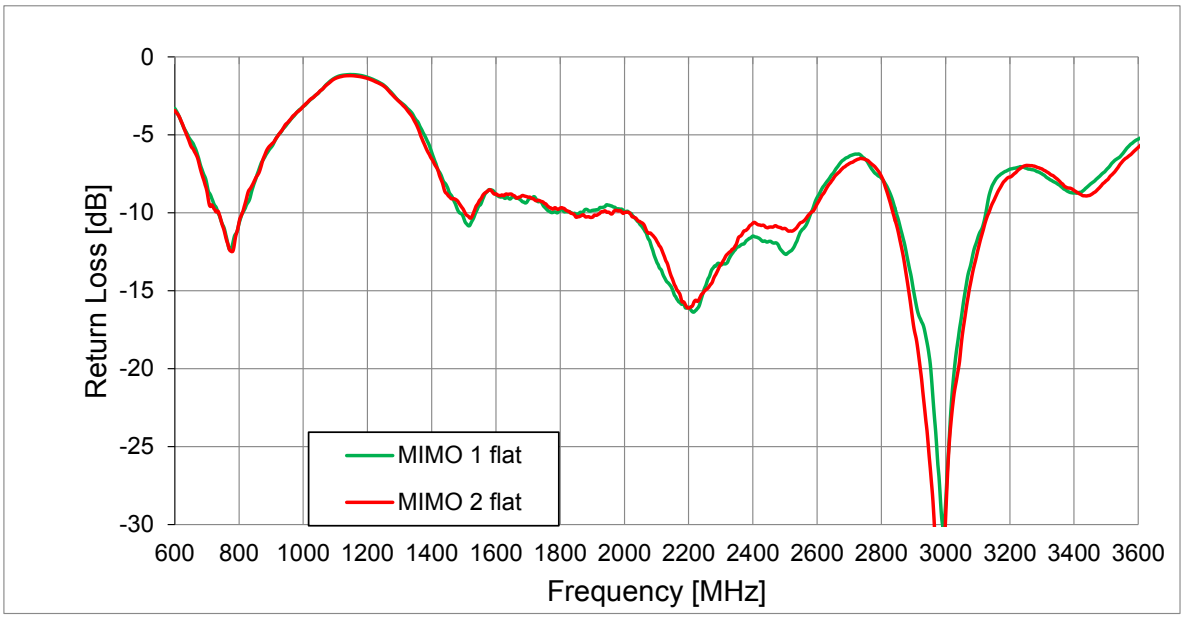


Figure 2. S_{11} FXUB.71 on 2mm ABS

Next, efficiency is measured for the FXUB.71, and the results shown in FIGURE 3

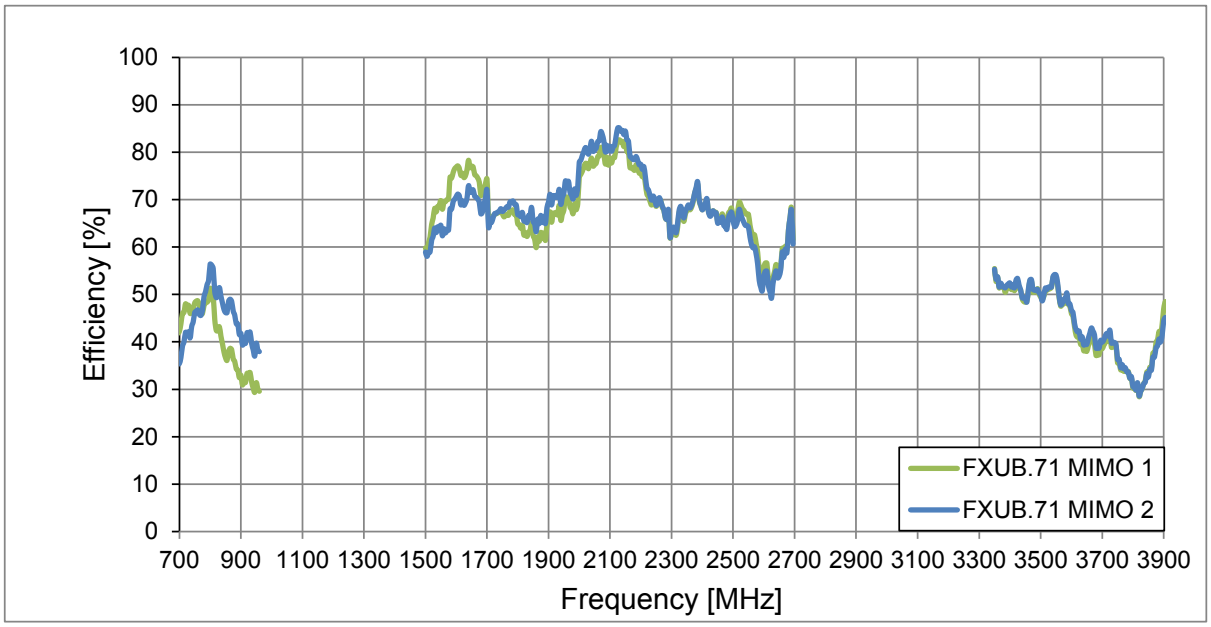


Figure 3. Efficiency for the FXUB.71 on 2mm ABS

3 Influence of U-Shape Bending

The influence of bending the FXUB.71 into a U-Shape with different distances between the U spaces. The diagram below describes the different setup tested.

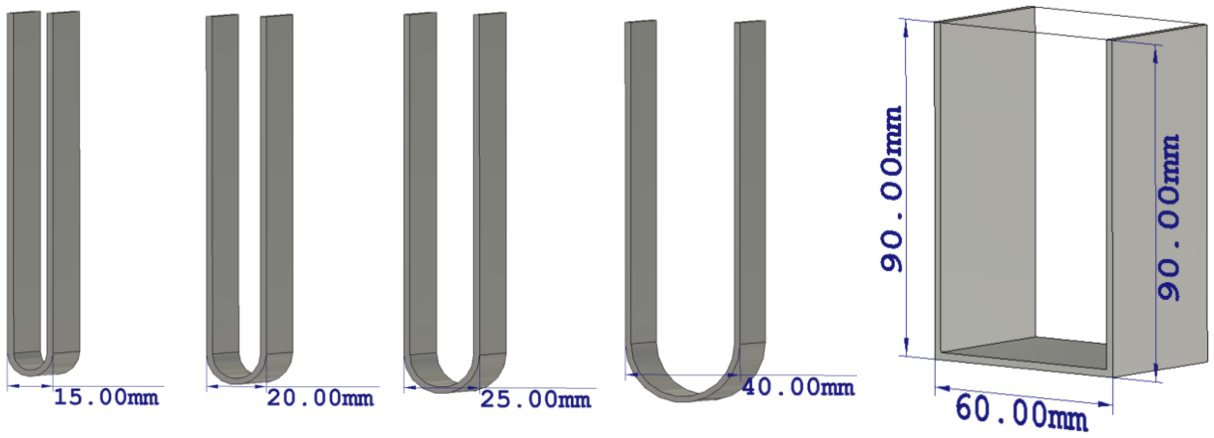


Figure 4. U-Shape dimensions

Also it was considered to have the FXUB.71 in an "L" shape so that the MIMO 1 is at 90° to MIMO 2. The following diagram illustrates this scenario.

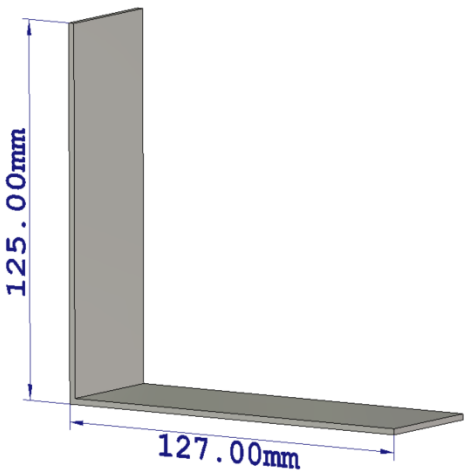


Figure 5. L-Shape dimensions

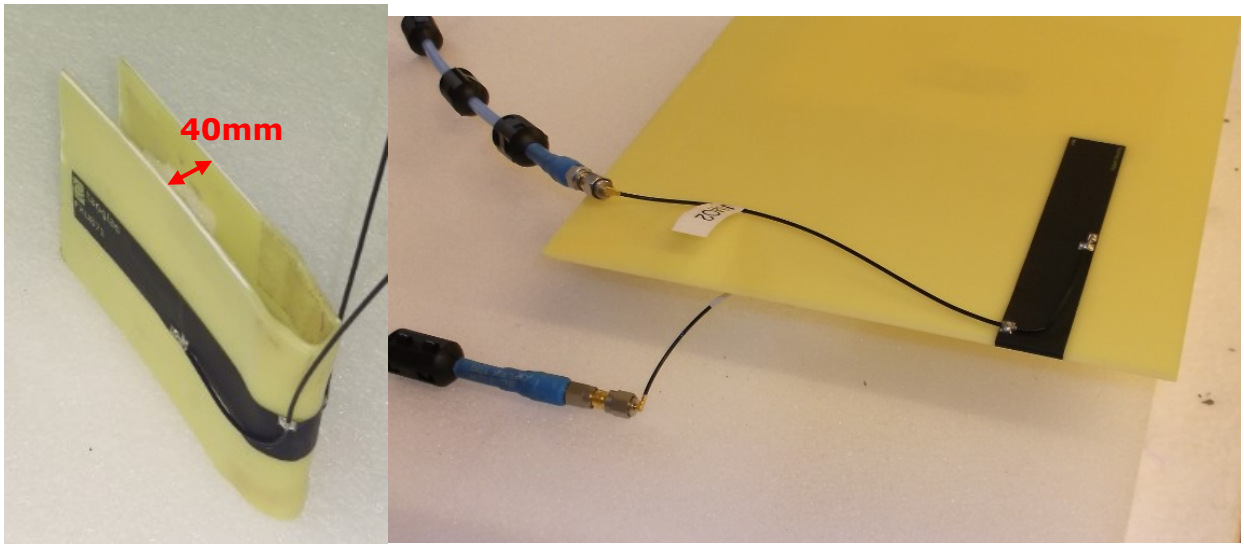


Figure 6. *Setup photos for 40mm U-Bend and complete U-bend*

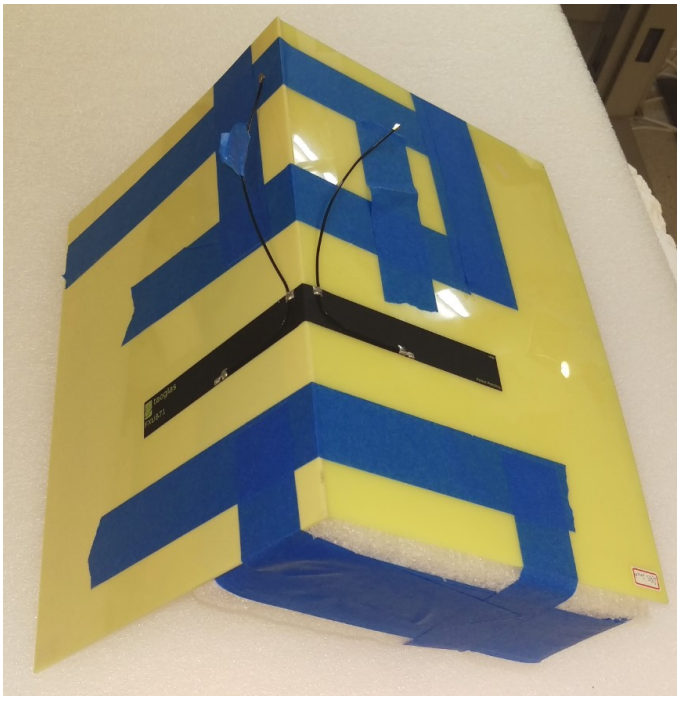


Figure 7. *90° L-shape setup.*

3.1 Test Setup

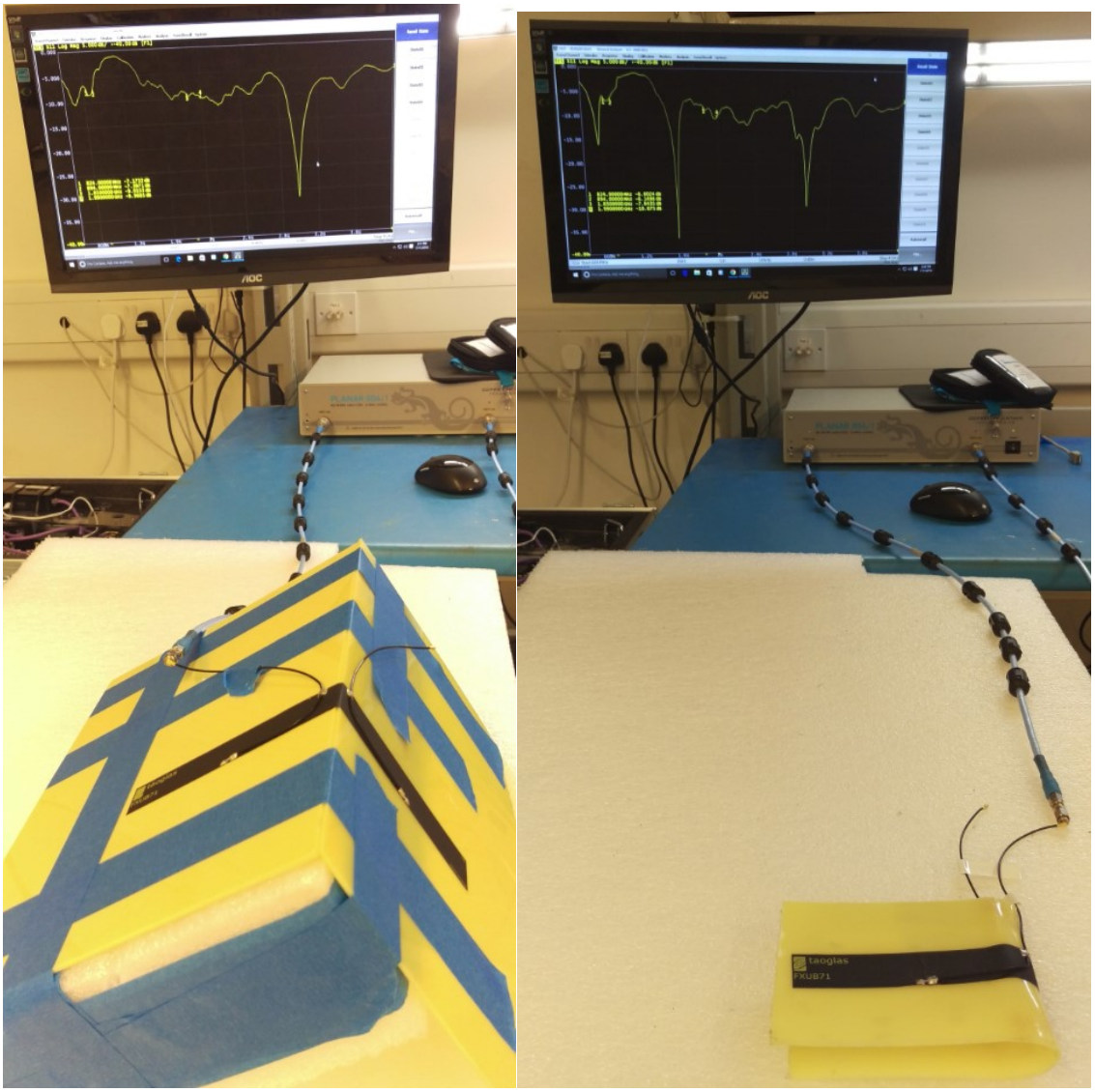


Figure 8. S_{11} Setup Measurement 90° L-Shape and 40mm U-Shape on 2mm ABS

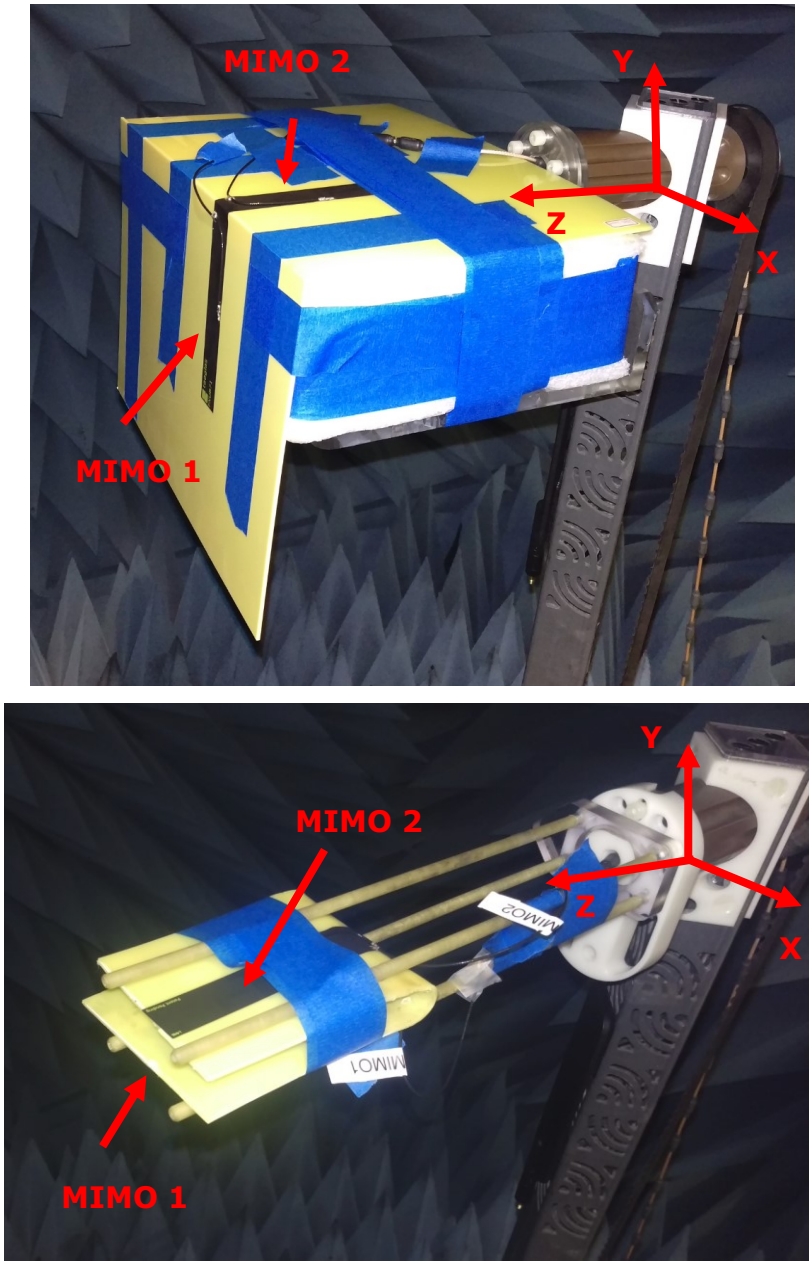


Figure 9. OTA ETS Lindgren Chamber measurements set-up

3.2 Return Loss for 15mm and 20mm U-Shape

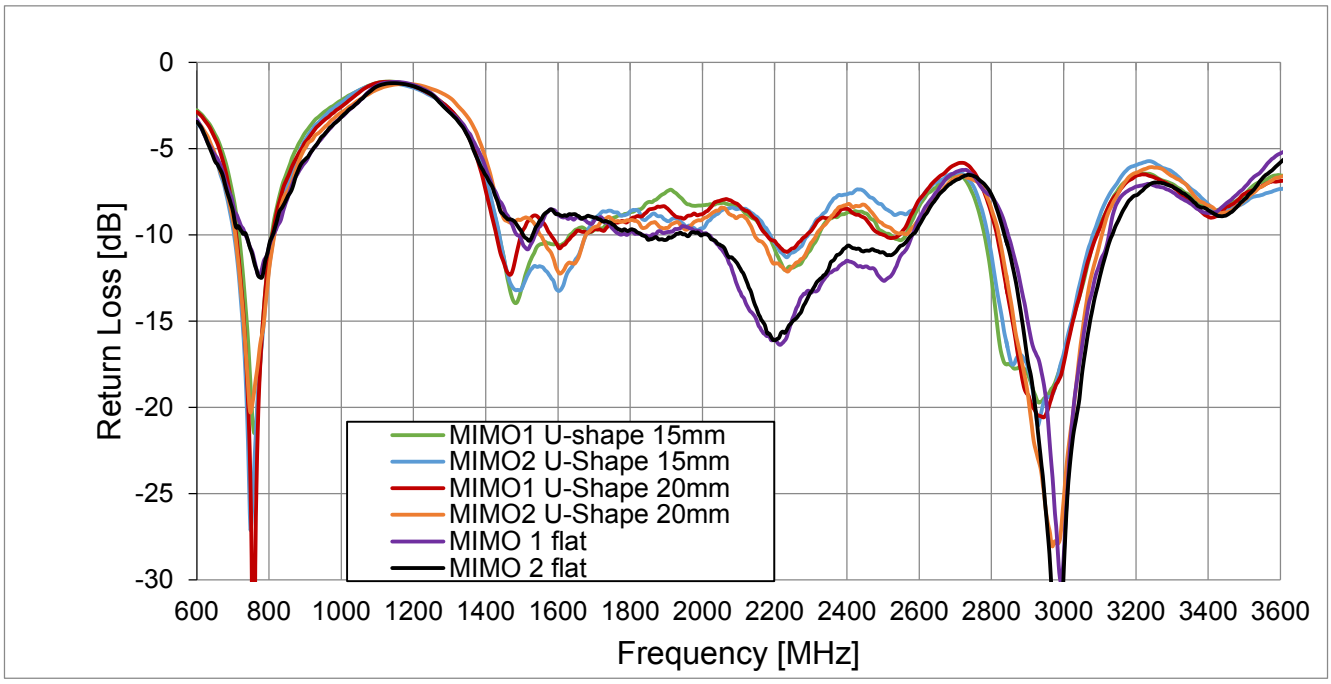
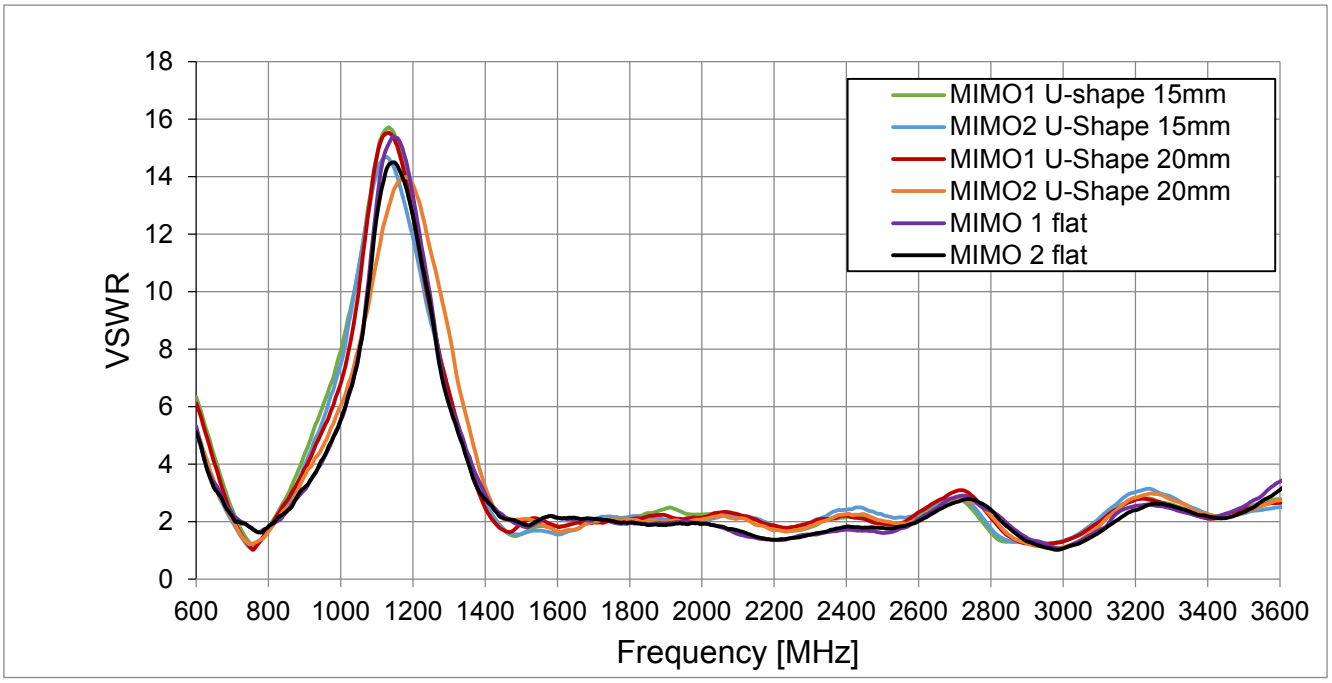


Figure 10. S_{11} plot for U-Bend 15mm and 20mm comparing to flat



3.3 Return Loss for 25mm and 40mm U-Shape

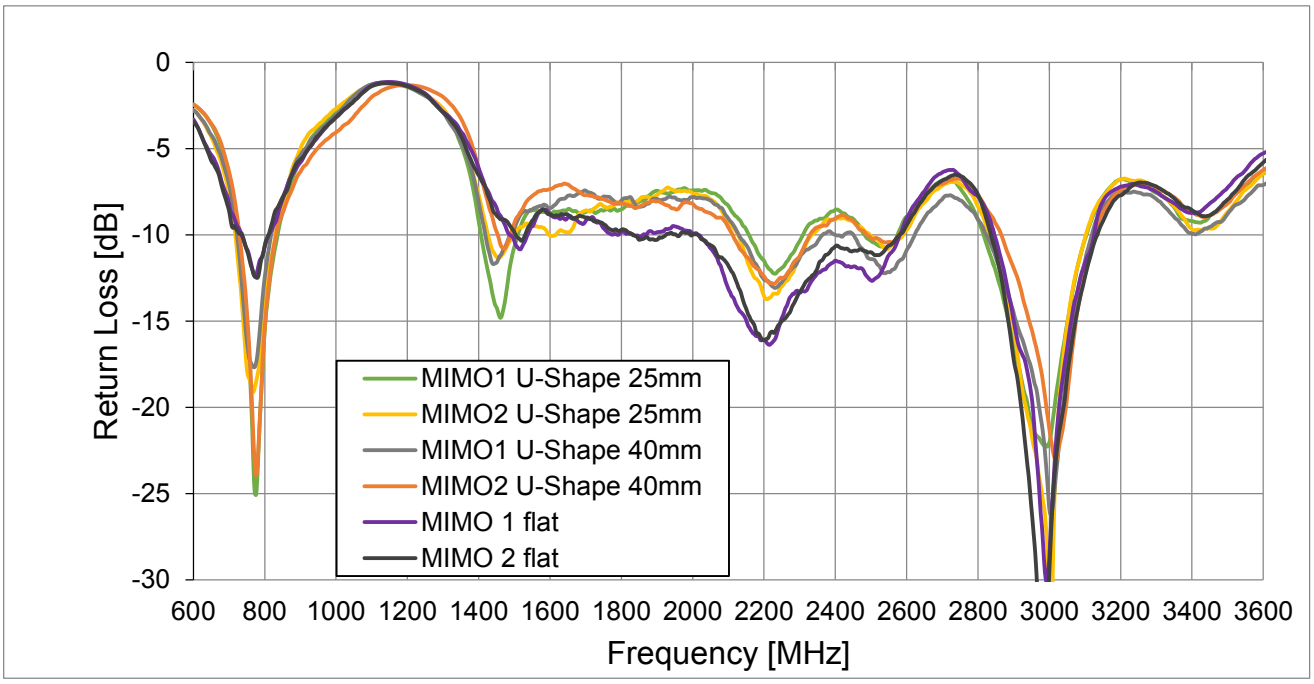
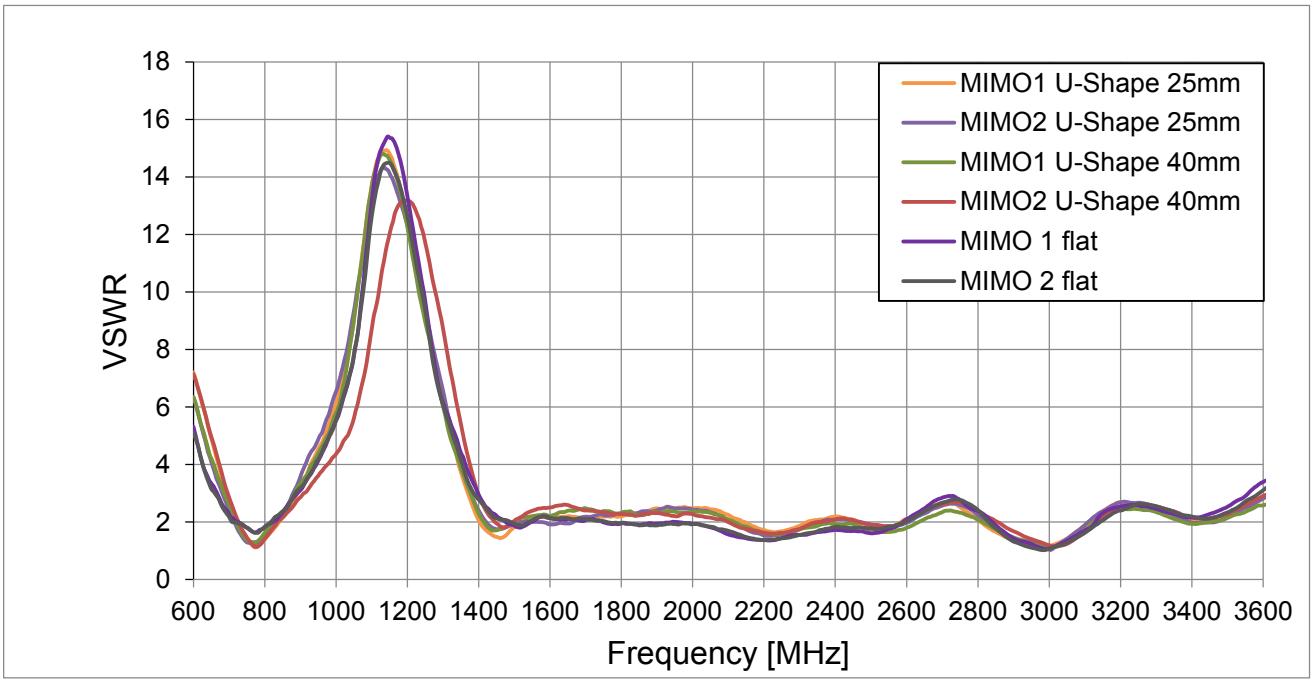
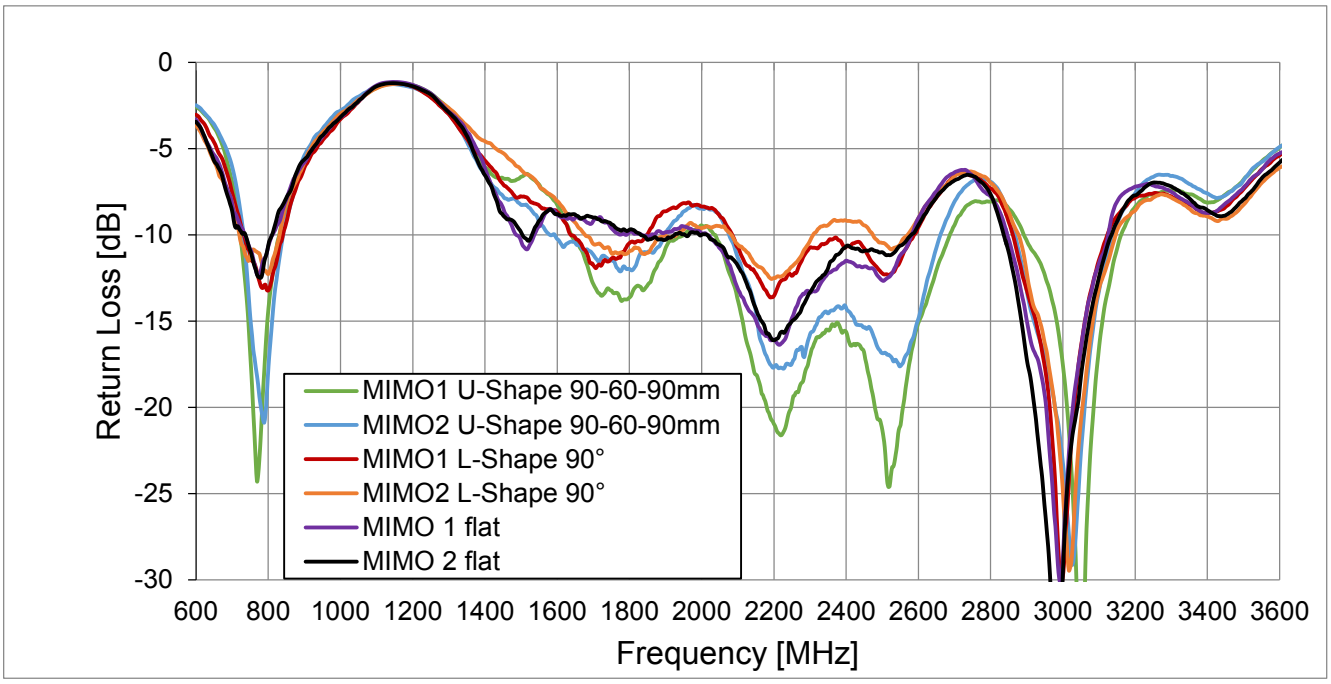
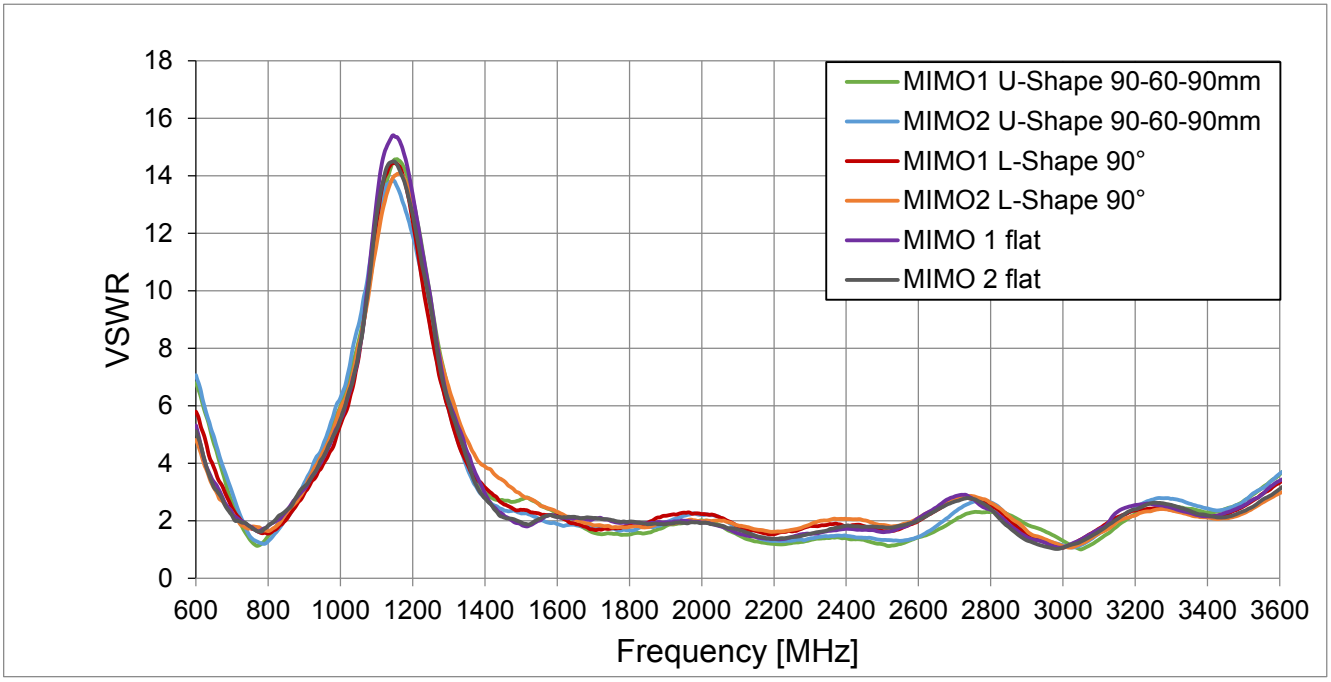


Figure 11. S_{11} plot for U-Bend 25mm and 40mm comparing to flat

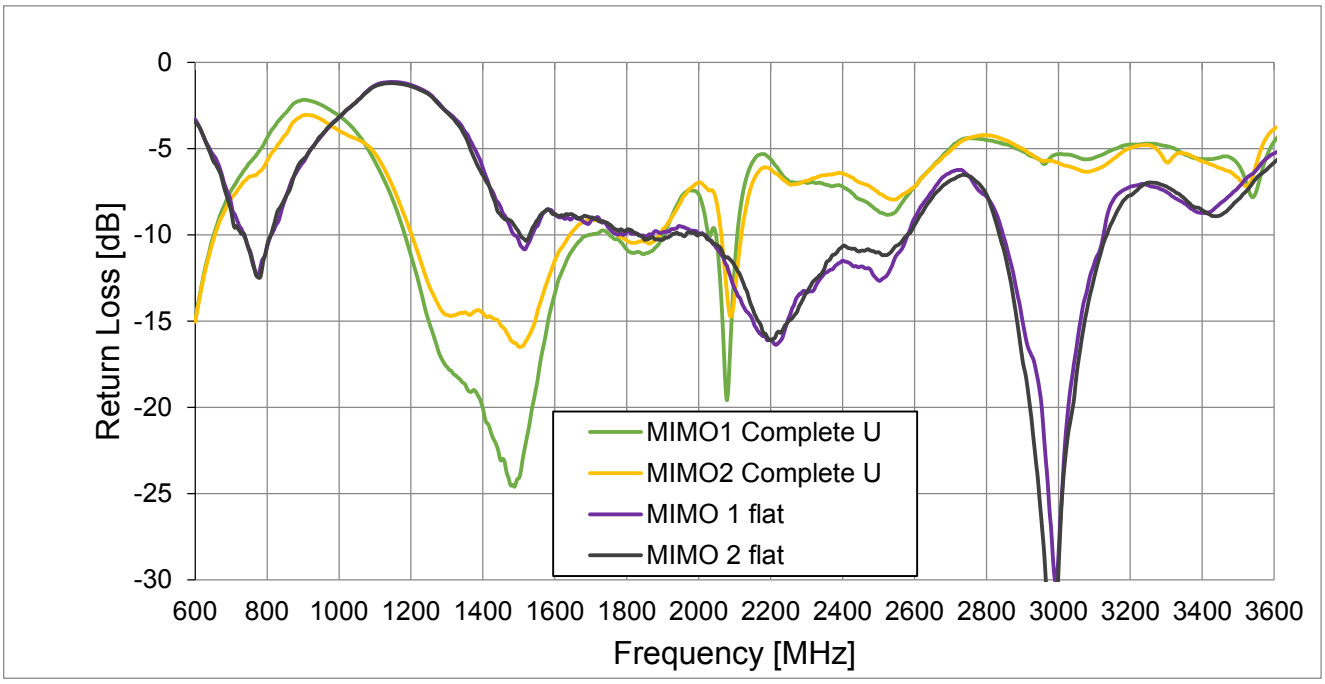


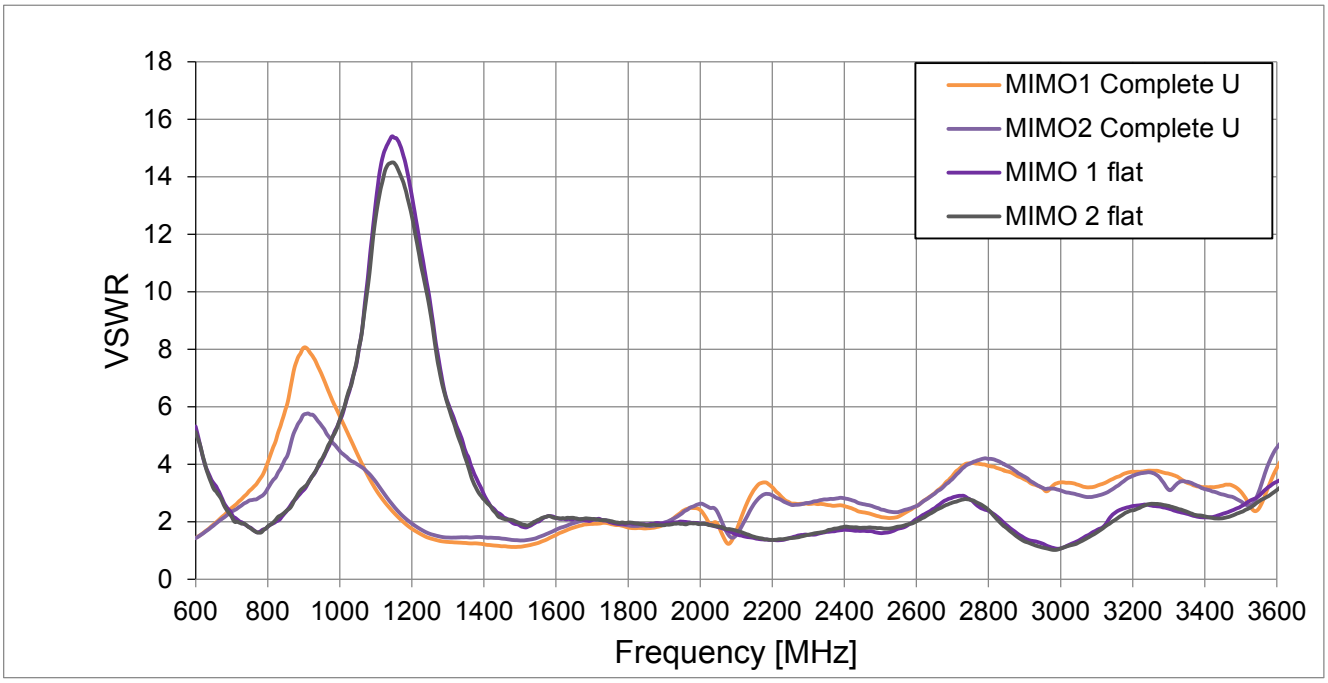
3.4 Return Loss for 90-60-90mm and L-Shape



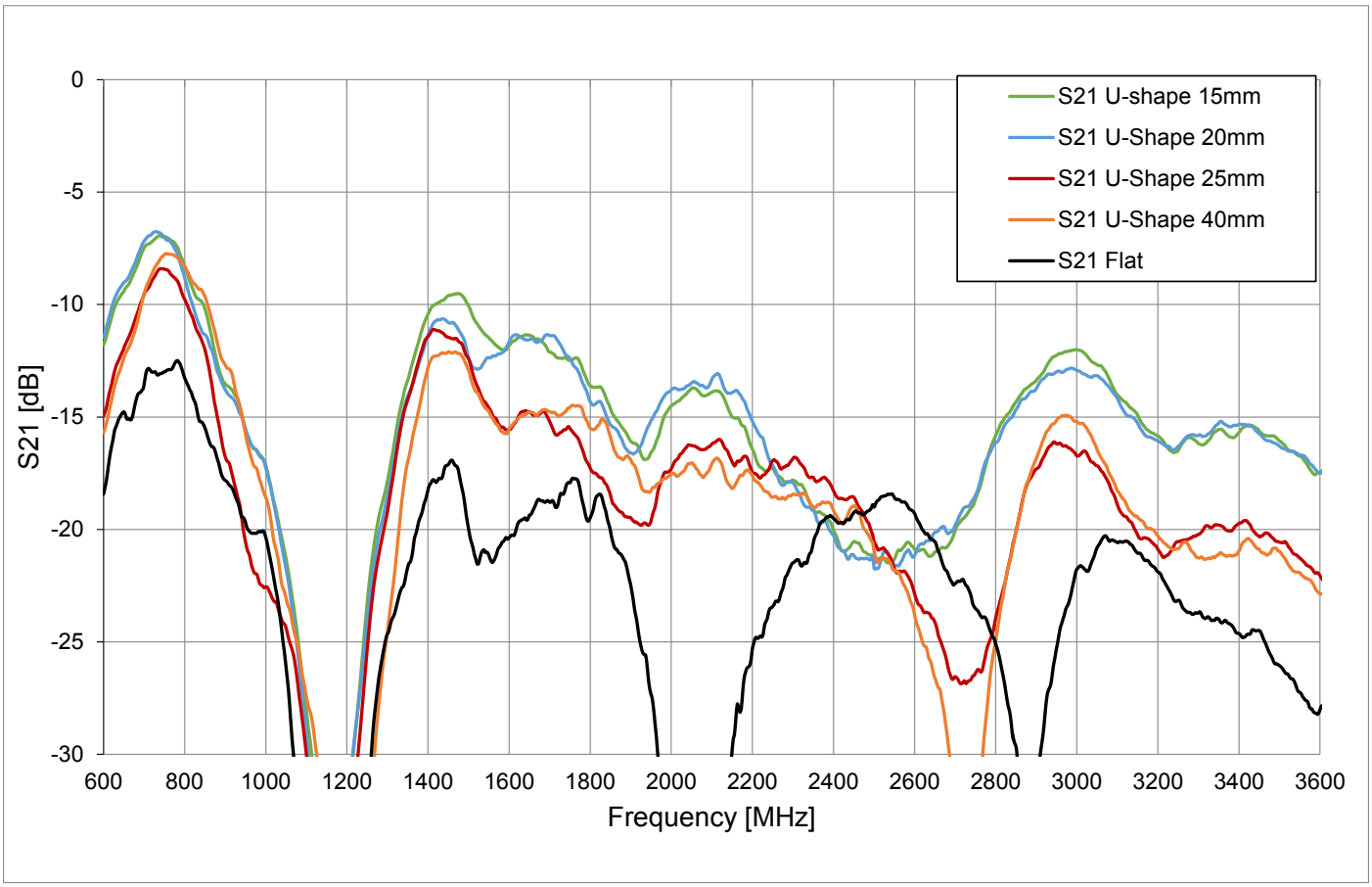


3.5 Return Loss for complete U-Shape (2mm U-Bend)

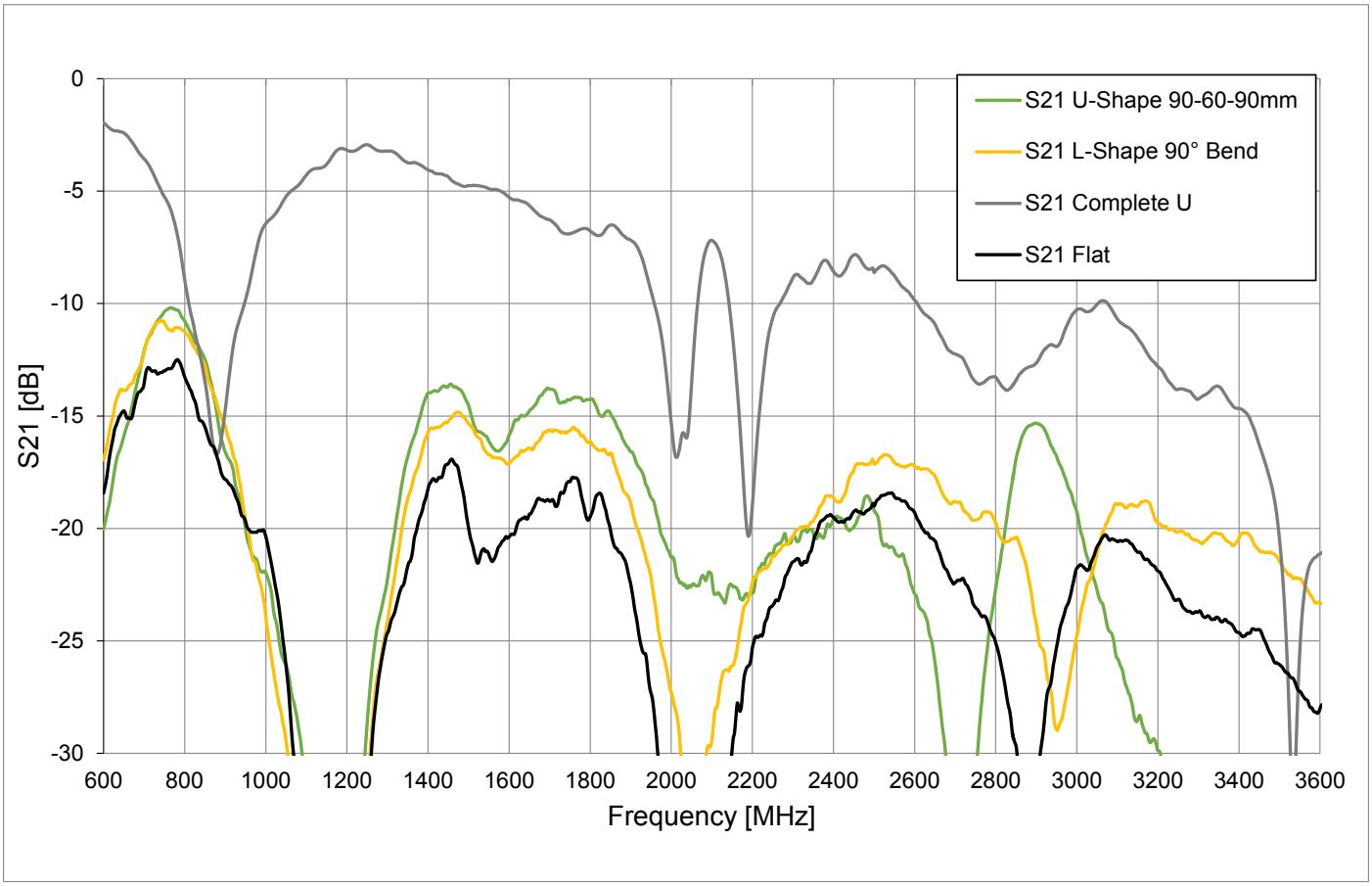




3.6 Isolation U-Shape



3.7 Isolation for U-Shape 90-60-90, L-Shape and complete U



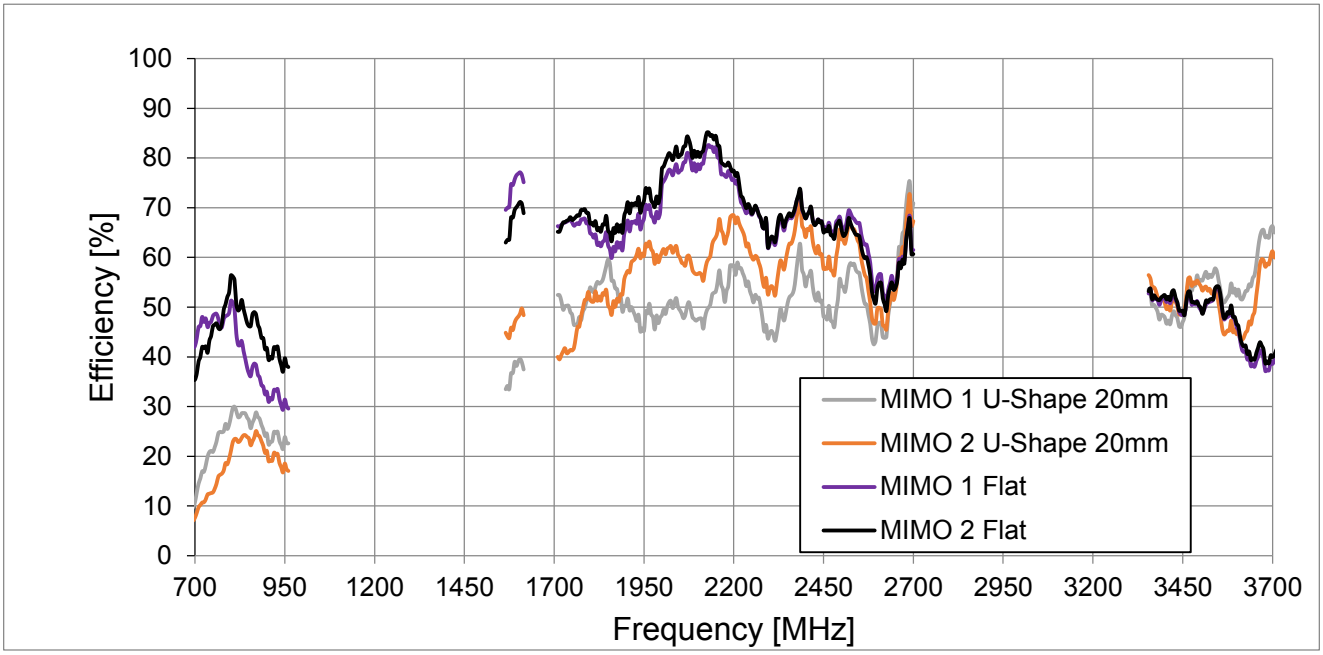
From the return loss results of the 15mm / 20mm/ 25mm / 40mm U-Shape it can be seen that the 20mm results can be chosen as a representative for the efficiency, peak gain and average gain measurements as these results will be similar to the 15mm measurements. As the isolation for 25 mm/40mm U shape bend diameter are better the efficiency results will be between the best case (flat) and the worst case (20 mm bend diameter). This can also be applied for the U-Shape 90mm-60mm-90mm.

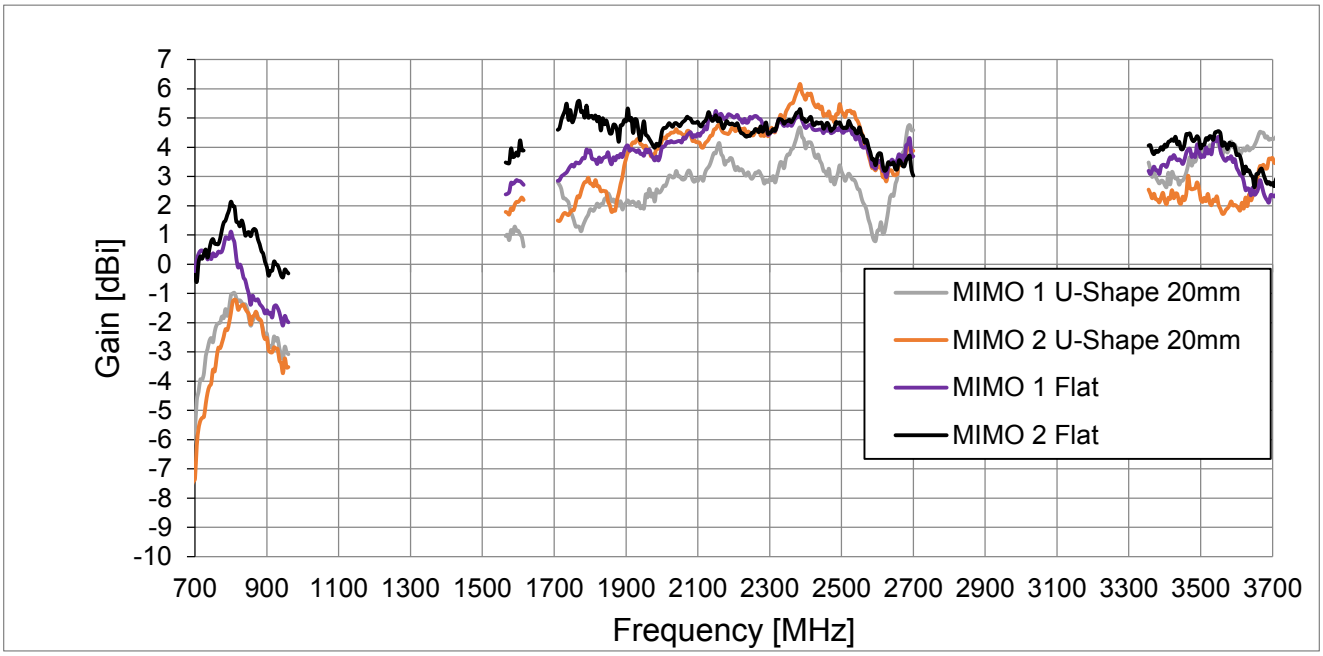
The 90° L-Shape can be studied further for efficiency measurements as these results can serve as a reference when determining similar antenna configurations.

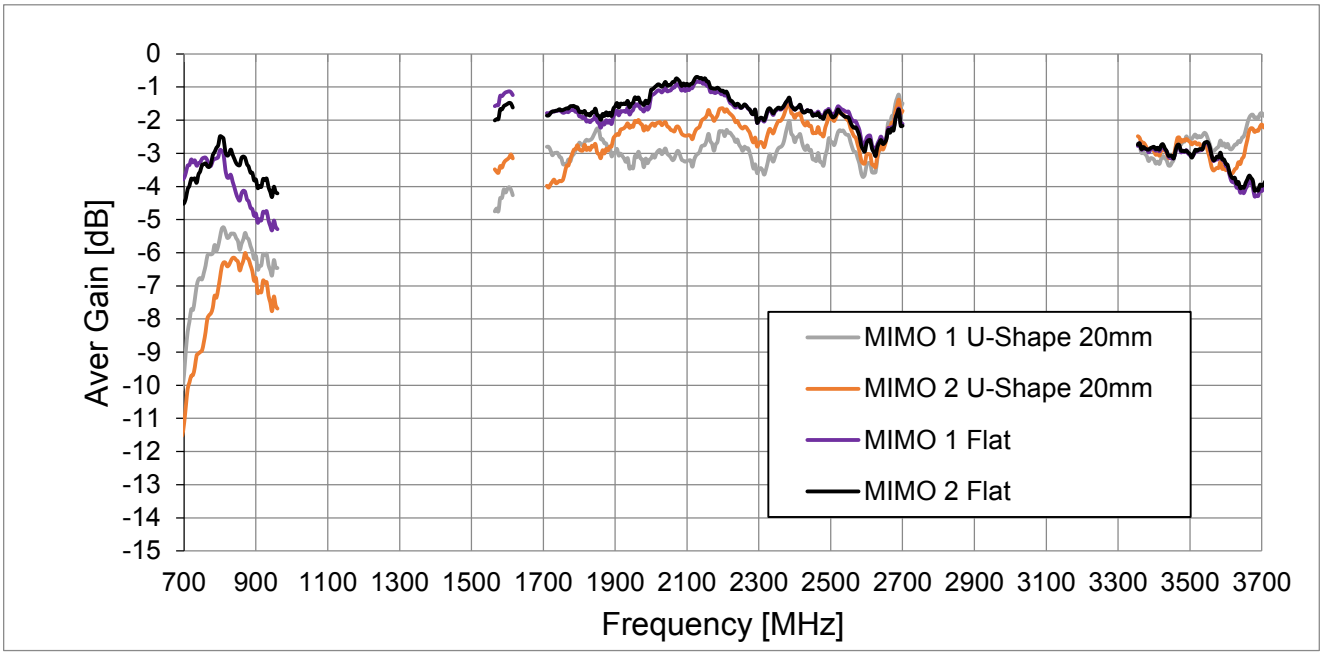
Further evaluation of the 2mm U-Bend is not necessary because we have very poor results from S11 and S21 measurements which means that the efficiency will be lower than that of the 20 mm bend.

4 Efficiency Results

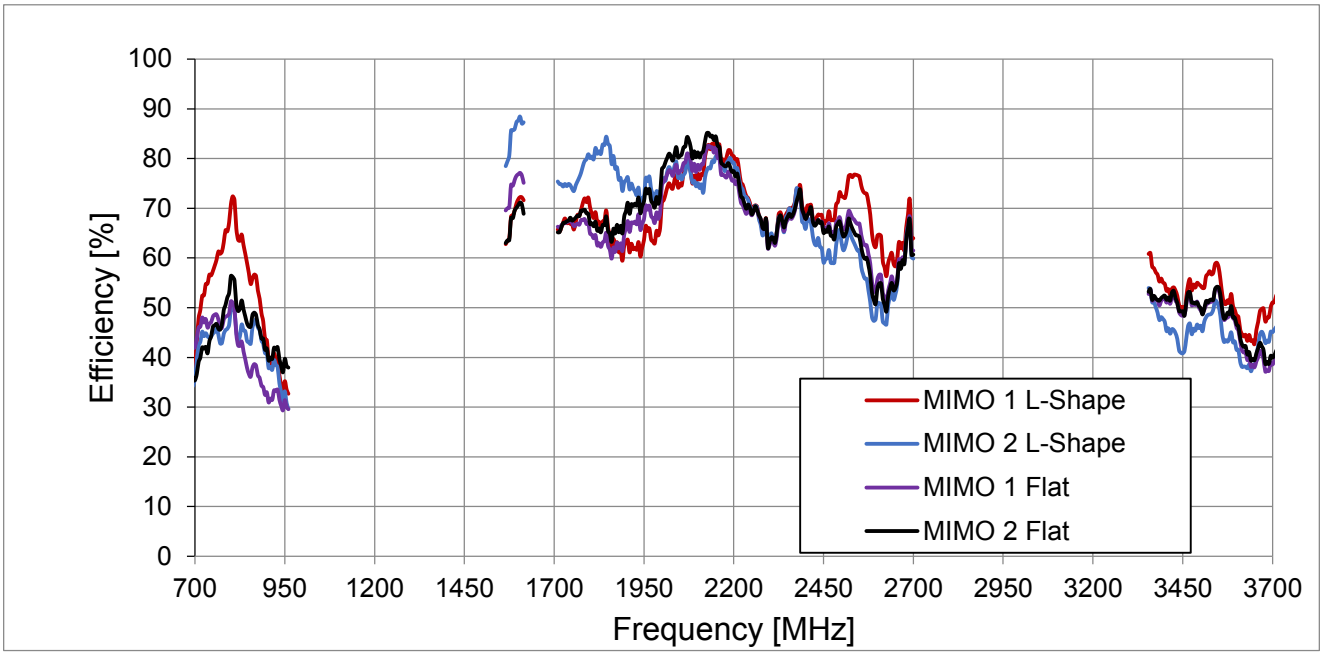
4.1 U-Shape 20mm vs Flat

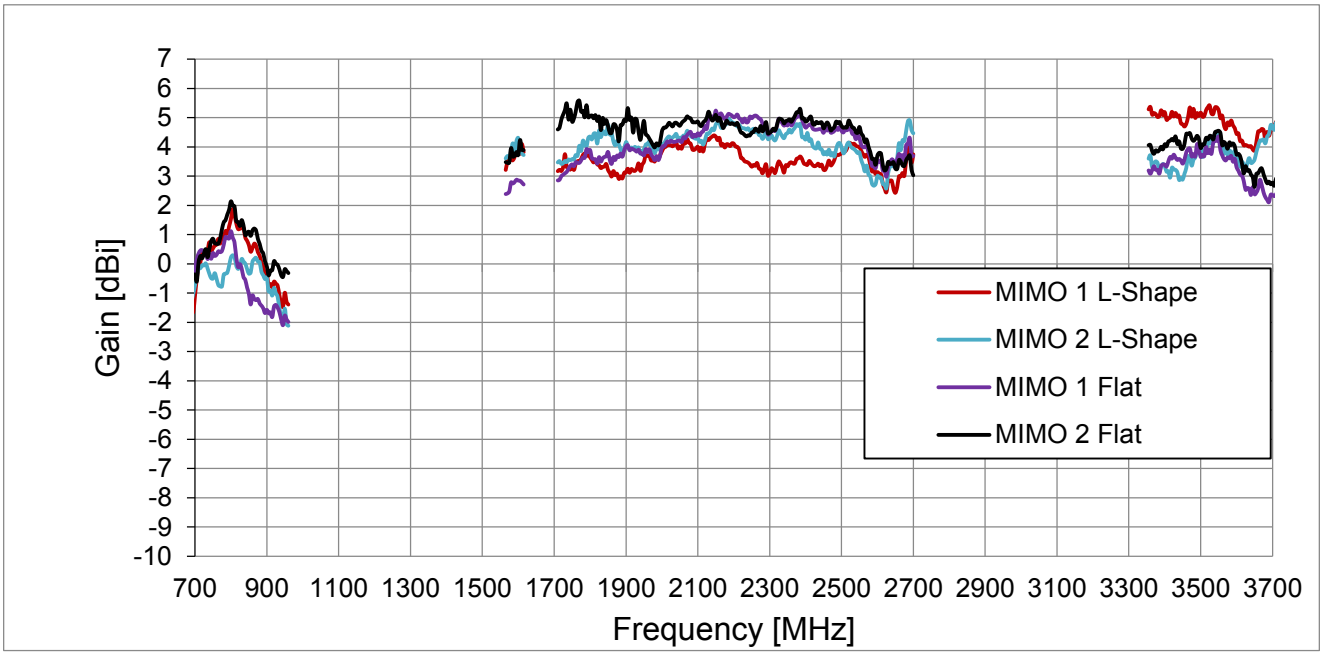


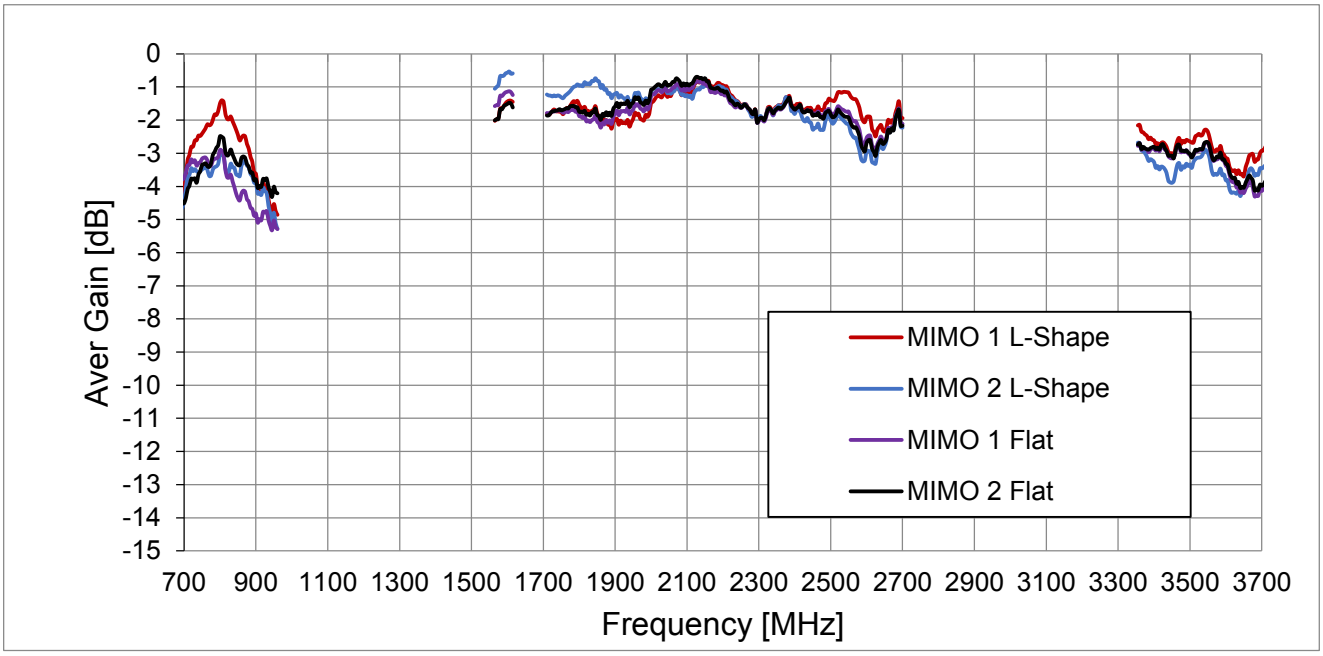




4.2 90° L-Shape vs Flat



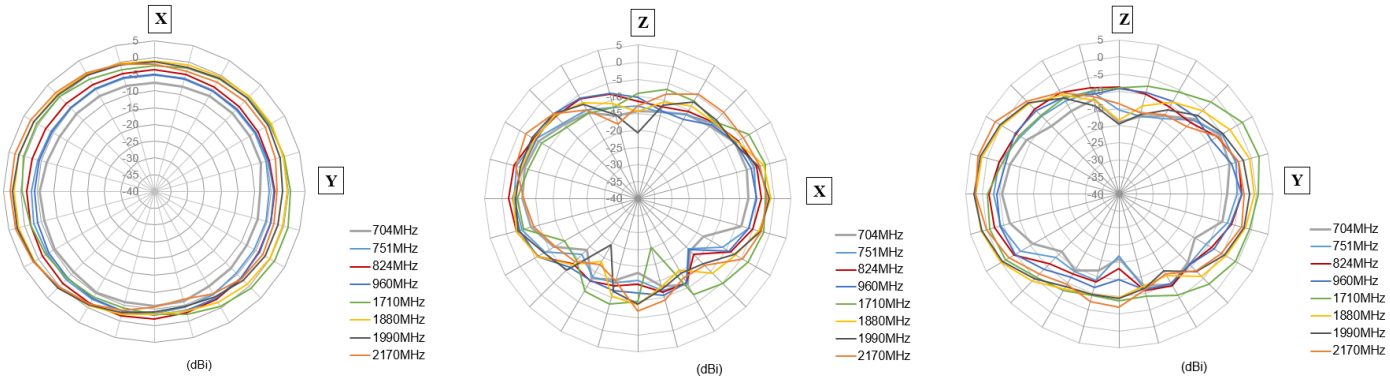

Gain [dBi]
7
6
5
4
3
2
1
0
-1
-2
-3
-4
-5
-6
-7
-8
-9
-10
700 900 1100 1300 1500 1700 1900 2100 2300 2500 2700 2900 3100 3300 3500 3700
Frequency [MHz]
MIMO 1 L-Shape
MIMO 2 L-Shape
MIMO 1 Flat
MIMO 2 Flat


Aver Gain [dB]
0
-1
-2
-3
-4
-5
-6
-7
-8
-9
-10
-11
-12
-13
-14
-15
700 900 1100 1300 1500 1700 1900 2100 2300 2500 2700 2900 3100 3300 3500 3700
Frequency [MHz]
MIMO 1 L-Shape
MIMO 2 L-Shape
MIMO 1 Flat
MIMO 2 Flat

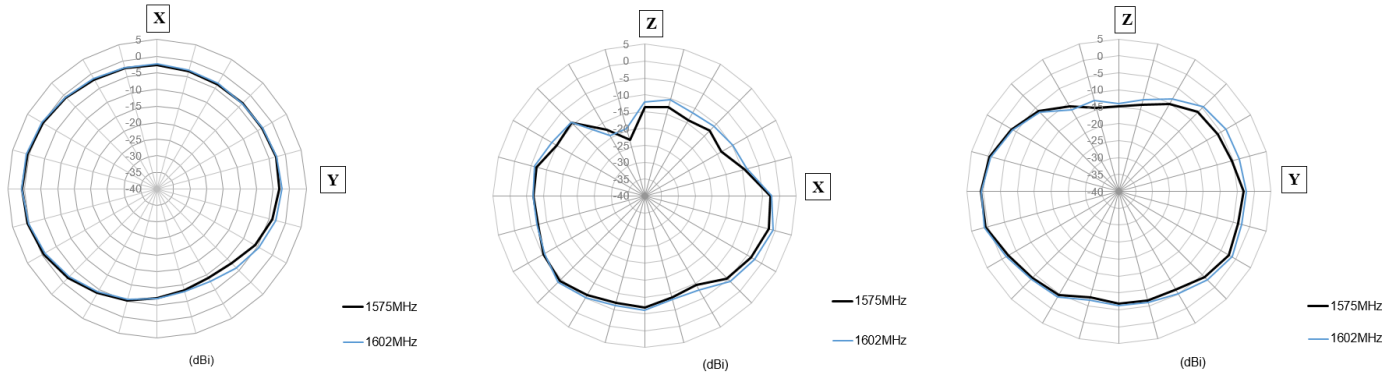
5 Radiation Pattern

5.1 20mm U-Shape MIMO 1

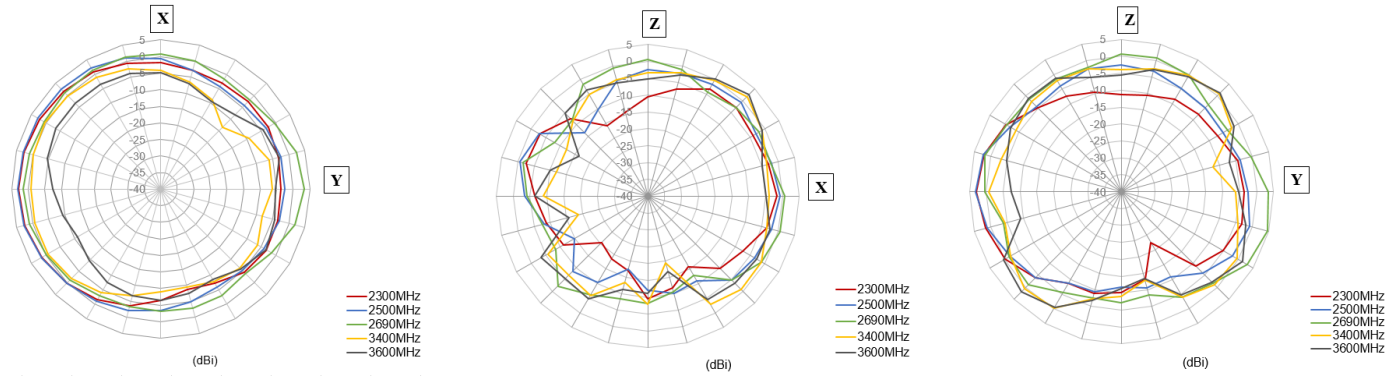
5.1.1 704MHz – 2170MHz



5.1.2 1575 MHz and 1602 MHz

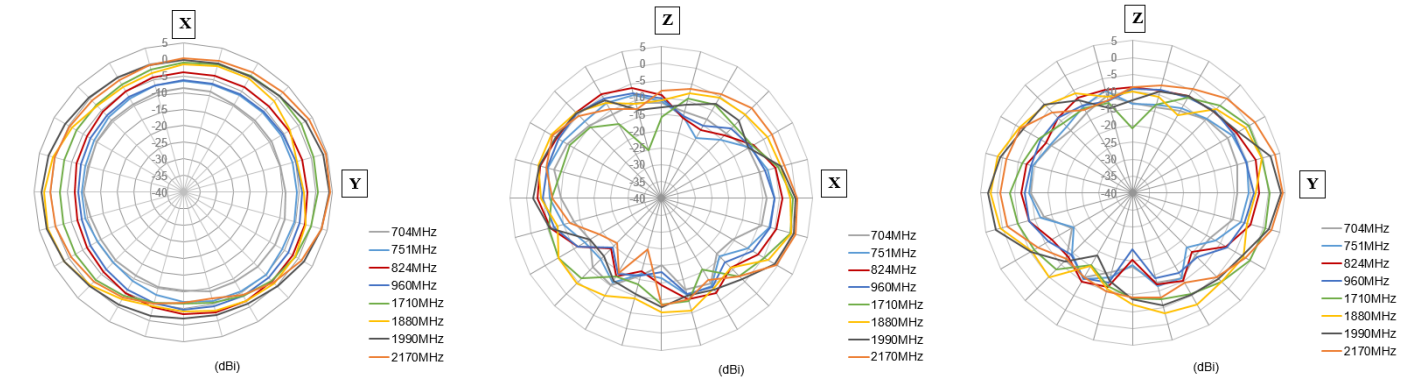


5.1.3 2300MHz – 3600MHz

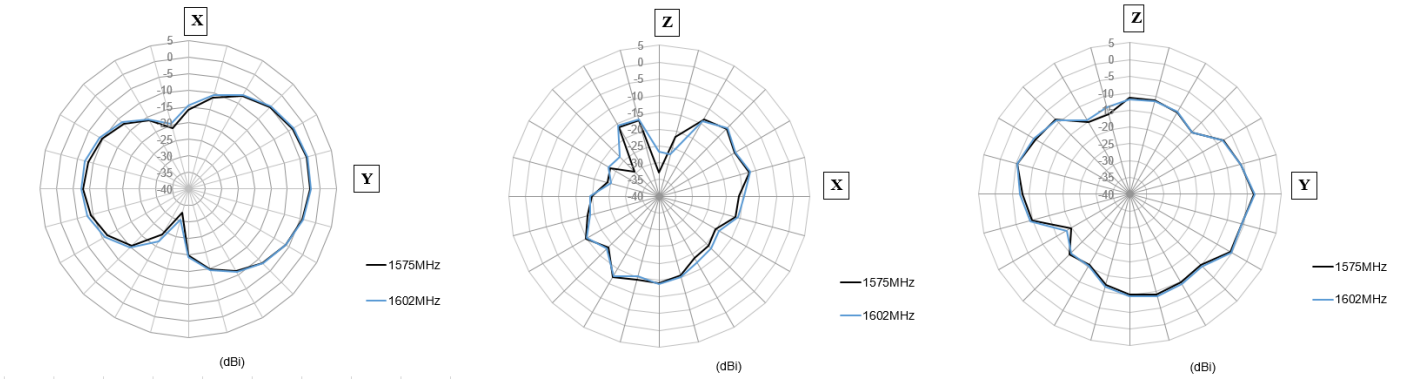


5.2 20mm U-Shape MIMO 2

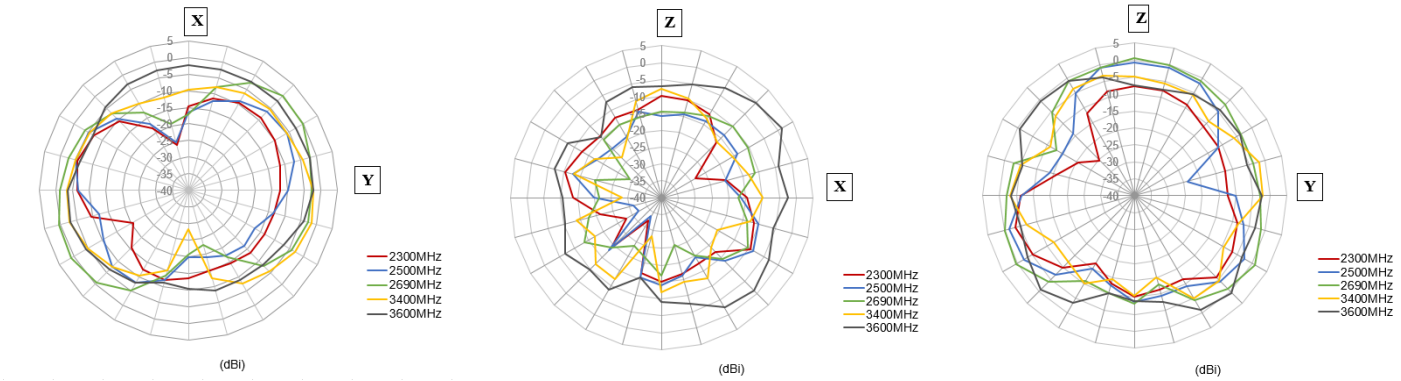
5.2.1 704MHz – 2170MHz



5.2.2 1575MHz – 1602MHz

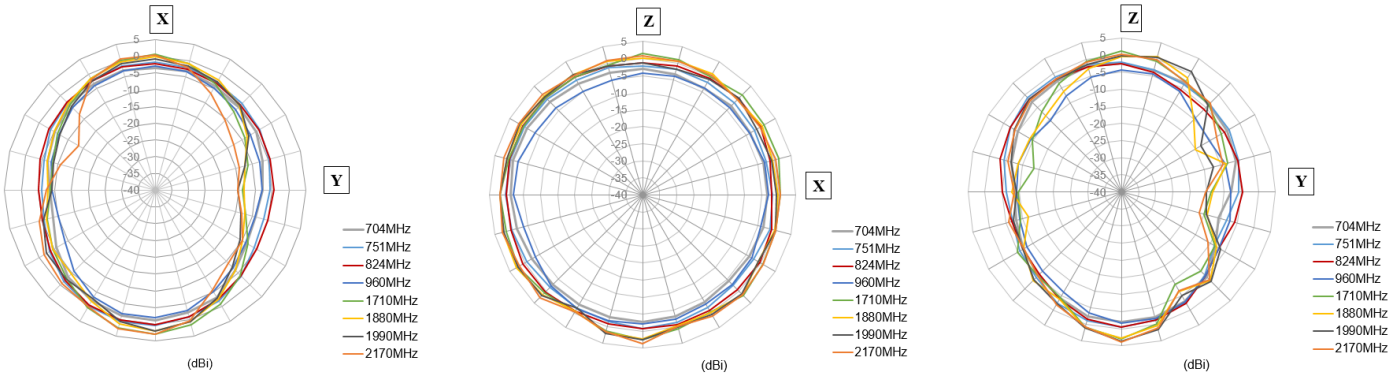


5.2.3 2300MHz – 3600MHz

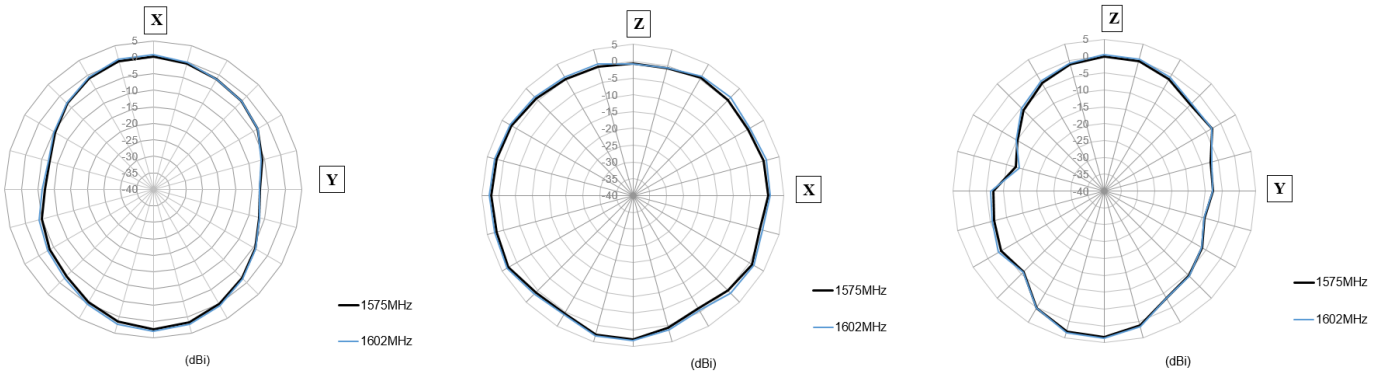


5.3 90° L-Shape MIMO 1

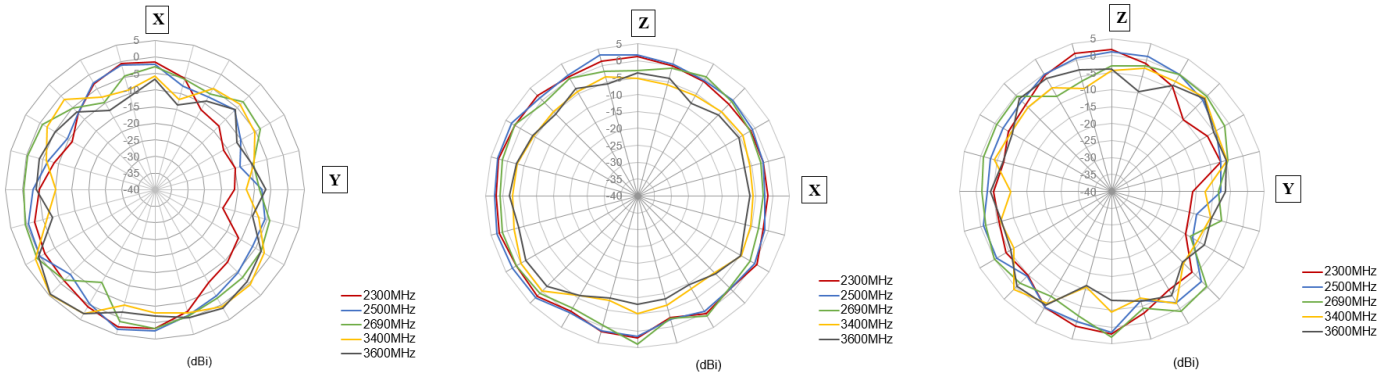
5.3.1 704MHz – 2170MHz



5.3.2 1575MHz – 1602MHz

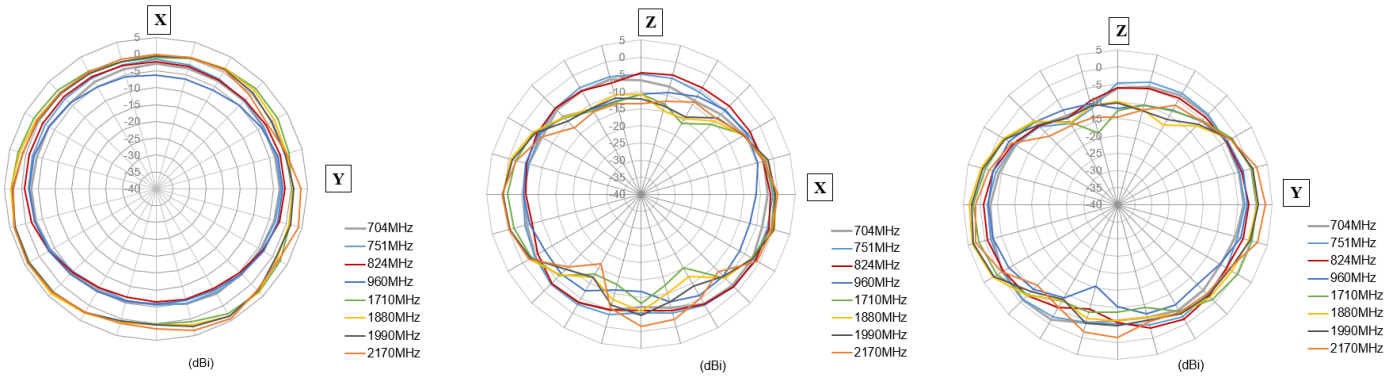


5.3.3 2300MHz – 3600MHz

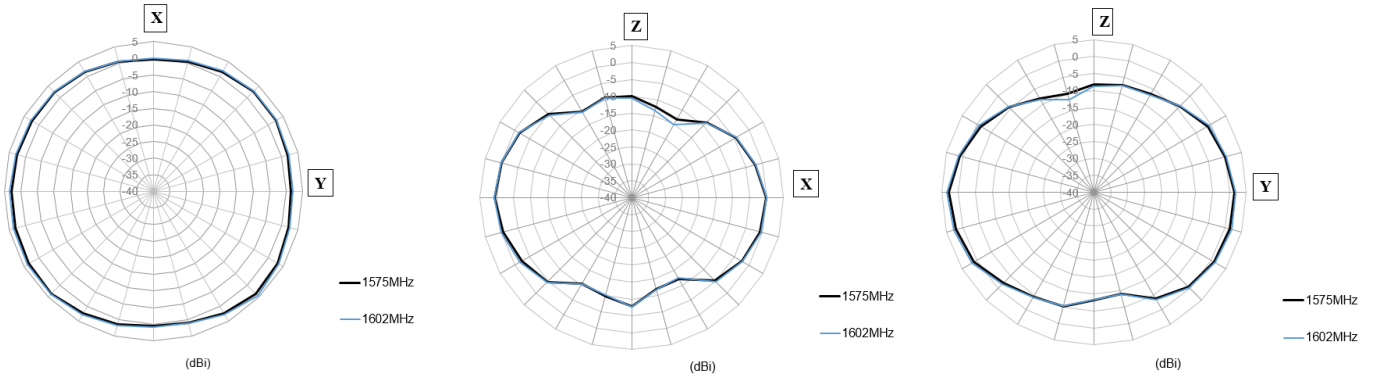


5.4 90° L-Shape MIMO 2

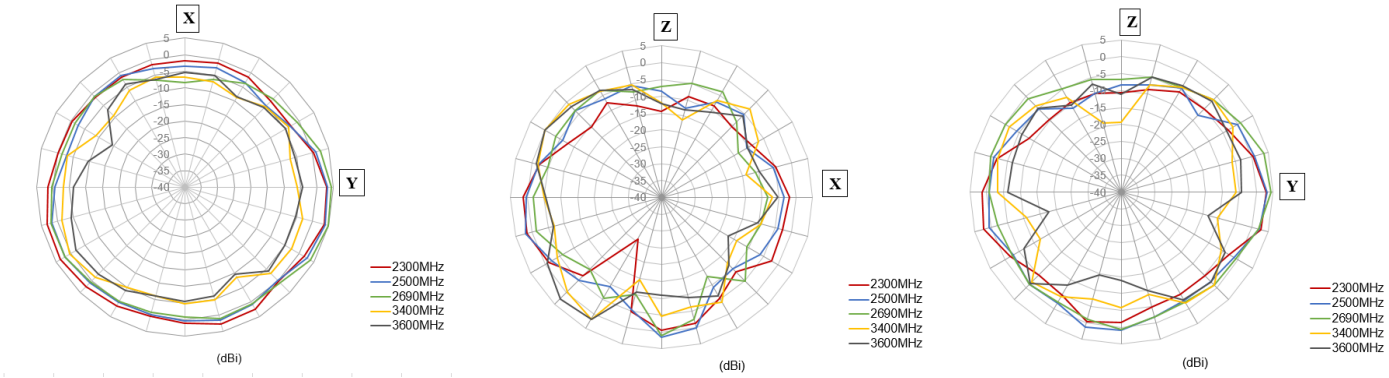
5.4.1 704MHz – 2170MHz



5.4.2 1575MHz – 1602MHz

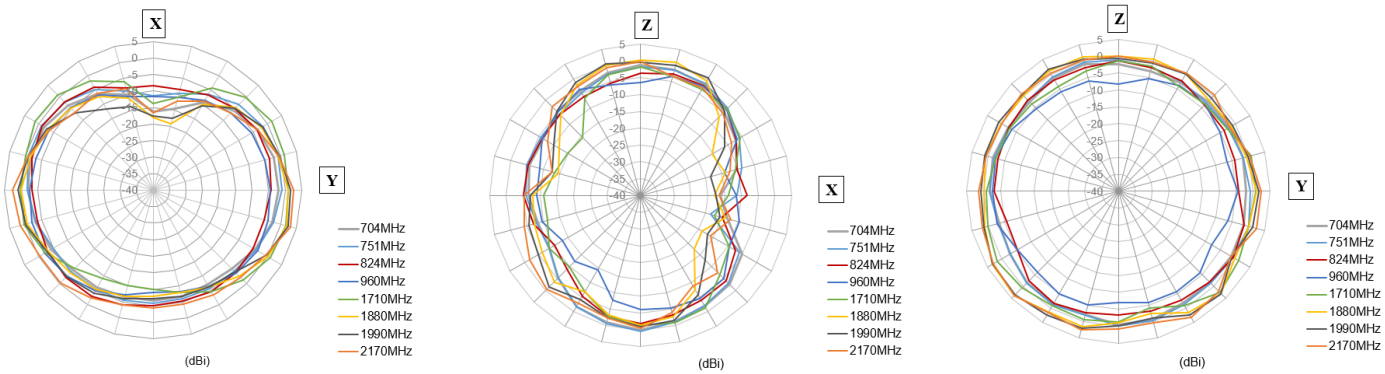


5.4.3 2300MHz – 3600MHz

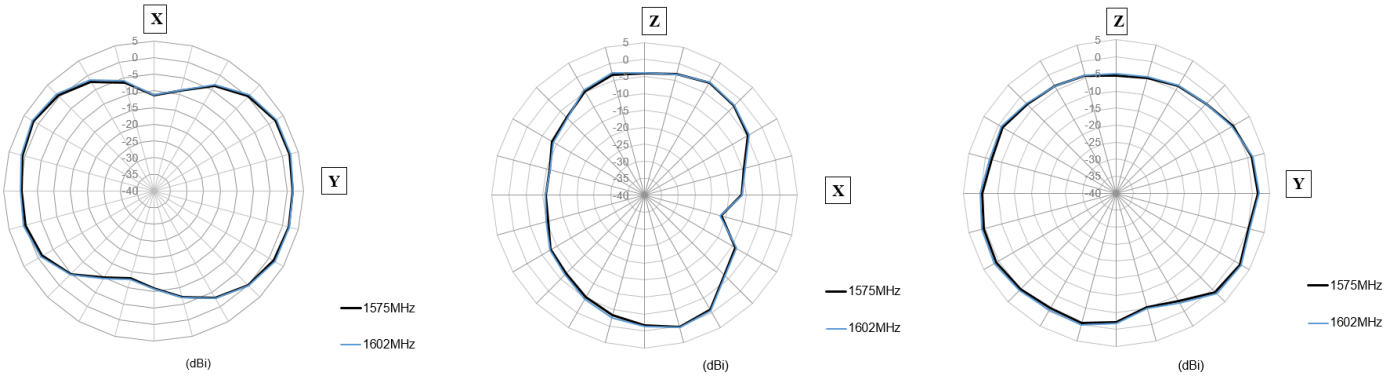


5.5 Flat MIMO 1

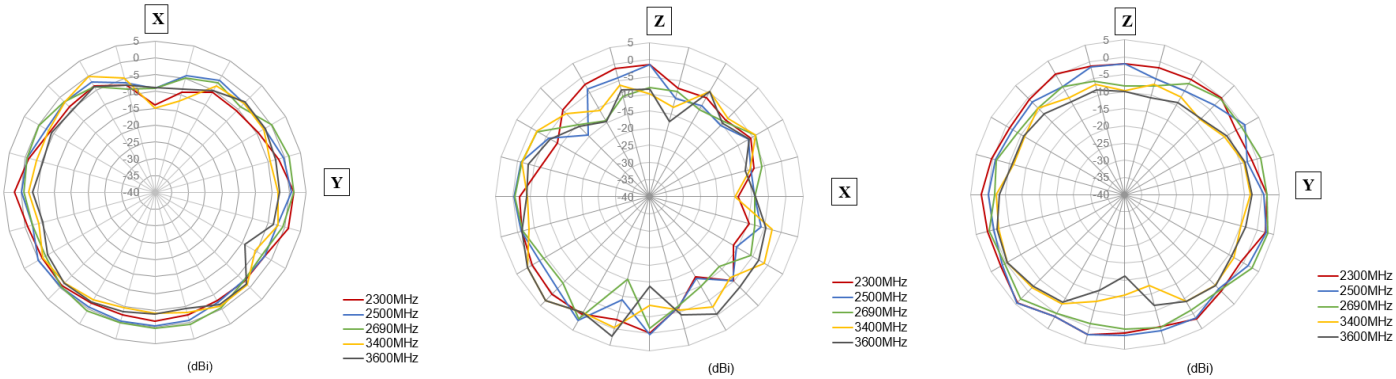
5.5.1 704MHz – 2170MHz



5.5.2 1575MHz – 1602MHz

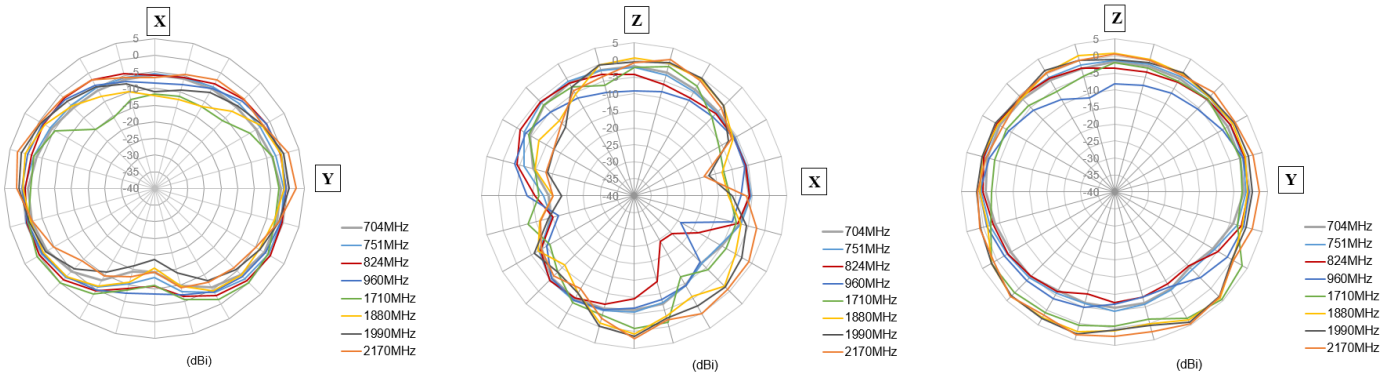


5.5.3 2300MHz – 3600MHz

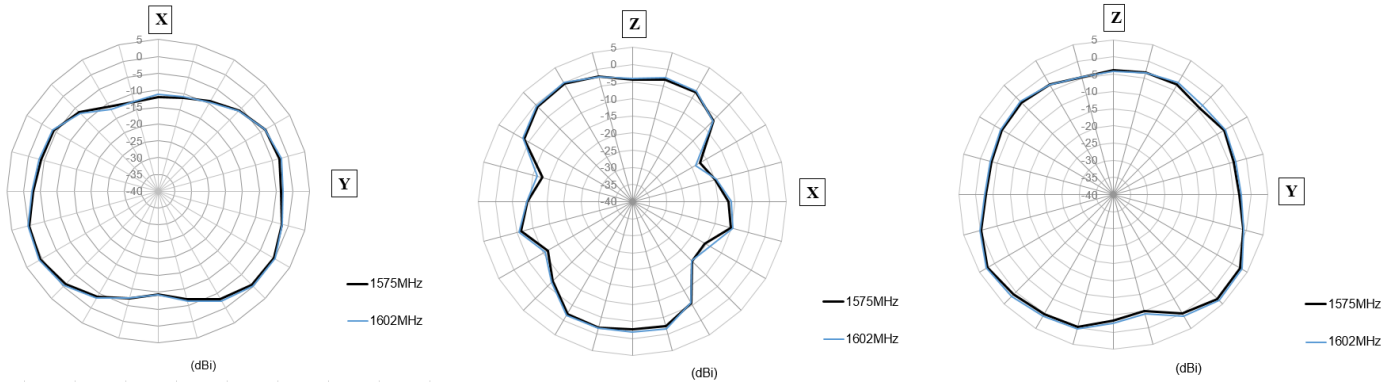


5.6 Flat MIMO 2

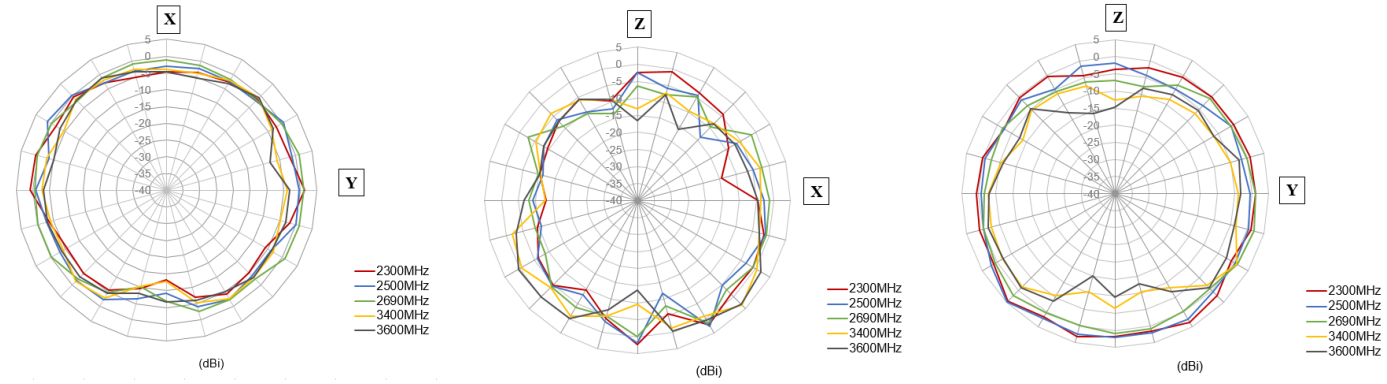
5.6.1 704MHz – 2170MHz



5.6.2 1575MHz – 1602MHz



5.6.3 2300MHz – 3600MHz



6 Conclusion

The table below outlines the results from the tests performed. The results shown are the minimum value in the bands shown.

FXUB.71 Bend Influence											
	Band	28	5	8	GPS ~ GNSS	3	2	1	WiFi	7	42
	Frequency MHz	703~ 803	824~ 894	880~ 960	1565~ 1612	1710~ 1880	1850~ 1990	1920~ 2170	2400~ 2500	2500~ 2690	3400~ 3600
		Efficiency (%)									
FXUB.71 Flat	MIMO 1	42	32	30	69	60	60	65	64	50	46
	MIMO 2	35	41	37	63	63	63	69	63	49	46
FXUB.71 20mm U-Shape	MIMO 1	12	24	21	33	46	45	45	46	42	46
	MIMO 2	9	21	17	44	39	48	55	56	45	44
FXUB.71 90° L-Shape	MIMO 1	43	43	33	63	61	59	60	67	56	48
	MIMO 2	39	41	30	78	73	70	70	59	46	41
		Peak Gain (dBi)									
FXUB.71 Flat	MIMO 1	0.2	-1.7	-2.1	2.3	2.8	3.4	3.5	4.4	3.0	3.3
	MIMO 2	-0.6	0.3	-0.4	3.4	4.2	4.0	4.0	4.5	3.1	3.7
FXUB.71 20mm U-Shape	MIMO 1	-4.6	-2.2	-3.2	0.6	1.1	1.8	1.9	2.7	0.8	2.6
	MIMO 2	-6.2	-2.4	-3.7	1.7	1.4	1.8	3.7	4.8	2.8	1.7
FXUB.71 90° L-Shape	MIMO 1	-0.5	-0.1	-1.4	3.25	2.9	2.9	3.1	3.2	2.4	4.4
	MIMO 2	-0.7	-0.4	-2.1	3.6	3.4	3.7	3.7	3.6	2.6	2.8

The minimum efficiency of the 20mm U-Shape is very poor in the low band particularly in Band 28 (703MHz – 803MHz). The 20mm U-Shape antenna configuration is not recommended for this band. For higher frequencies this configuration performs very well.

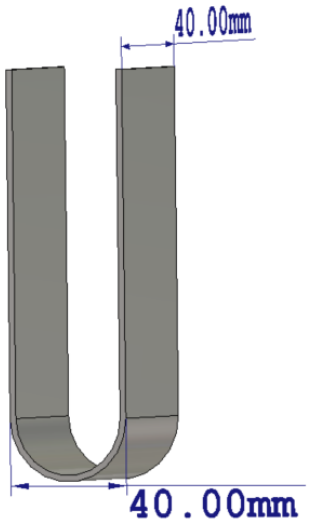
The 20 mm U-shape is the minimum acceptable bend for which the isolation is still good between the two MIMO antennas, however this shape results in poor efficiency for the low band. Next step is to discover the minimum bend diameter for which the low band performance is acceptable.

The 90° L-Shape configuration performs very well across all the bands with a minimum efficiency of 30% for MIMO 2 in Band 8 (880MHz – 960MHz). This configuration and similar configurations are recommended where space is a restriction. The measurements show that L-shape bend is acceptable to be used since both isolation and efficiency results are good for all frequency bands.

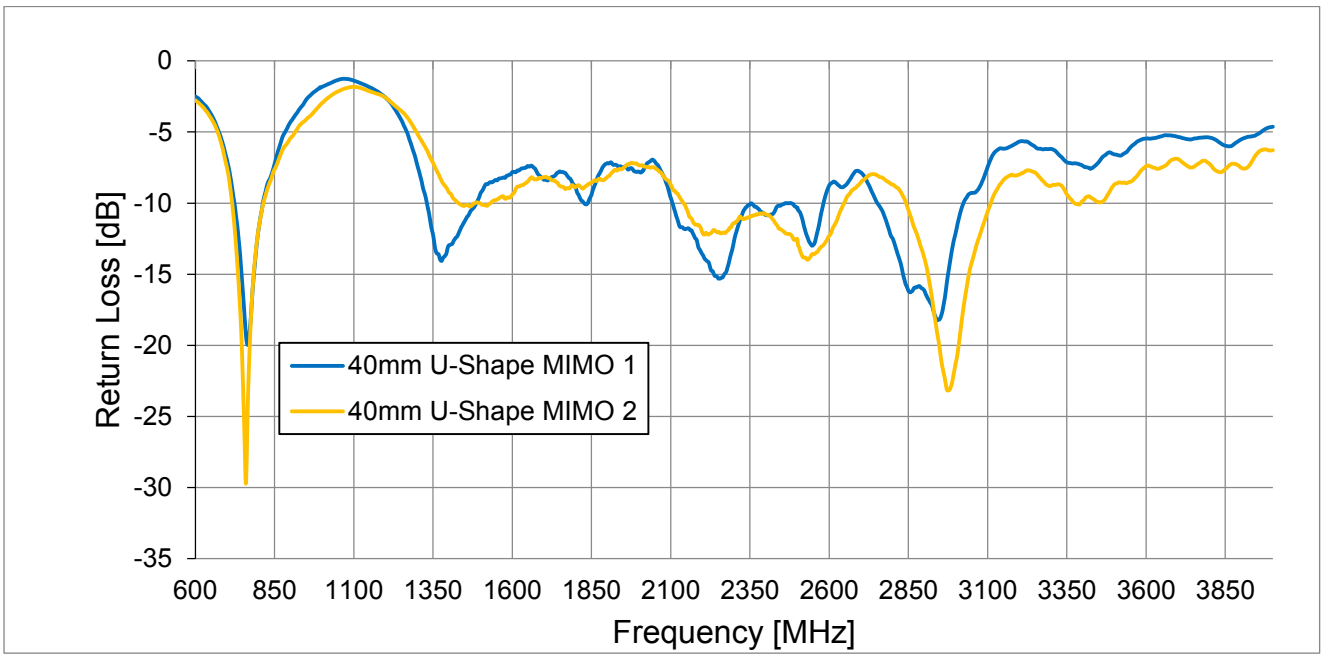
7 Further Study

A further study was completed to find the minimum diameter bend that would give minimum efficiency (20%) across all bands.

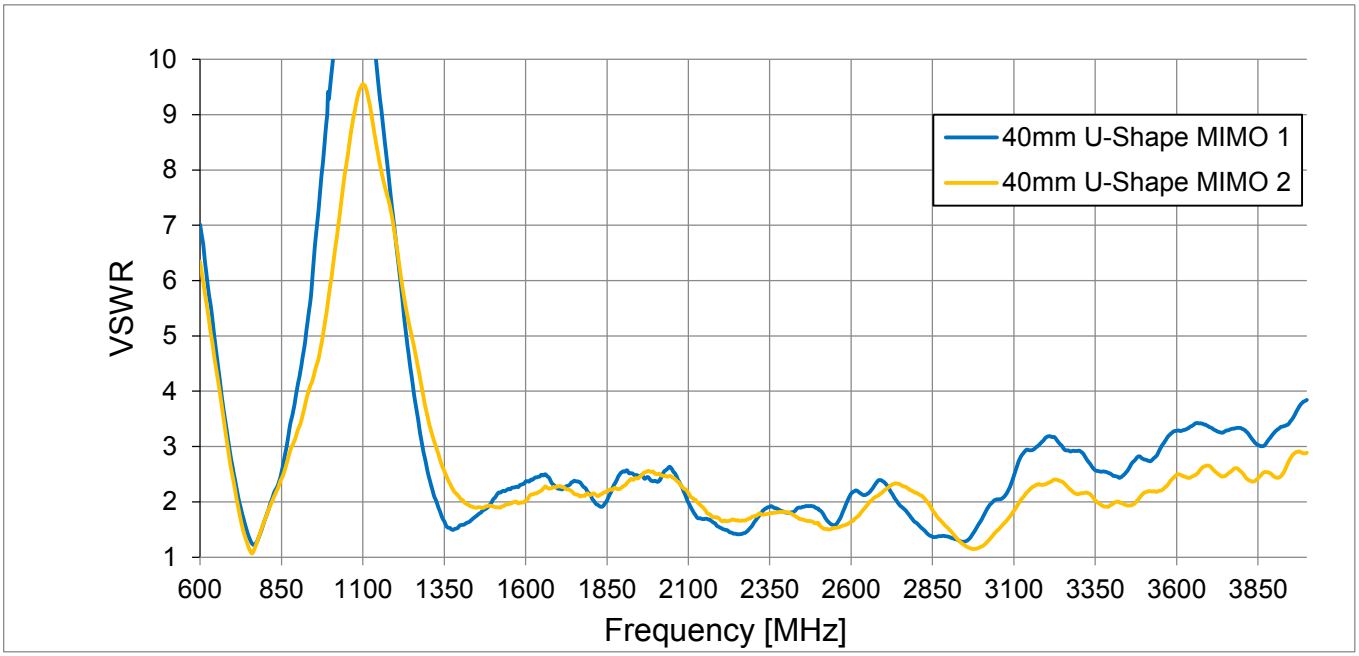
A 40mm U-Bend shape gives the minimum 20% efficiency on the low band.



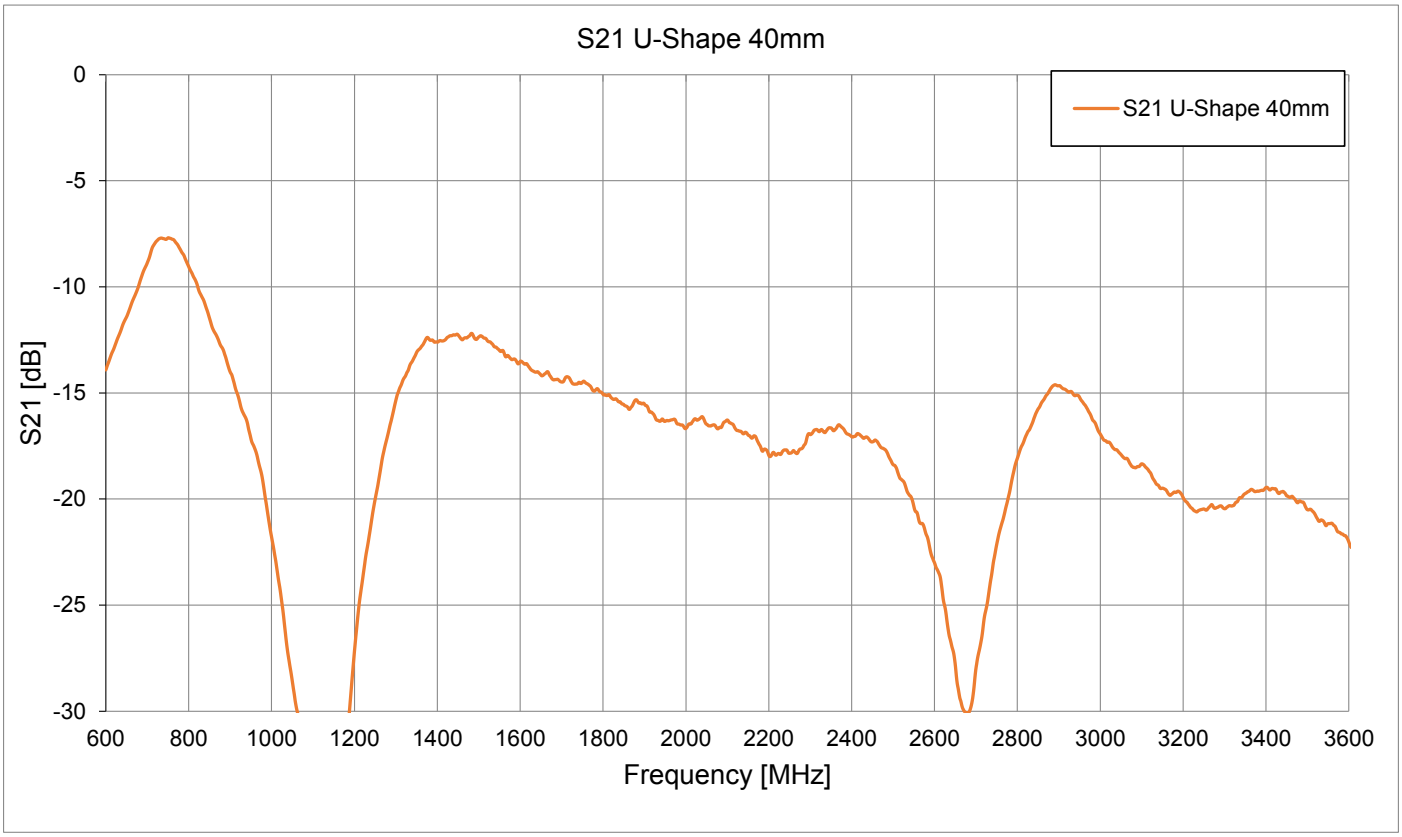
7.1 Return Loss



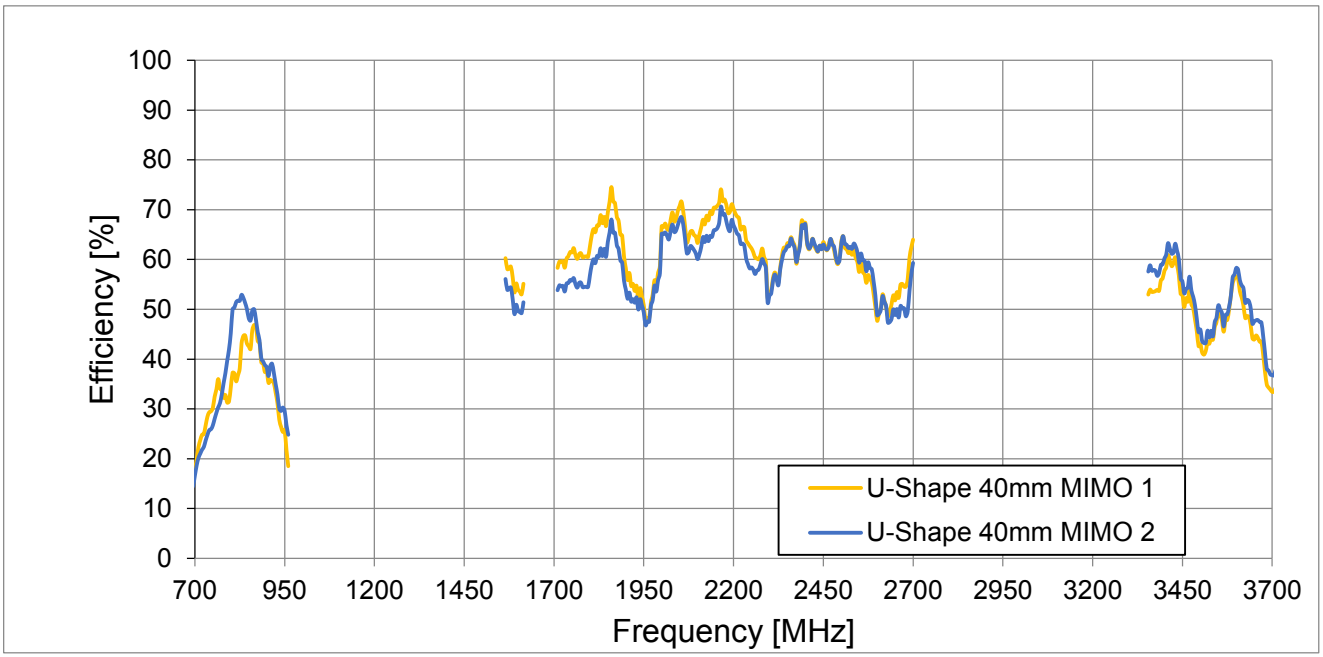
7.2 VSWR



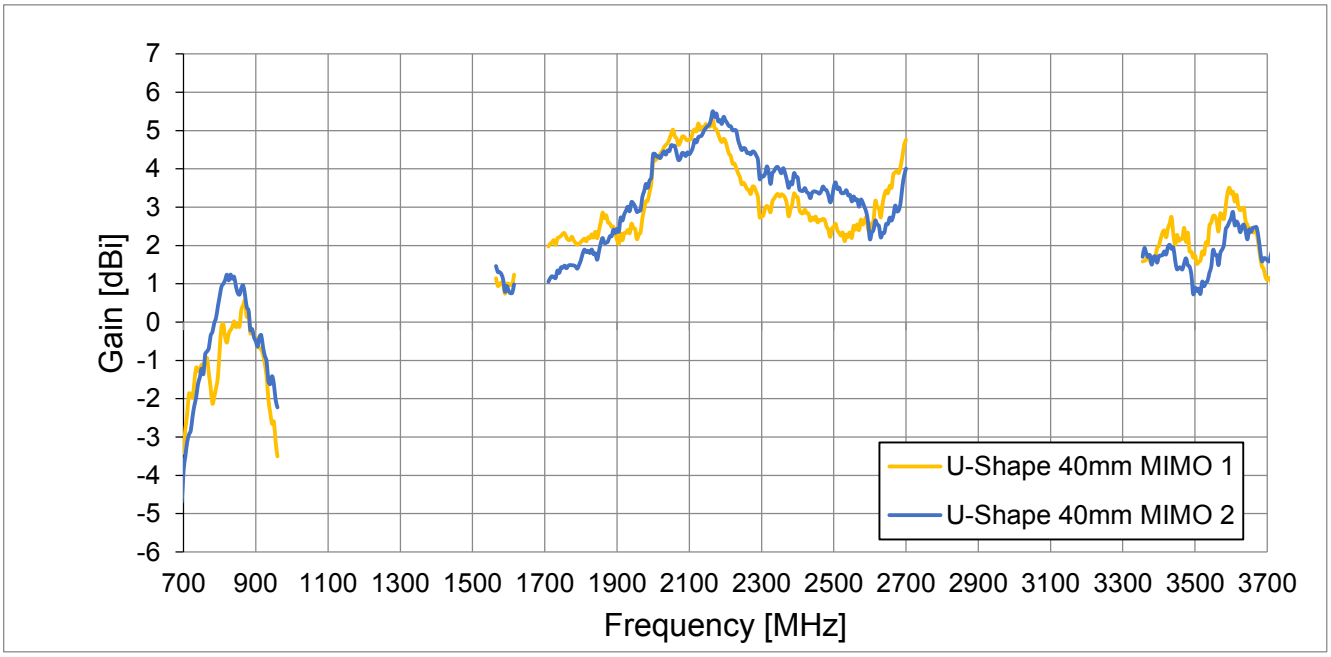
7.3 Isolation



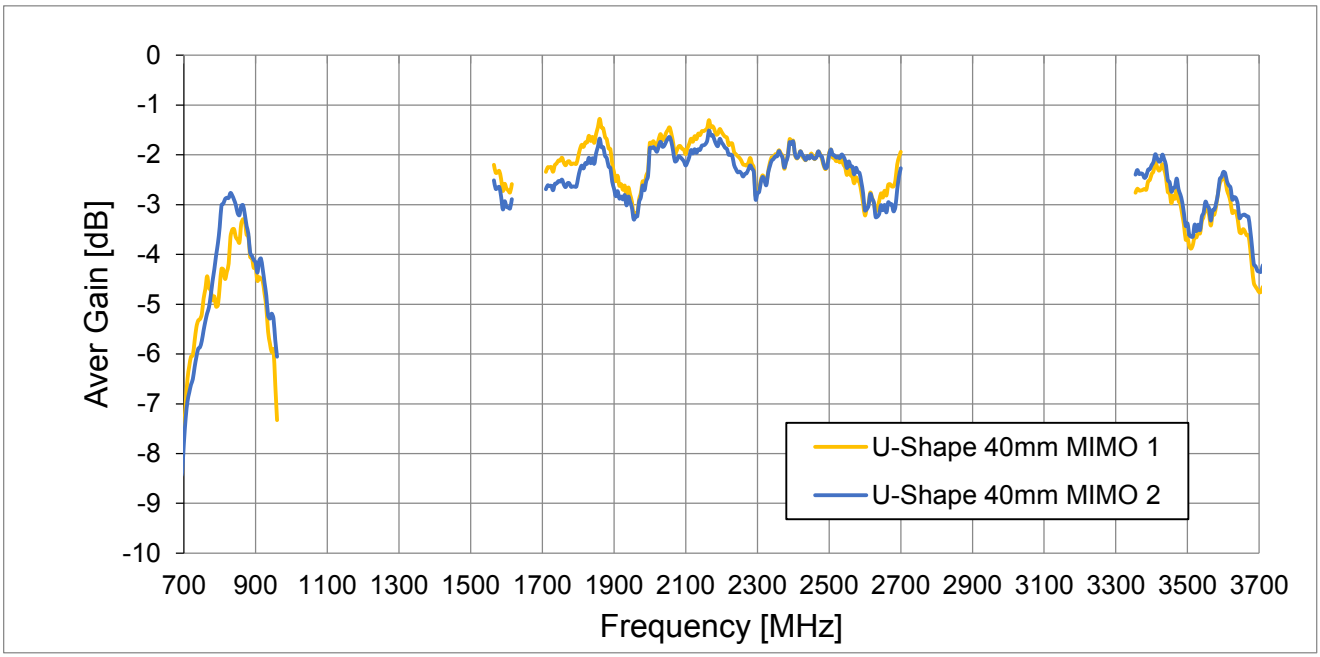
7.4 Efficiency



7.5 Peak Gain

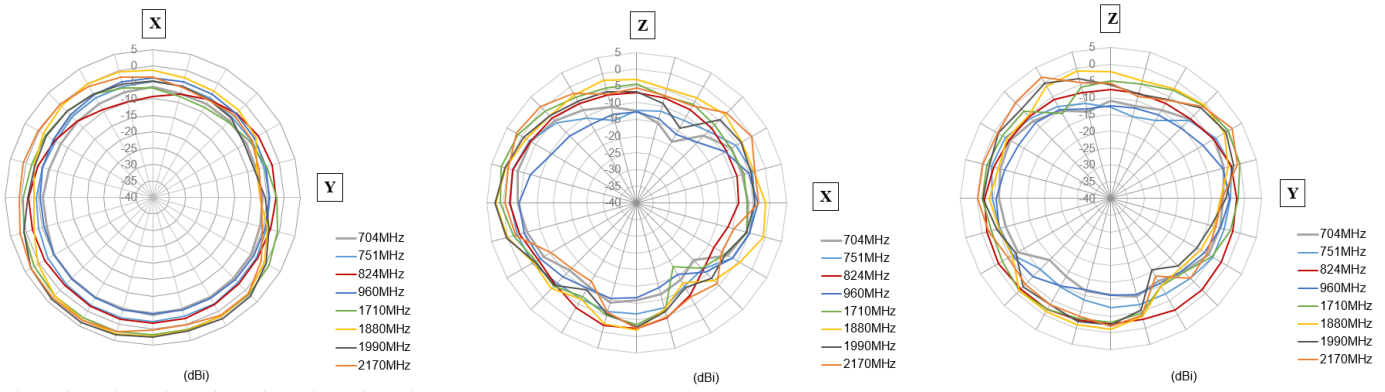


7.6 Average Gain

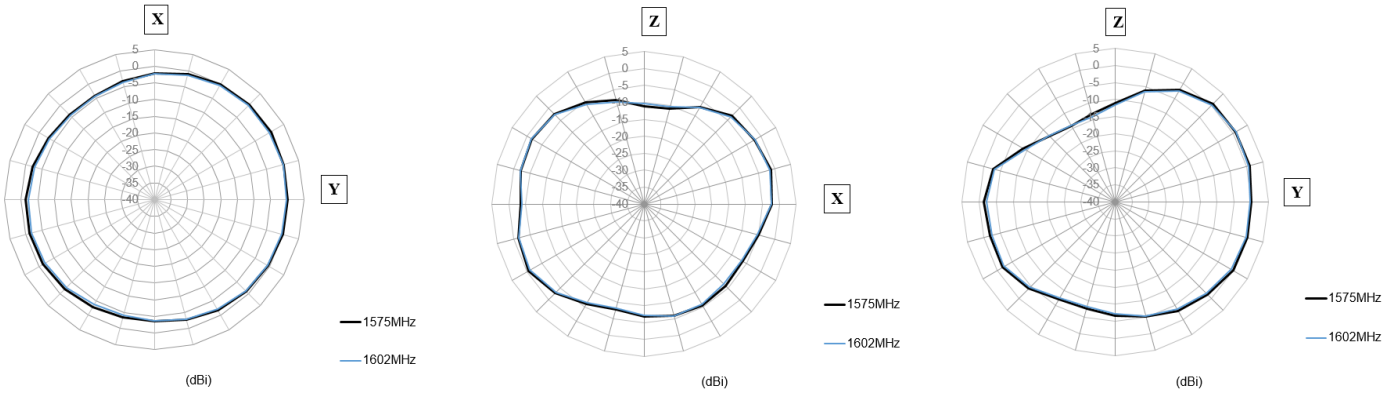


7.7 Radiation Pattern – 40mm U-Shape – MIMO 1

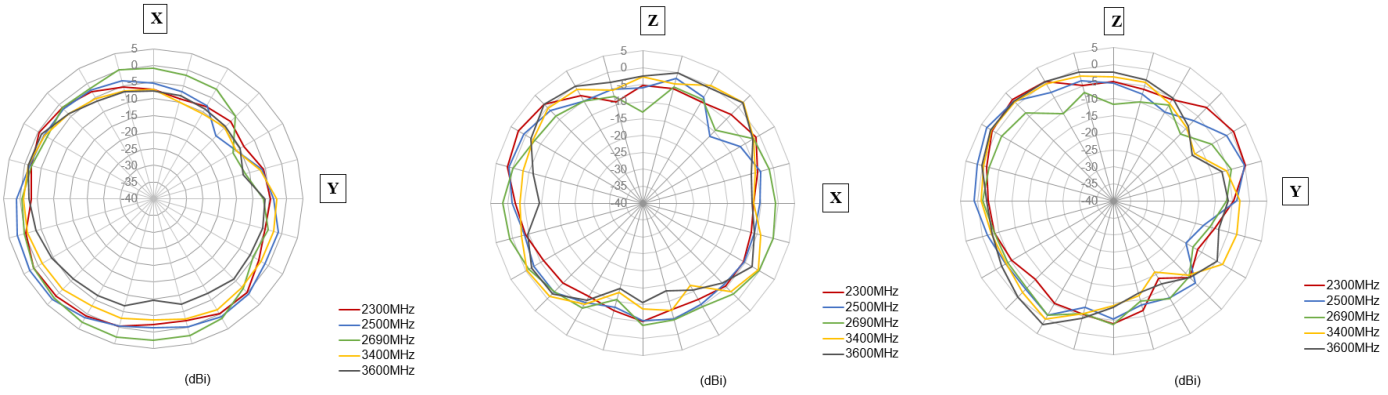
7.7.1 704MHz – 2170MHz



7.7.2 1575MHz – 1602MHz

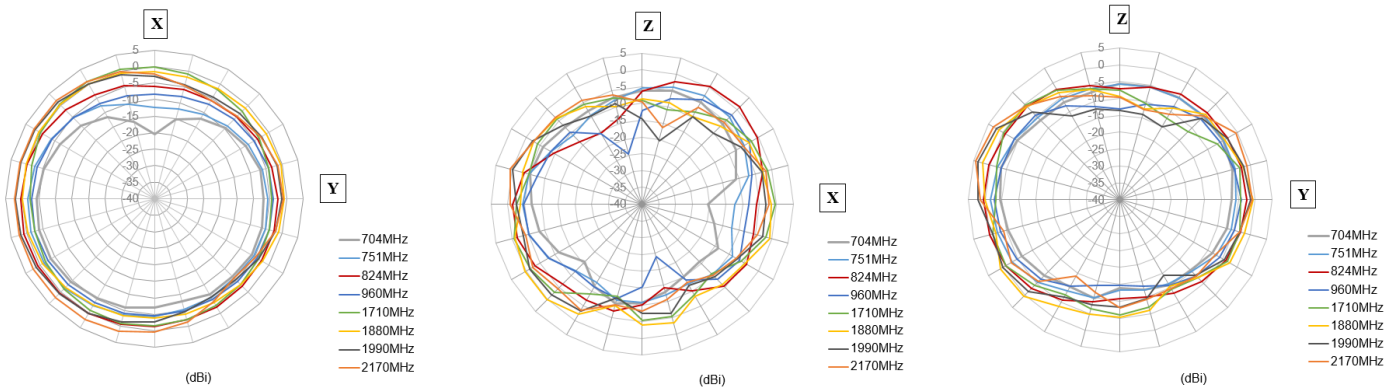


7.7.3 2300MHz – 3600MHz

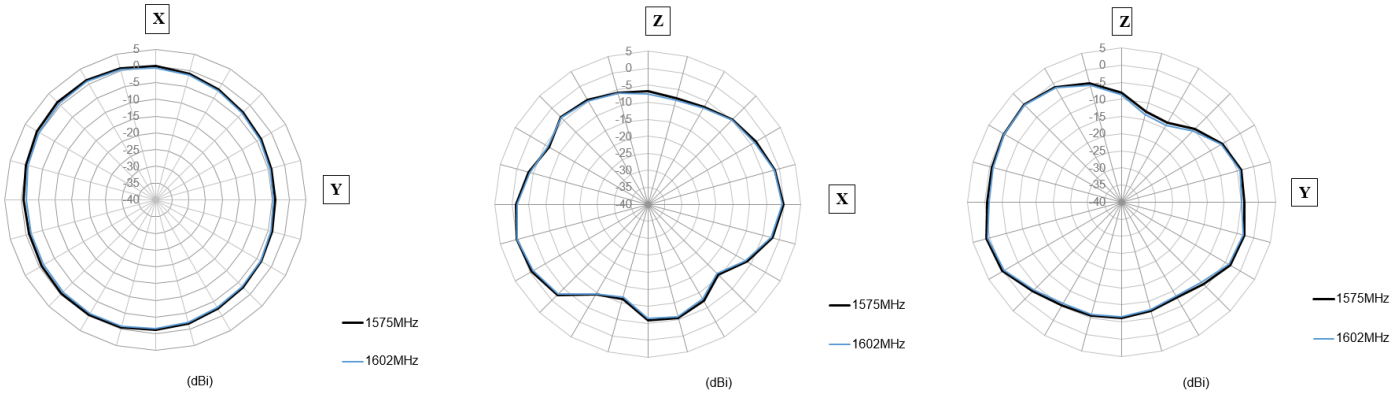


7.8 Radiation Pattern – 40mm U-Shape – MIMO 2

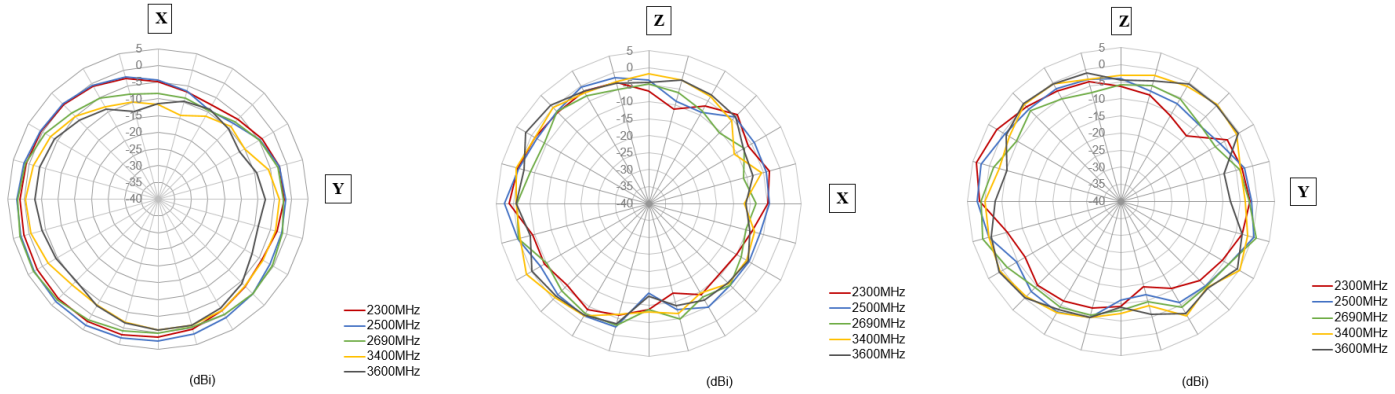
7.8.1 704MHz – 2170MHz



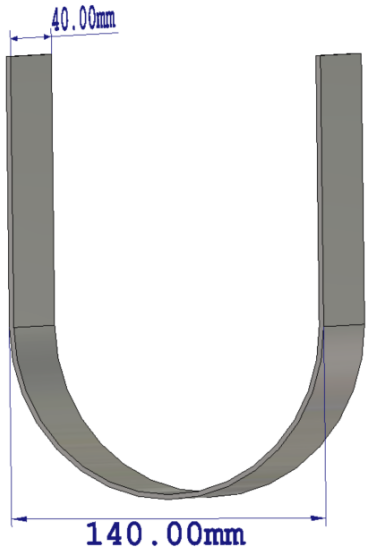
7.8.2 1575MHz – 1602MHz



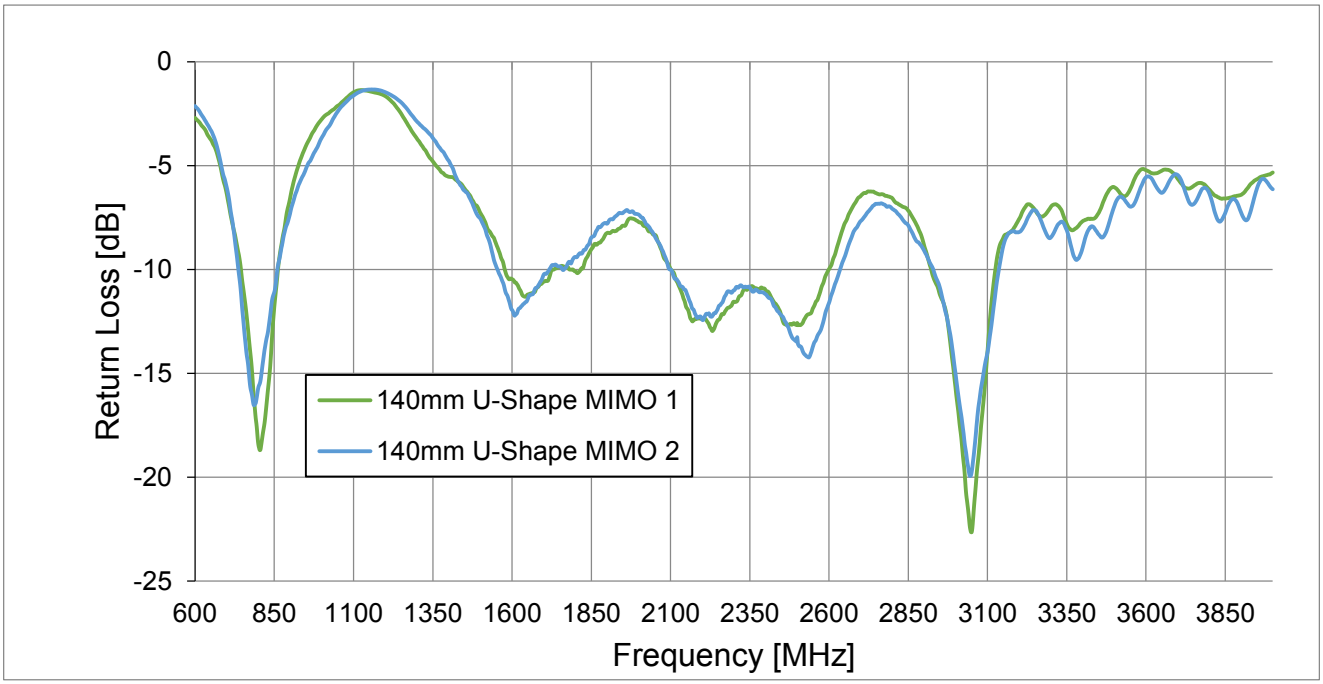
7.8.3 2300MHz – 3600MHz



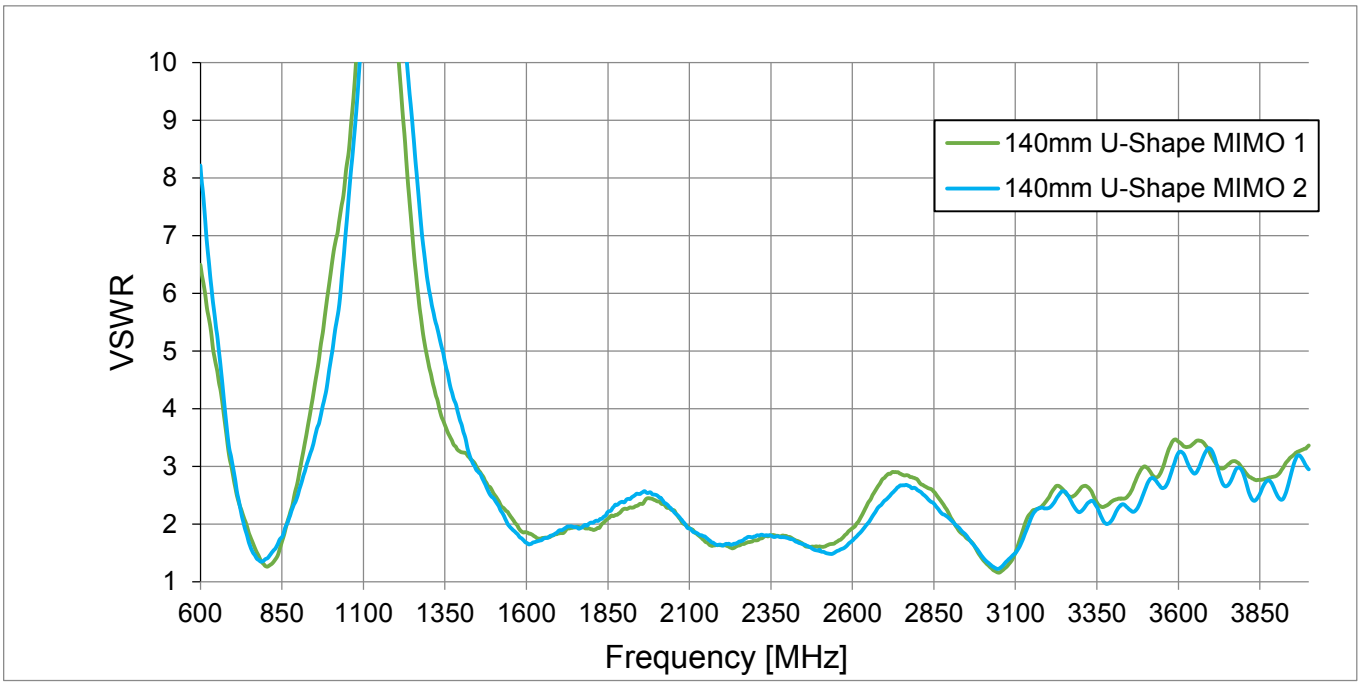
8 A curve shape that reflects customer use cases.



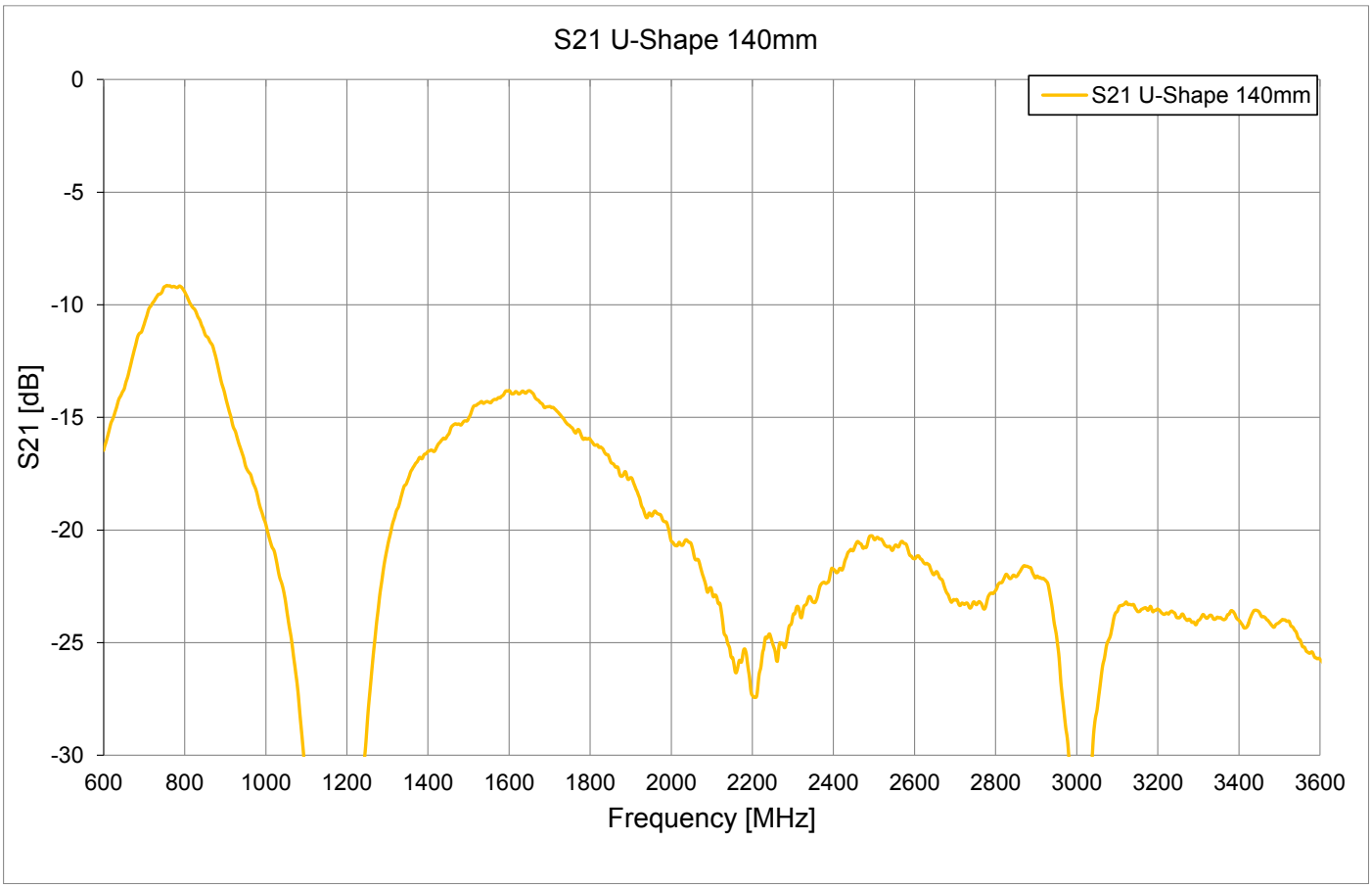
8.1 Return Loss – 140mm U-Shape



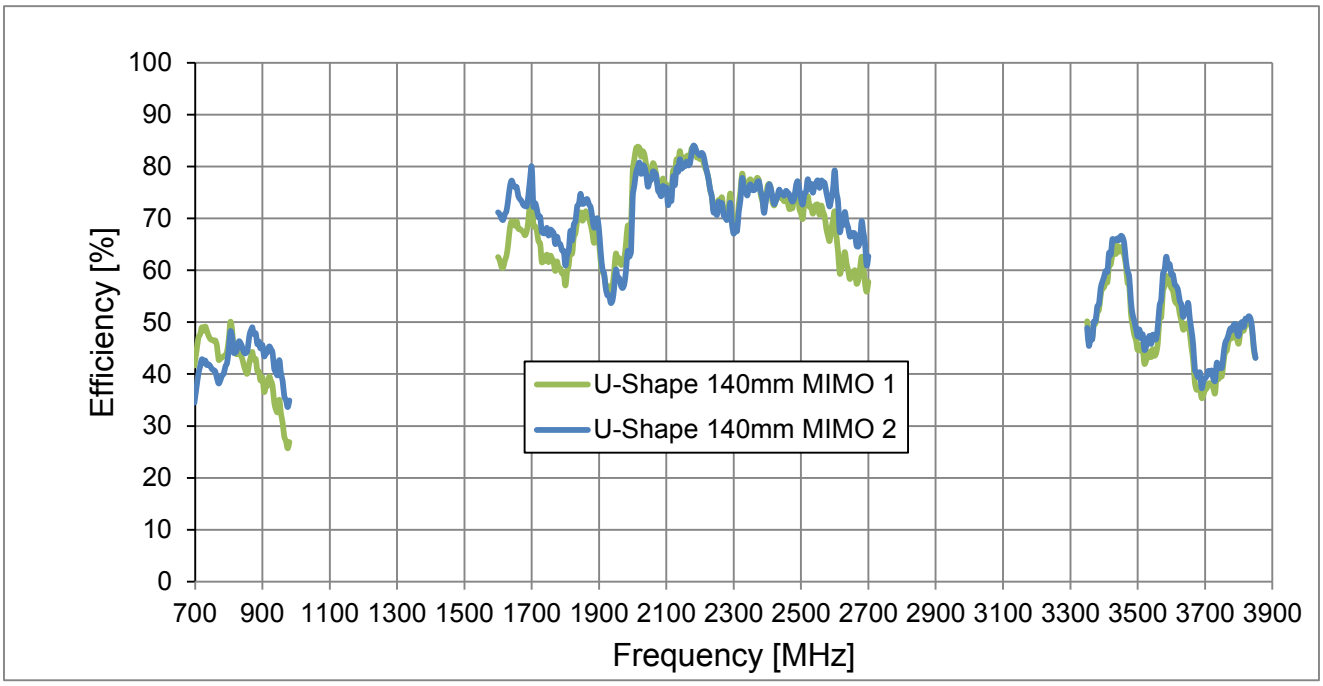
8.2 VSWR – 140mm U-Shape



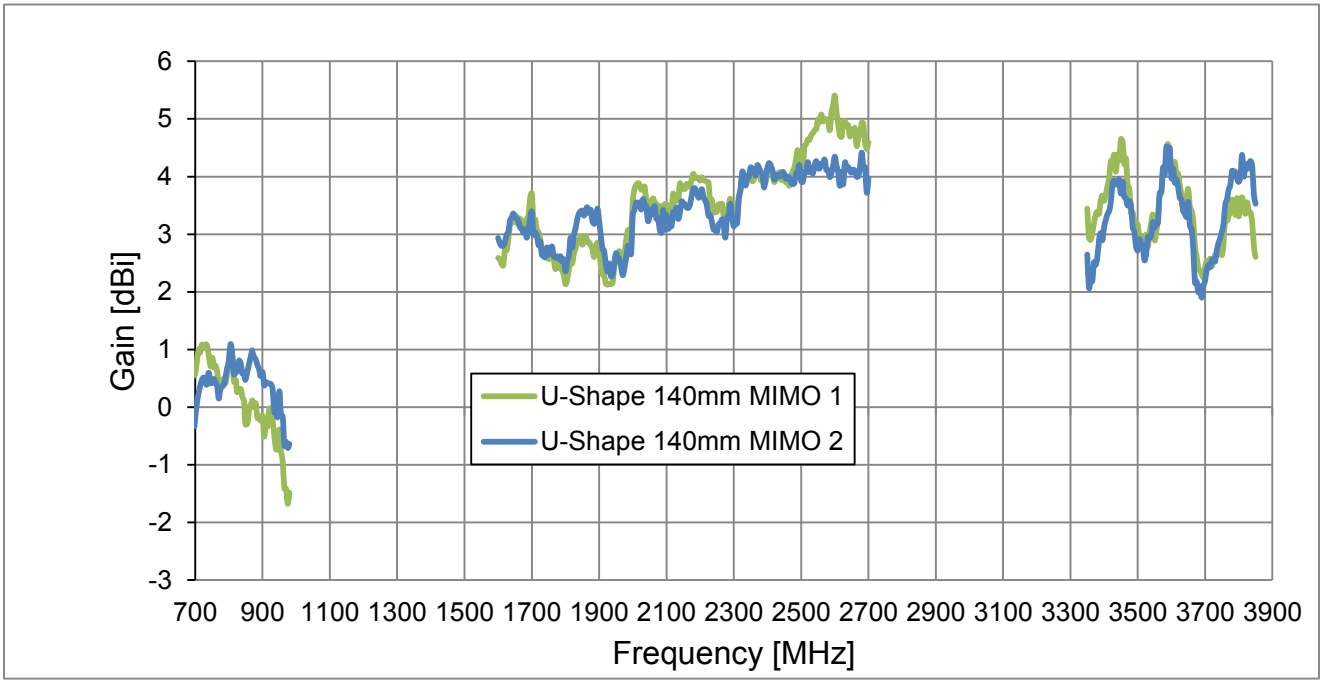
8.3 Isolation – 140mm U-Shape



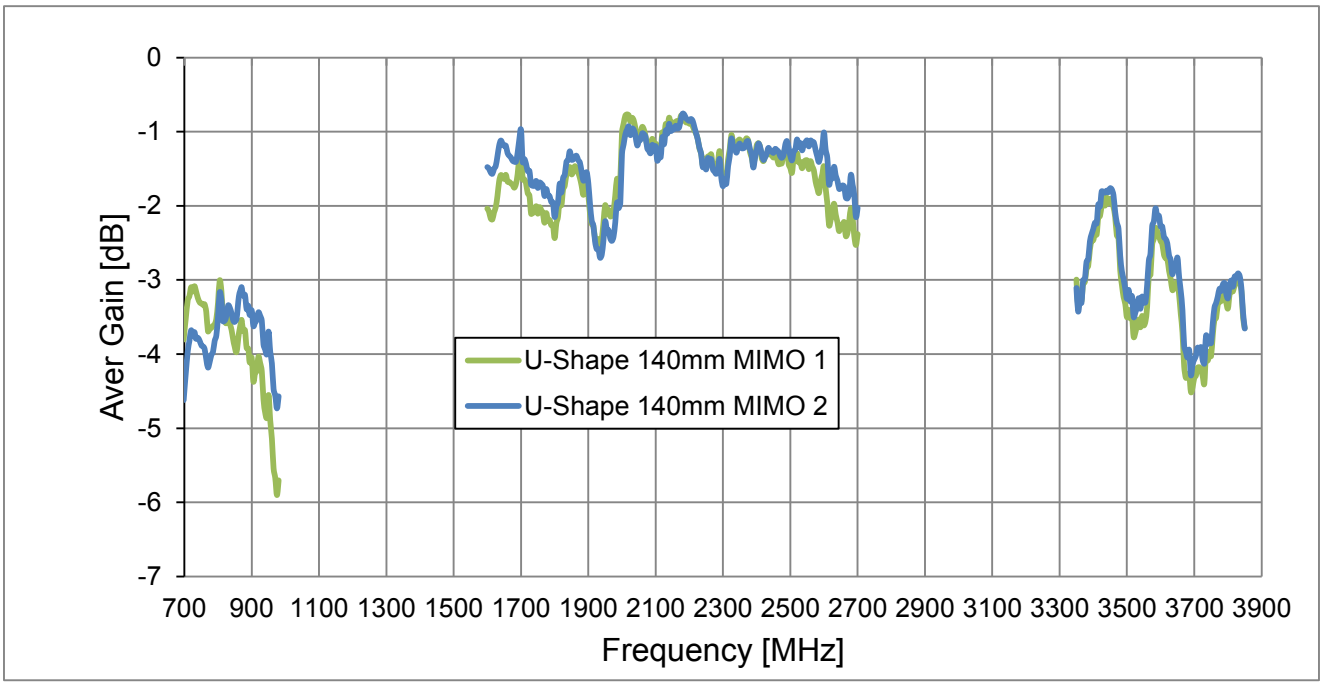
8.4 Efficiency – 140mm U-Shape



8.5 Peak Gain – 140mm U-Shape

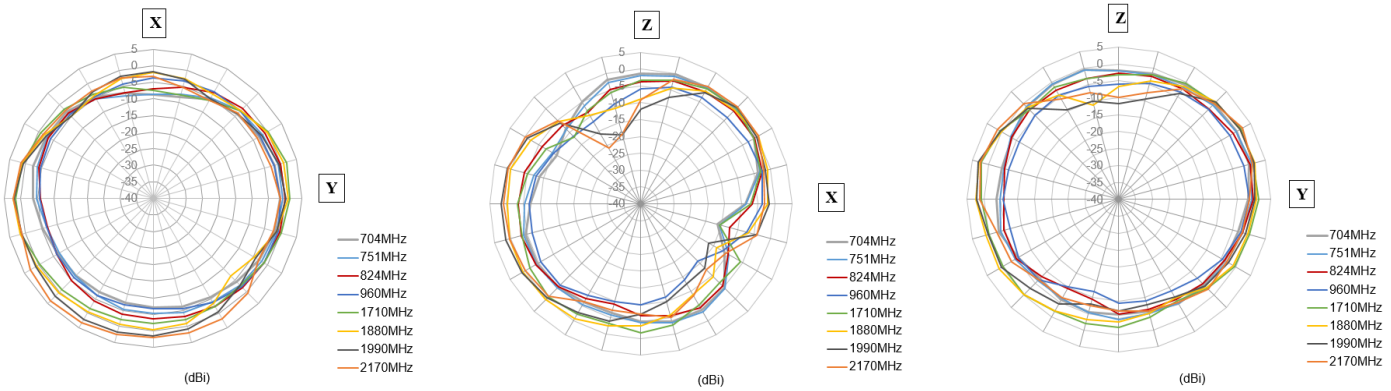


8.6 Average Gain – 140mm U-Shape

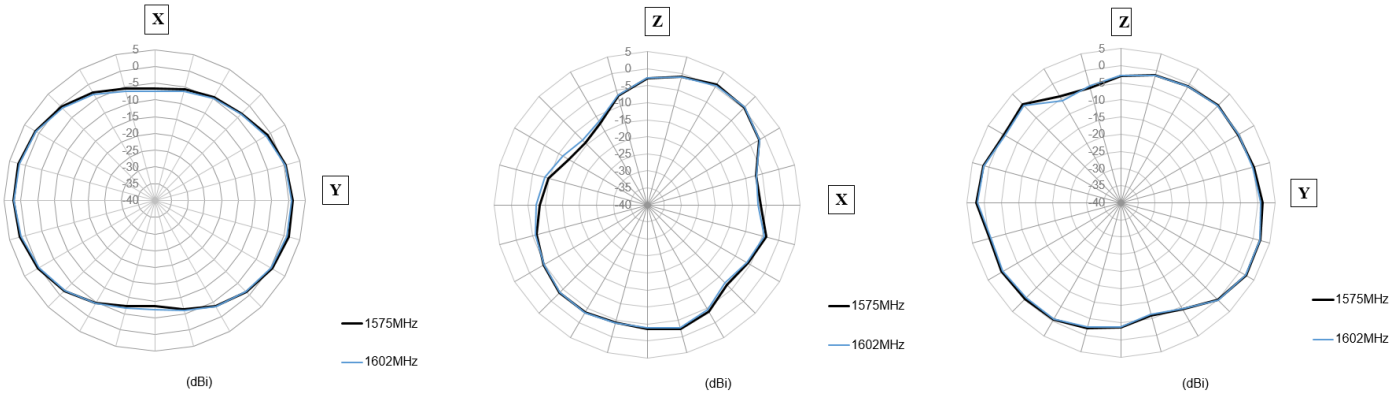


8.7 Radiation Pattern U-Shape 140mm - MIMO 1

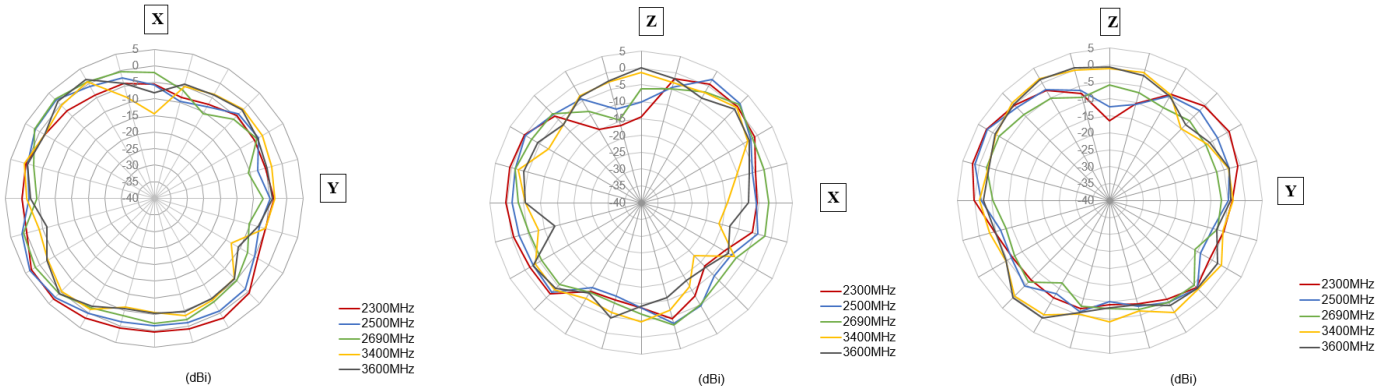
8.7.1 704MHz – 2170MHz



8.7.2 1575MHz – 1602MHz

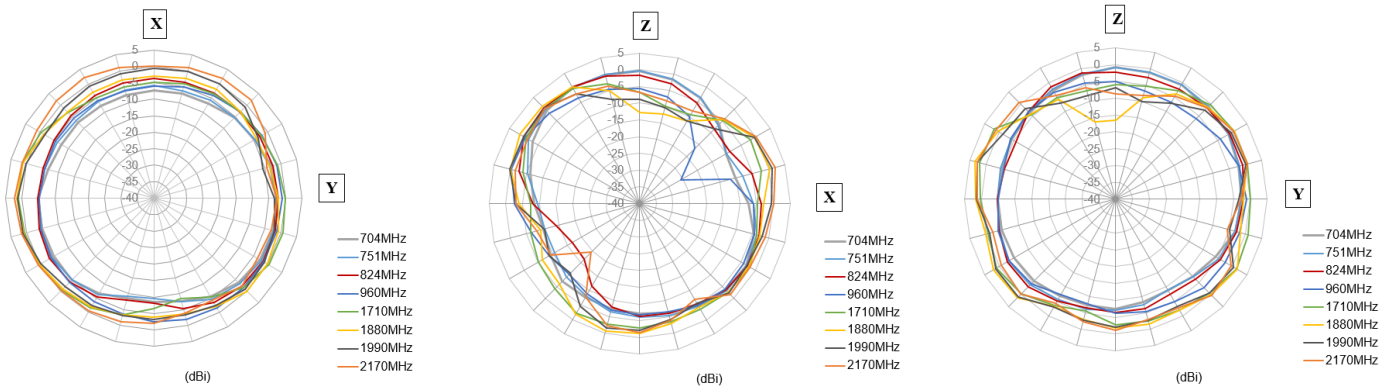


8.7.3 2300MHz – 3600MHz

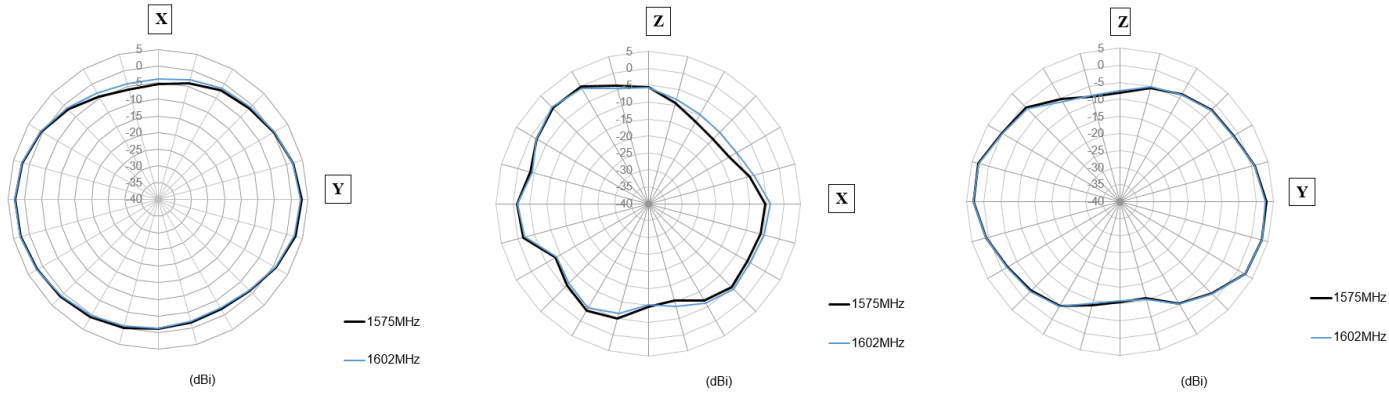


8.8 Radiation Pattern U-Shape 140mm – MIMO 2

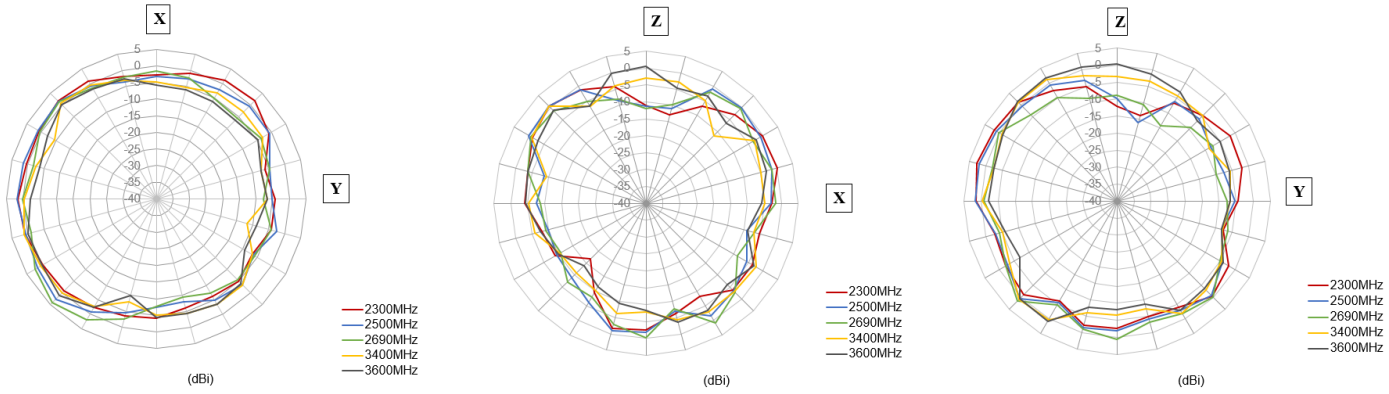
8.8.1 704MHz – 2170MHz



8.8.2 1575MHz – 1602MHz

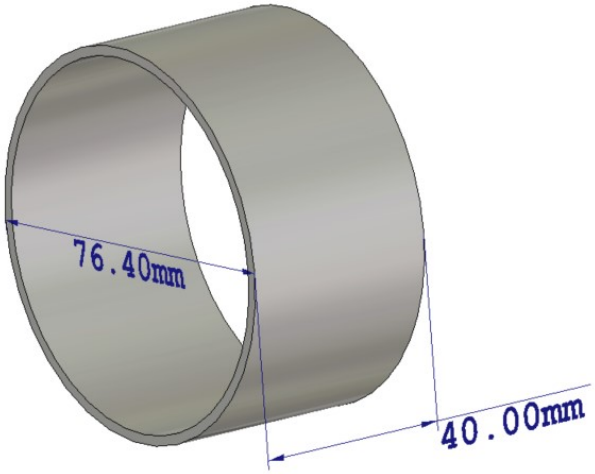


8.8.3 2300MHz – 3600MHz

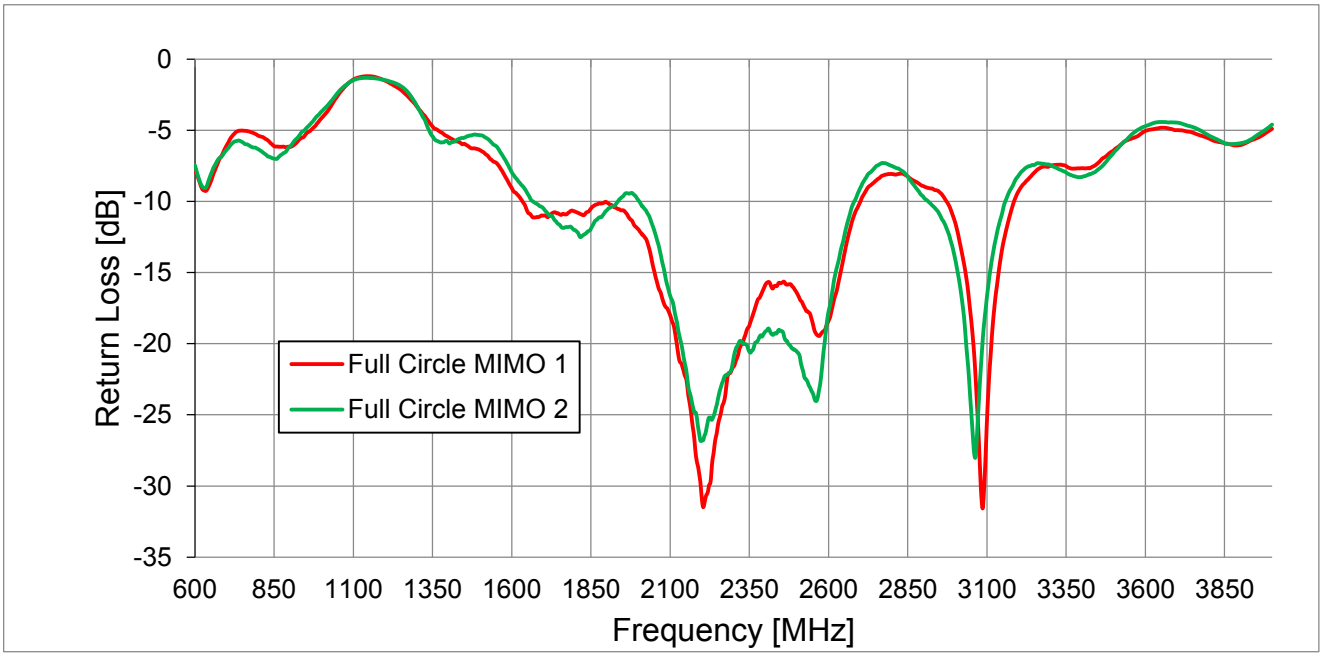


9 Full Circle

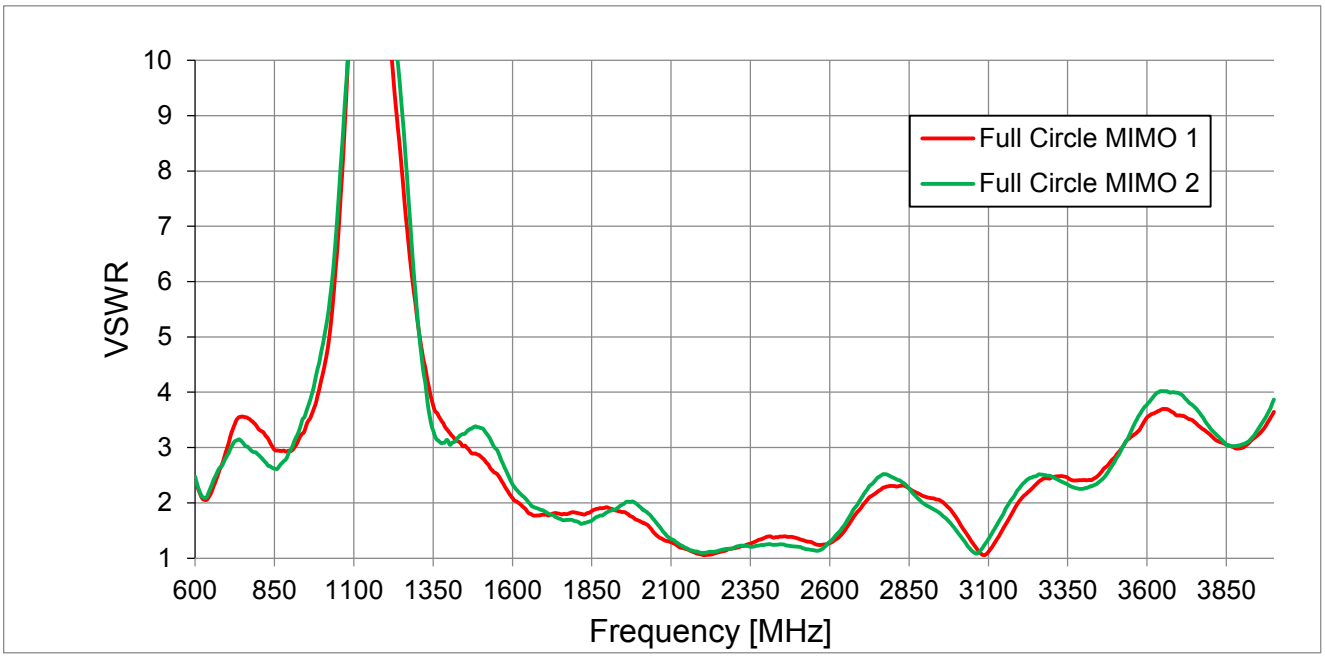
Finally to test a complete circular shape so that one end of the antenna touches the other end, a ring with an outer diameter of 76.4mm is used. This ring is 40mm wide to accommodate the antenna.



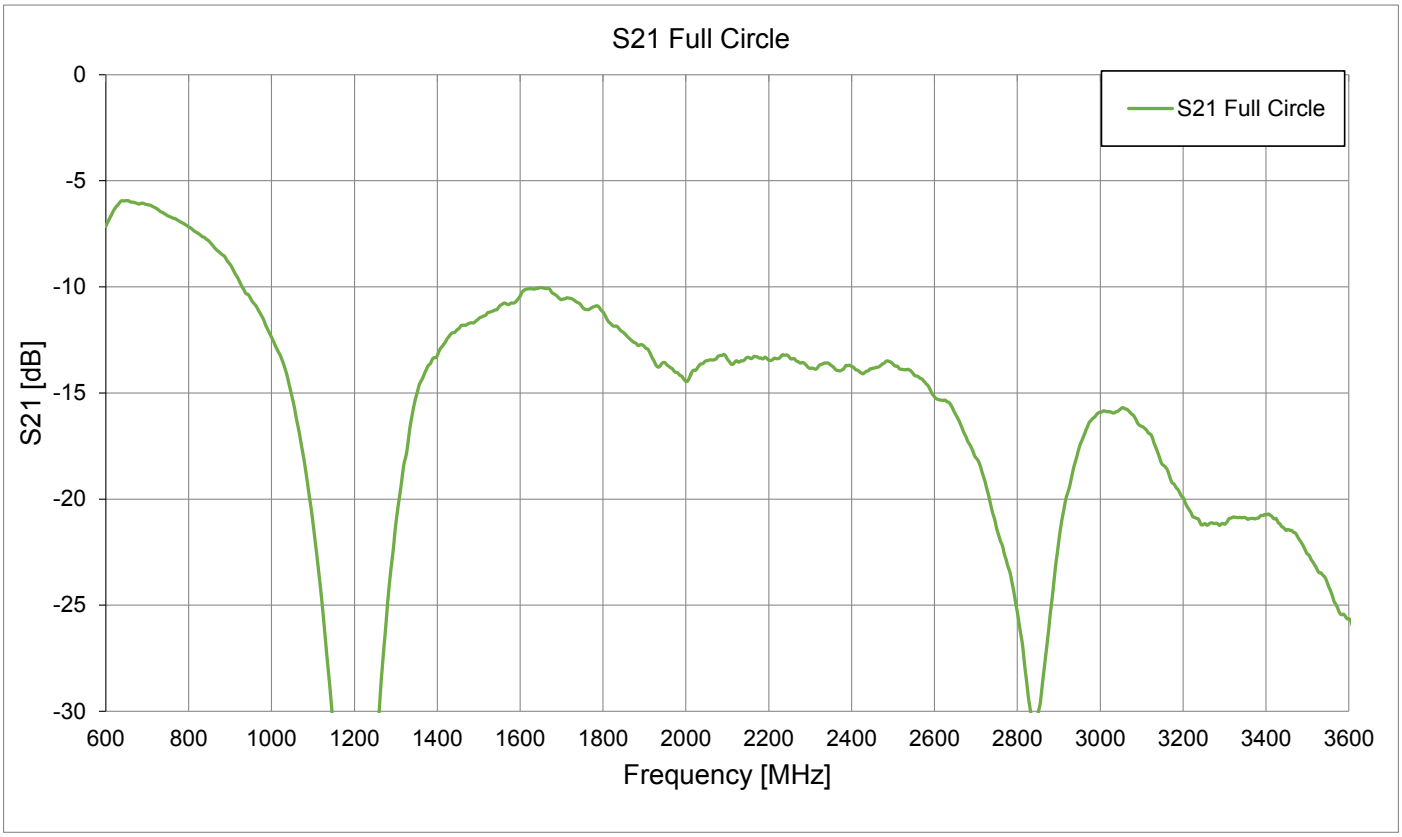
9.1 Return Loss – Full Circle



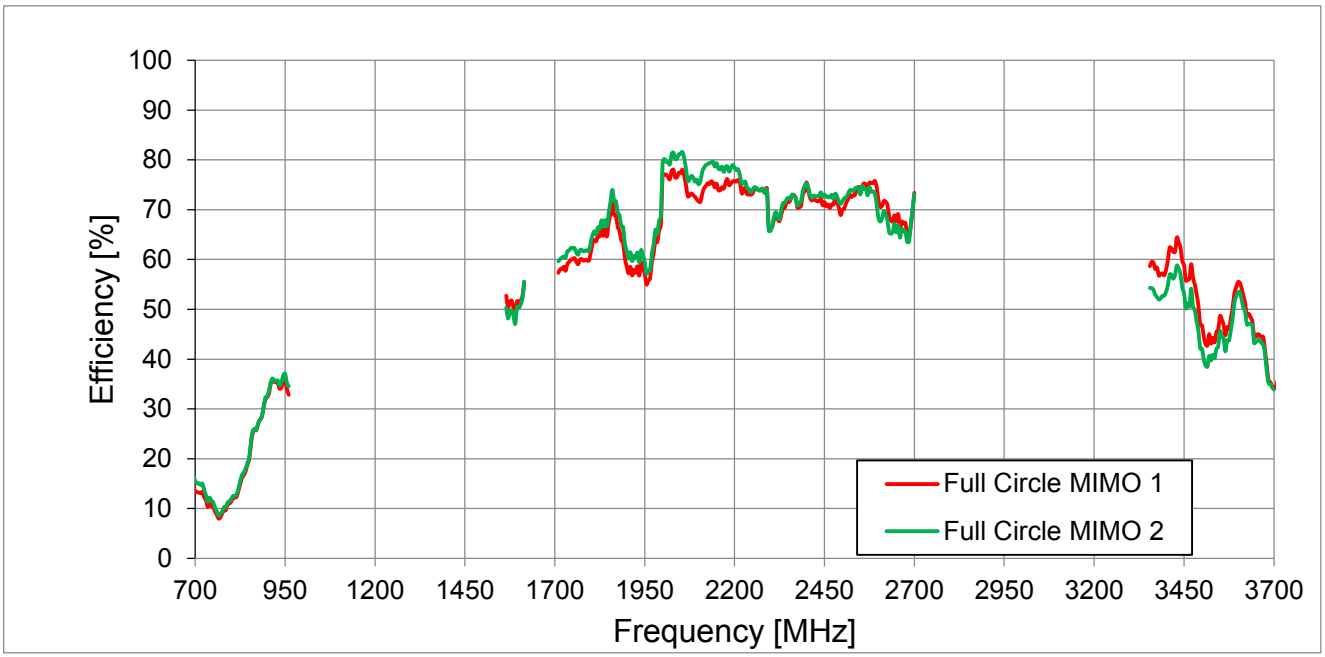
9.2 VSWR – Full Circle



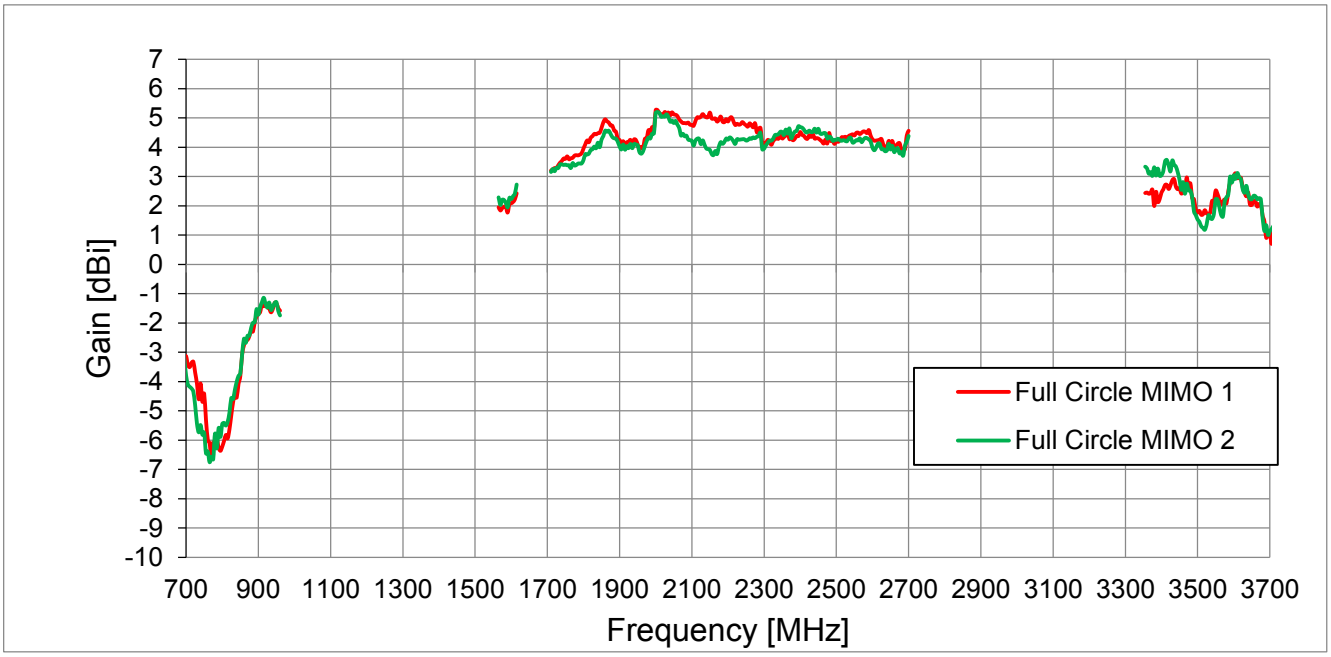
9.3 Isolation – Full Circle



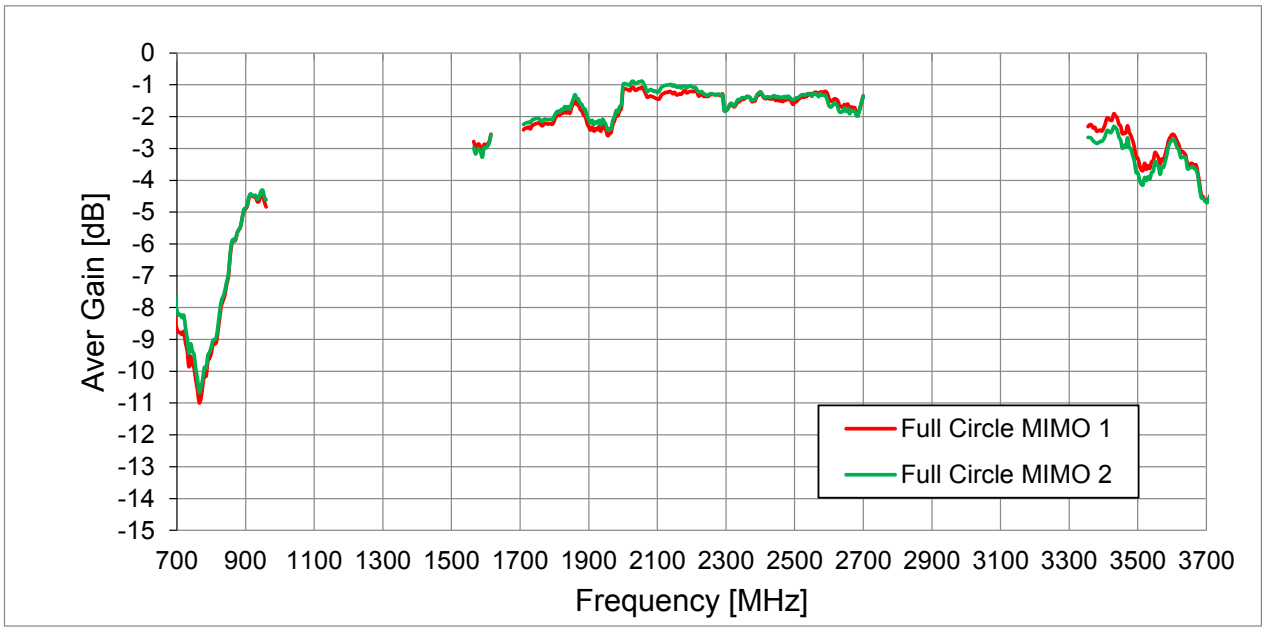
9.4 Efficiency – Full circle



9.5 Peak Gain – Full Circle

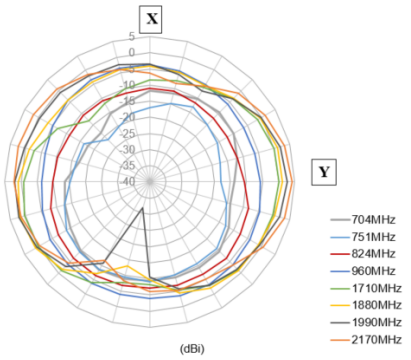


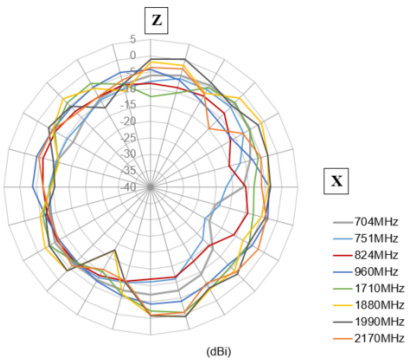
9.6 Average Gain – Full Circle

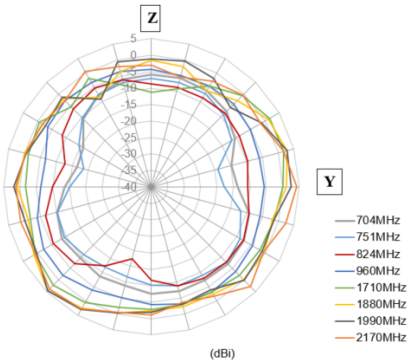


9.7 Radiation Pattern – Full Circle – MIMO 1

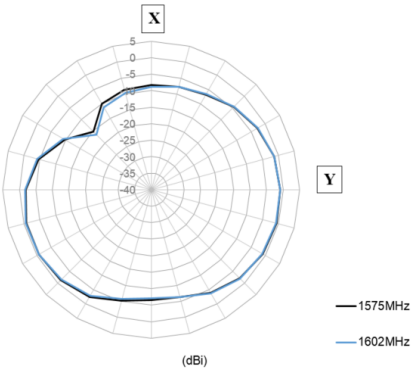
9.7.1 704MHz – 2170MHz

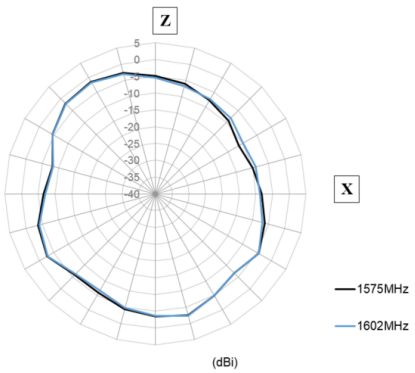


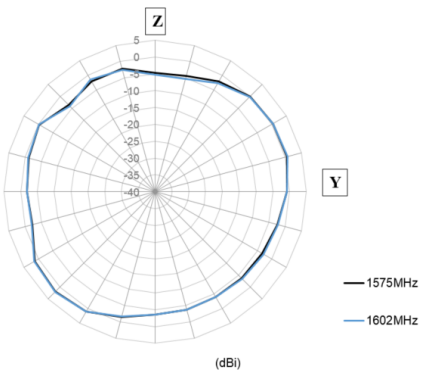




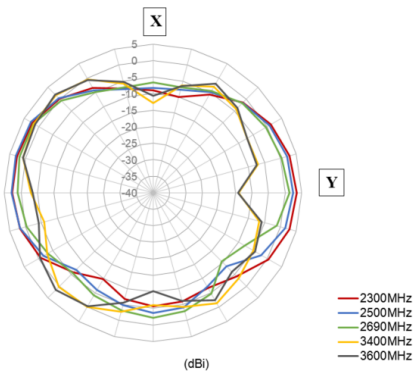
9.7.2 1575MHz – 1602MHz

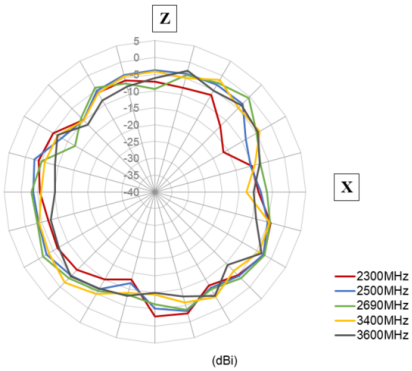


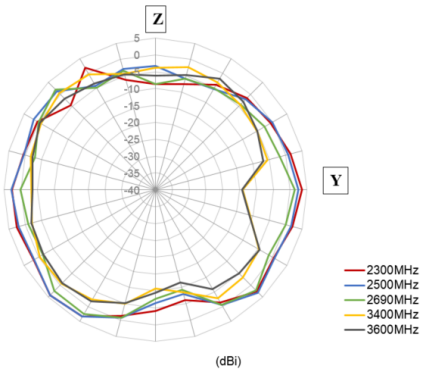




9.7.3 2300MHz – 3600MHz

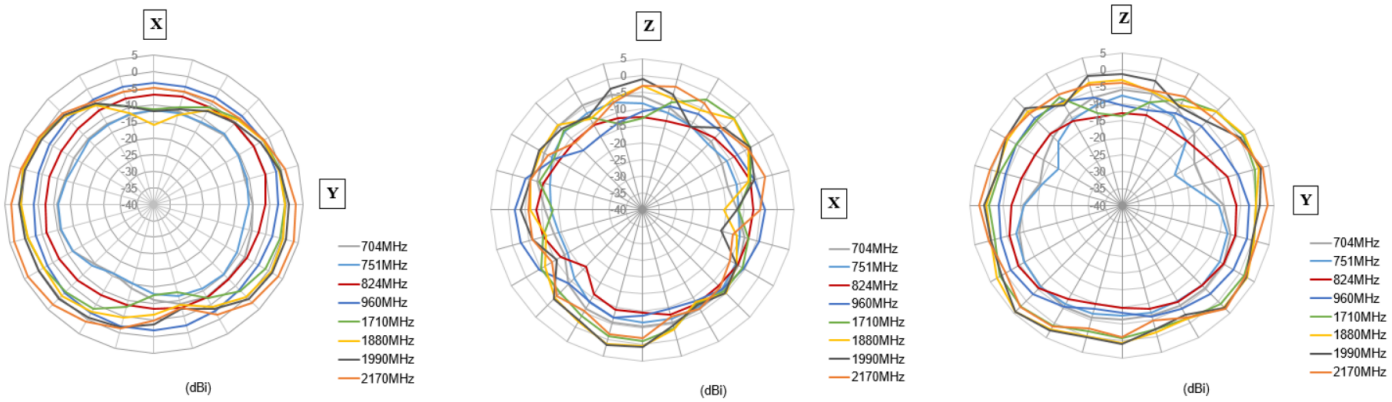




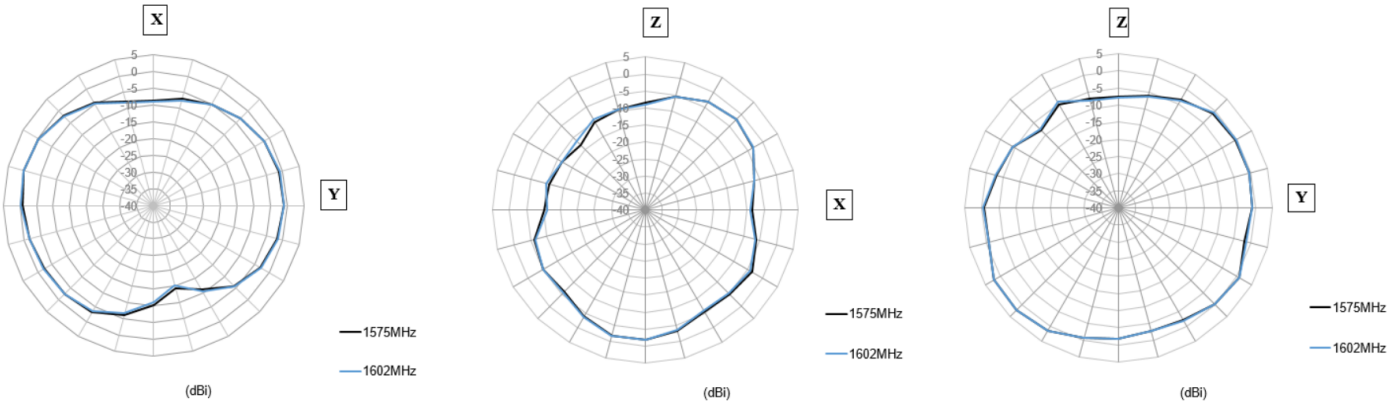


9.8 Radiation Pattern – Full Circle – MIMO 2

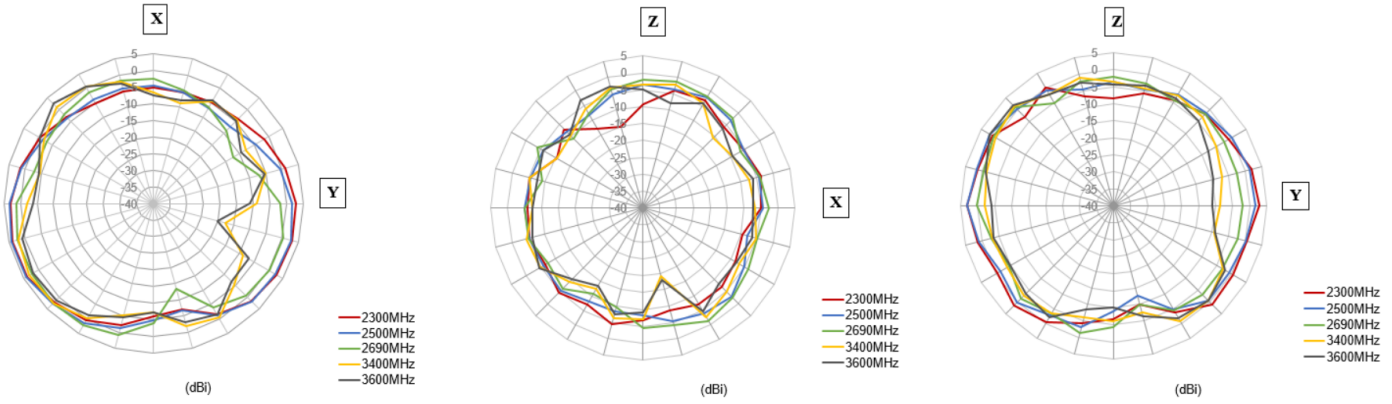
9.8.1 704MHz – 2170MHz



9.8.2 1575MHz – 1602MHz



9.8.3 2300MHz – 3600MHz



10 Conclusion

The results presented below are the minimum values in the band.

FXUB.71 Bend Influence											
	Band	28	5	8	GPS ~ GNSS	3	2	1	WiFi	7	42
	Frequency MHz	703~ 803	824~ 894	880~ 960	1565~ 1612	1710~ 1880	1850~ 1990	1920~ 2170	2400~ 2500	2500~ 2690	3400~ 3600
		Efficiency (%)									
FXUB.71 Flat	MIMO 1	42	32	30	69	60	60	65	64	50	46
	MIMO 2	35	41	37	63	63	63	69	63	49	46
FXUB.71 40mm U-Shape	MIMO 1	20	37	19	53	58	48	48	59	48	41
	MIMO 2	19	39	25	49	53	47	47	59	47	43
FXUB.71 140mm U-Shape	MIMO 1	43	39	31	64	57	56	56	71	57	42
	MIMO 2	37	44	39	70	61	54	54	73	65	45
FXUB.71 Full Circle	MIMO 1	8	14	27	48	58	55	55	69	64	43
	MIMO 2	8	16	28	47	60	57	57	71	64	38
		Peak Gain (dBi)									
FXUB.71 Flat	MIMO 1	0.2	-1.7	-2.1	2.3	2.8	3.4	3.5	4.4	3.0	3.3
	MIMO 2	-0.6	0.3	-0.4	3.4	4.2	4.0	4.0	4.5	3.1	3.7
FXUB.71 40mm U-Shape	MIMO 1	-2.8	-0.4	-3.5	0.7	2.0	2.0	2.1	2.2	2.1	1.5
	MIMO 2	-3.5	-0.4	-2.2	0.7	1.0	1.8	2.8	3.1	2.1	0.7
FXUB.71 140mm U-Shape	MIMO 1	0.4	-0.3	-0.9	2.2	2.1	2.1	2.1	3.8	4.2	2.8
	MIMO 2	0	0.5	-0.2	2.8	2.4	2.3	2.3	3.9	3.8	2.5
FXUB.71 Full Circle	MIMO 1	-6.6	-5.1	-2.3	1.8	3.2	3.9	3.9	4.1	4.0	1.7
	MIMO 2	-6.7	-4.6	-2.2	1.9	3.1	3.7	3.7	4.2	3.7	1.2

The 40mm U-Shape presented gives the minimum 20% efficiency in the low band, this is the minimum curve acceptable and 40mm is the minimum distance that should be observed between the MIMO antennas in order to get at least 20% efficiency across all the bands.

By placing the FXUB71 in a configuration where the ends meets (i.e. a full circle), the efficiency in the low band drops to a poor level <10% and this is not acceptable nor a recommended configuration for this antenna.

A typical configuration where the FXUB.71 is placed in a 140mm U-Shape gives efficiency values – 30% to 40% in the low band, 50% to 60% in the mid band and 40% to 50% in the high band. The values are similar to when the FXUB.71 is placed flat.