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Horn Antenna with T-shaped dual ridges

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Abstract - *In this paper, the design, simulation and fabrication results of horn antenna with T-shaped dual ridges for 1.5 to 6.5 GHz frequency range is presented. In this, we have designed horn antenna with two different shapes of ridges. Then we have analyzed simulation results of both the antenna design and found that antenna-I is giving better result as compare to antenna -II. Hence we decided to go for fabrication of antenna design-I. The proposed antenna can be used for EMC testing. The designed antenna is simulated on CST software and testing is done by using vector network analyzer. The overall size of proposed antenna is 282*400 mm2. The various results of proposed antenna such as bandwidth, efficiency, gain, VSWR and return loss parameters are simulated. Measurement results of designed antenna show good agreement with the simulation.*

Key Words: **Electromagnetic compatibility testing, Dual Horn antenna, VSWR, Waveguide**

1. INTRODUCTION

The radiating element which has shape of horn is called as horn antenna. Horns are among the simplest and most widely used microwave antennas.It consists of waveguide which has one end blown out and other end is used to provide connection with EM source. Hence this arrangement radiates EM energy. The revolutionary growth in wireless communication technology makes great demands on the design of antennas with compact size and multiband operation, which are vital for the compatibility with multiple communication standards and portability of modern wireless terminal devices. There are different types of horn antenna used. Simple horn antennas have relatively limited bandwidth. [4] In order to increase this bandwidth ridges are used in horns. Ridges are inserted to increase bandwidth, cut-off frequency, surfaces of antenna provided for larger radiation and energy that can be radiated. An advantage of horn antennas is they don't have resonant elements hence can operate over wide bandwidth. [1].

Horn antennas are having applications in the areas of wireless communications, electromagnetic sensing, biomedicine and RF heating. The DRH antennas are mostly used in electromagnetic interference and compatibility applications for generating electromagnetic fields. [8] Horn antennas are used in various areas such as EMC testing, radar, satellite tracking system, communication system and reflectors feeding. Horn antennas are used for transmission and reception of microwave signal. [14] Horn antennas are very popular at UHF (300MHz-3GHz), they are used for making electromagnetic interference measurements. A horn antenna has short length of rectangular, pyramidal or cylindrical waveguide which is closed at one end and open ended pyramidal or conical shaped horn on the other end. The radio waves were introduced into the waveguide by using a coaxial cable attached to the side. Then introduced radio wave radiates out in narrow beam at the horn end. In some hardware the radio waves are directed between the transmitter or beneficiary and the reception apparatus by a waveguide; for this situation the horn is joined to the finish of the waveguide. In outside horns, for example, the horns of satellite dishes, the open mouth of the horn is regularly secured by a plastic sheet straightforward to radio waves, to bar dampness.

In literature survey, the previously developed techniques for horn antenna design are studied under [1] with their advantages and disadvantages. Firstly simple horn antenna without ridge is designed, and then inserted ridges into the waveguide to increase the bandwidth. Antennas are designed for maximum frequency of 7GHz. Both the antennas are simulated using CST software and hardware results are measured on vector network analyzer for reflection coefficient and VSWR etc.

2. ANTENNA DESIGN-I (T-SHAPE DUAL RIDGES)

The size of antenna-I is 282*400 mm^2. The antenna is simulated for numerous antenna parameters like return loss, efficiency, VSWR, bandwidth, directivity, radiation pattern and gain etc. Firstly simple horn antenna of size 282*400 mm2 is designed. Below fig shows the geometry of simple horn antenna. All the dimensions of antenna are in mm.

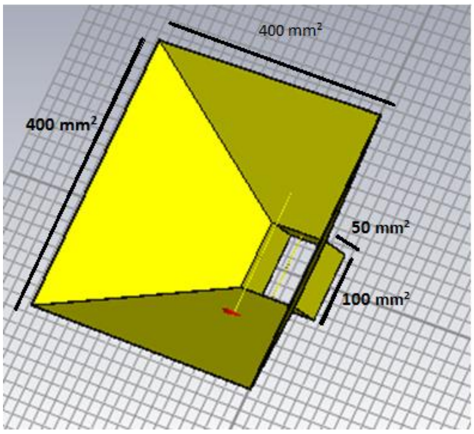

Fig-1: Simple horn antenna geometry for design-I

Then the T-shaped dual ridges are inserted into the simple horn, as shown in Fig-2. The overall height of antenna design-I with T shape ridge is 282mm and width of horn is 400mm.The overall size of back cavity is 100*50mm2and thickness is 1mm. Pyramidal shape horn is used to design this antenna and T- shaped ridges are inserted into the pyramidal horn section to increase the bandwidth of horn antenna.

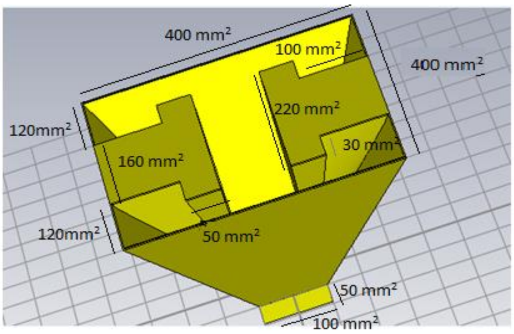

Fig-2: Geometry of Horn antenna with T-shaped dual ridge

3. SIMULATION RESULTS OF ANTENNA-I (WITHOUT RIDGES AND WITH T-SHAPE RIDGES)

Return loss of antenna -I: Fig-3 shows the S11 graph of simple horn antenna design-I. Antenna covers the 1 GHz bandwidth. Frequency band 1 GHz has return loss value nearly -18 dB. After inserting the T-shape dual ridges in the simple horn, bandwidth of the antenna is increased as shown in fig-4. Horn antenna with T-shaped dual ridges covers the 1.5 GHz to 6.5 GHz frequency band below -10 dB. Frequency band 1.5 GHz to 6.5 GHz has return loss value nearly -30 dB. The return loss values are calculated from this graph.

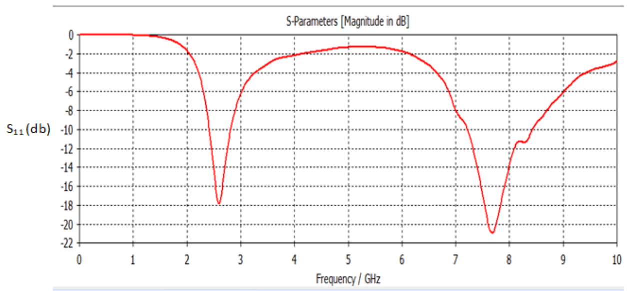

Fig-3: Return loss of simple horn antenna-I

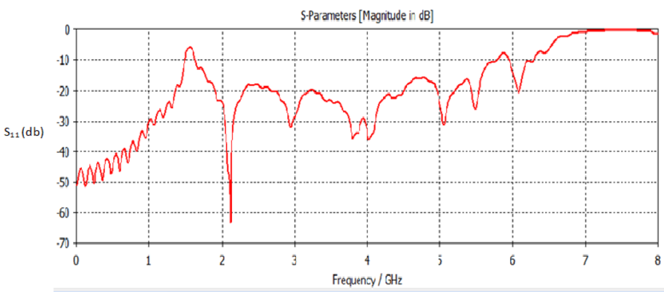

Fig -4: Return loss of horn antenna with T-shaped dual ridges design- I

VSWR of antenna-I: The fig.-5 shows the VSWR graph of simple horn antenna design-I. The VSWR ratio parameter is considered while Impedance matching, the ideal value of VSWR is 1 but, practically it is in between 1-2. The VSWR obtained for antenna design-I is 1.75. The VSWR obtained for antenna design-I with T-shape dual ridges is 1.4 for entire 1.5 GHz to 6.5GHz frequency band shown in fig-6. The VSWR measurement describes the voltage standing wave pattern which is present in transmission line because of the phase addition and subtraction of incident and reflected waves. The VSWR is a real and positive value for antennas all the time. The smaller the VSWR, better the antenna is matched to the transmission line and more power is delivered to the antenna.

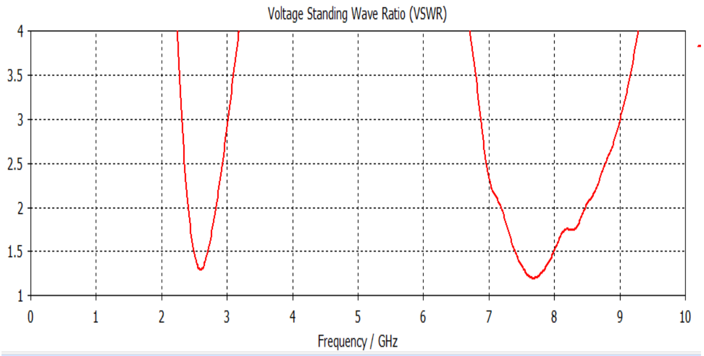

Fig-5: VSWR graph of simple horn antenna-I

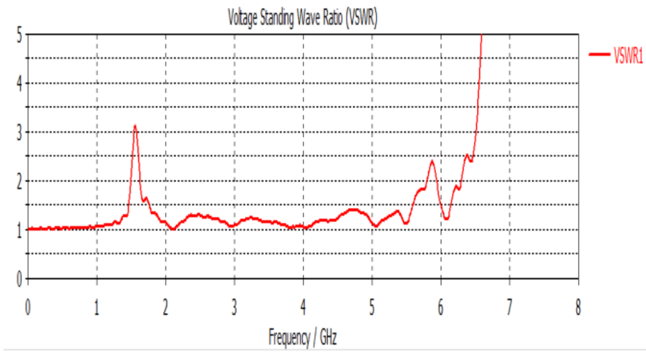

Fig-6: VSWR of horn antenna with T-shaped dual ridges design- I

Efficiency of antenna -I: The fig-7 summarizes efficiency of simple horn antenna design-I. The efficiency should be as large as possible. From the below efficiency graph, conclude that the antenna efficiency achieved for without ridge antenna design is 80% for 1 GHz frequency band. Fig-8 shows the antenna efficiency achieved with T-shaped dual ridges is 98% for 1.5 to 6.5 GHz frequency band.

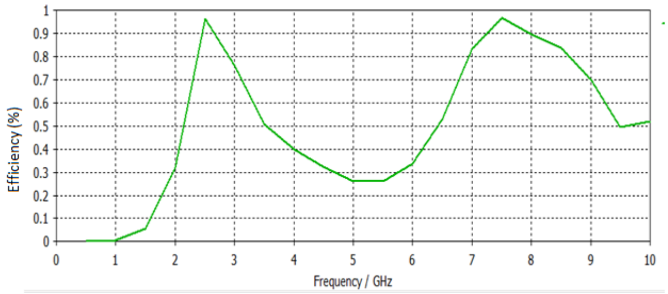

Fig-7: Efficiency graph of simple horn antenna-I

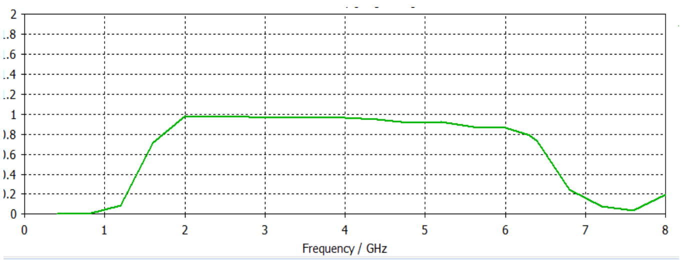

Fig-8 Efficiency graph of horn antenna with T-shaped dual ridges design- I

Gain of antenna design-I: The below fig-9 shows the gain graph of simple horn antenna design-I for 1GHz bands and fig-10 shows the gain of T-shaped dual ridge horn antenna for 1.5 GHz to 6.5 GHz bands. It is 12.8dBi for 1.5 GHz frequency and 14.8 dB for 6.5 GHz respectively. The gain and directivity of antenna are depends on each other.

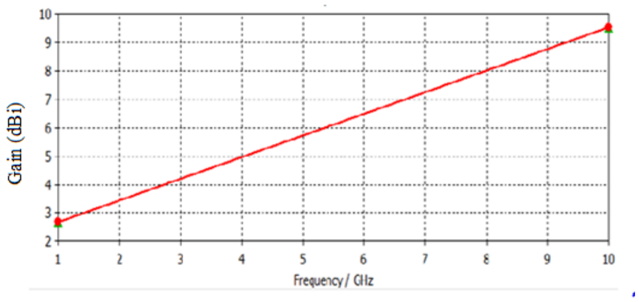

Fig-9: The gain of simple horn antenna-I.

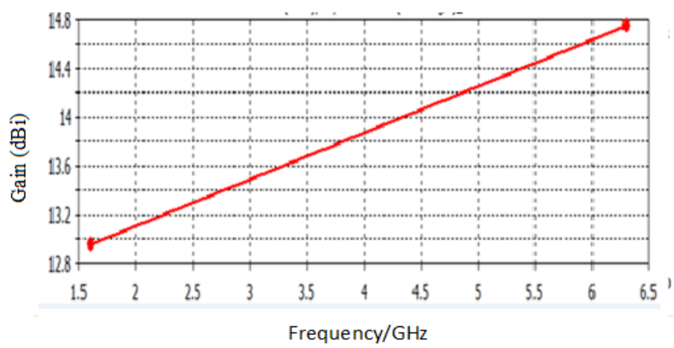

Fig-10: The gain of horn antenna with T-shaped dual ridges design- I

The 2-D radiation pattern of antenna-I: In fig-11 the 2-D radiation patterns for simple horn antenna design-I is shown. Fig-12 shows 2-D radiation patterns of horn antenna with T-shaped ridge design-I. The radiation pattern is a graphical portrayal of the radiation properties of antenna. A representation of the radiation characteristics of the radiator as a function of θ and φ for constant radial distance and frequency. The below fig shows the values of θ for proposed bands.

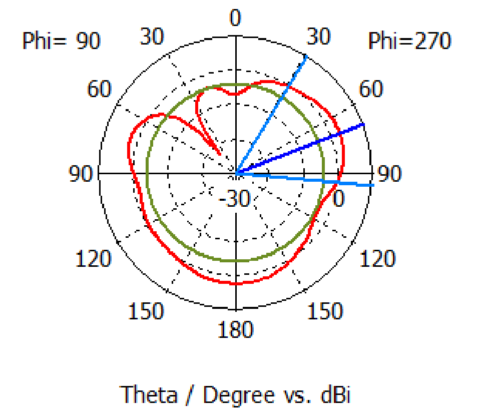

Fig-11: 2-D radiation pattern of simple horn antenna-I

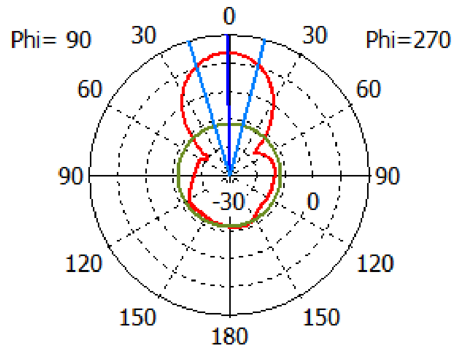

Fig-12: 2D radiation pattern of horn antenna with T-shaped dual ridges design- I

Table 1: Comparative analysis of antenna-I without ridge and with T-shaped ridge

Parameters	Antenna-I (without ridge)	Antenna-I (with T-shape ridges)
Frequency	2GHz to 3GHz	1.5GHz to 6.5 GHz
Return loss	- 18 Db	-30dB
VSWR	1.75	1.5
Bandwidth	1 GHz	4.8 GHz
Gain	3 dBi at 2.6GHz	13 dBi at 1.6 GHz
	7 dBi at 6GHz	14.8dBi at 6.3GHz
Efficiency	80%	97 %

Table 1 depicts the comparison of proposed antenna-I without ridge and with T-shaped ridges. After inserting the T-shaped ridges in the pyramidal horn section usable bandwidth of antenna is increased from 1GHz to 4.8 GHz. Also it shows better performance in gain and efficiency parameters.

4. ANTENNA DESIGN-II

The size of antenna-II is 252×400 mm^2. This antenna is also simulated for numerous antenna parameters like return loss, efficiency, VSWR, bandwidth, directivity, radiation pattern and gain. Also in this design, firstly simple horn antenna with size 252*400 mm2 is designed. Fig -13 shows the geometry of simple horn antenna.

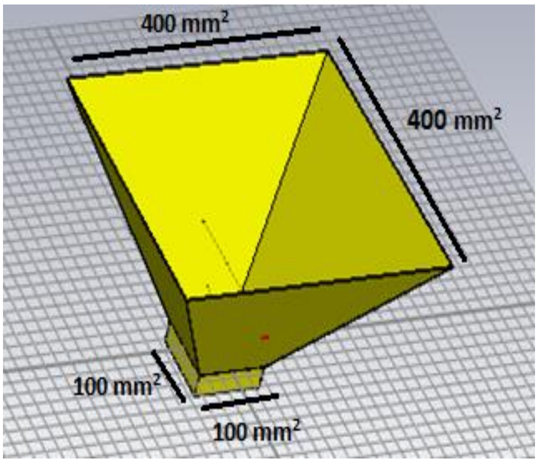

Fig-13: Simple horn antenna geometry of design-II

Geometry of Horn Antenna with triangular shaped ridges Design II is shown in fig-14.The overall height of antenna design-2 is 252mm and width of horn is 400mm.The overall size of back cavity is 100*30mm2 and thickness is 2mm.Pyramidal shape horn is used to design this antenna and triangular shaped ridges are inserted into the pyramidal horn section to increase the bandwidth of horn antenna.

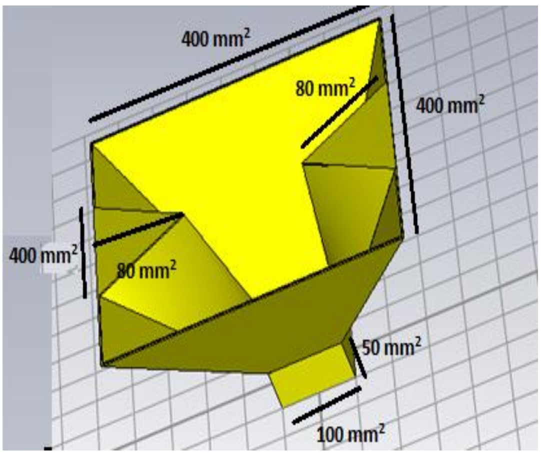

Fig -14 Geometry of Horn Antenna with triangular shaped ridges

5. SIMULATION RESULTS OF ANTENNA DESIGN-II (WITHOUT RIDGES AND WITH TRIANGULAR SHAPE RIDGES)

The various parameters of antenna design-II such as VSWR, gain efficiency, return loss, radiation pattern and directivity of antenna etc. are simulated on CST software.

Return loss of antenna design-II: Fig-15 shows the S11 graph of simple horn antenna design-II. Antenna covers the 1 GHz to 1.8 GHz frequency band below -10 dB. Frequency band 1 GHz to 1.8 GHz has return loss value nearly -15 dB. Fig-16 shows the S11 graph of horn antenna with triangular shape ridges. Antenna covers the 1.6 GHz to 5 GHz frequency band below -10 dB. Frequency band 1.6 GHz to 5 GHz has return loss value nearly -30 dB.

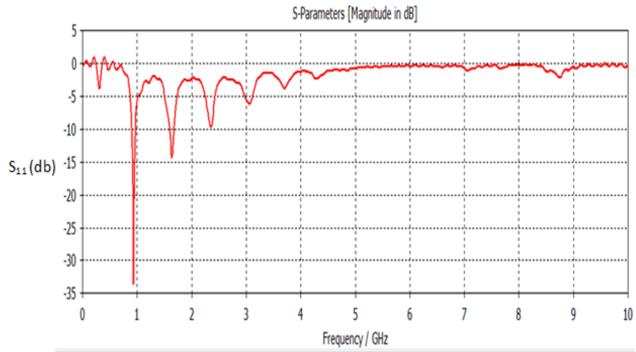

Fig- 15: Return loss of simple horn antenna design-II

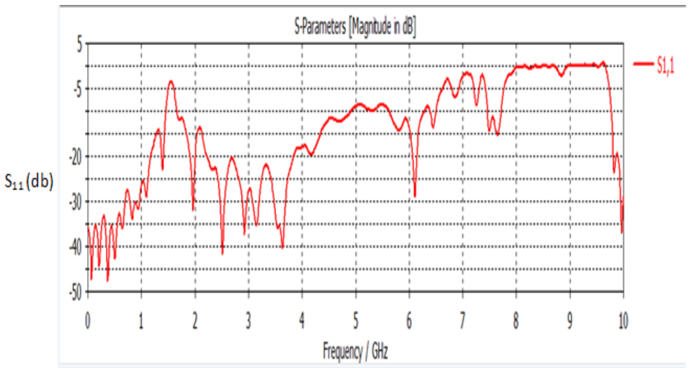

Fig-16: Return loss of antenna-II with triangular dual shape ridges

VSWR of antenna design-II: The fig-17 shows the VSWR graph of simple horn antenna design-II. The VSWR obtained for antenna design-II is less than 2 for entire 1 GHz to 1.8 GHz frequency band. The fig-18 shows the VSWR graph of antenna design-II with triangular shape dual ridges, it is 1.5 for entire 1.6 GHz to 5 GHz frequency band.

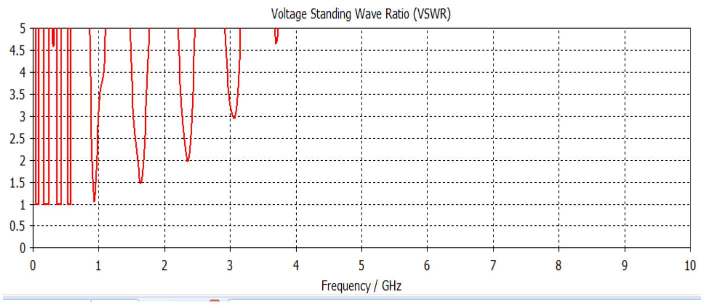

Fig-17: VSWR of simple horn antenna design-II

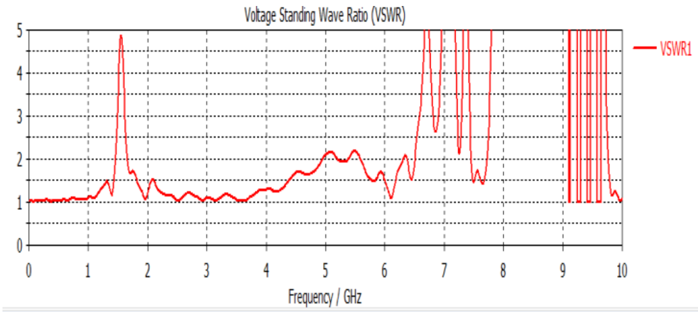

Fig-18: VSWR of antenna design-II with triangular shape dual ridges

Efficiency of simple horn antenna design-II: The fig-19 summarizes the efficiency of DRH antenna design-II. From the below efficiency graph, conclude that the antenna efficiency achieved for this design is 70% for 1 to 1.8 GHz frequency band. Antenna efficiency achieved with triangular shape ridges is 87% for 1.6 to 5 GHz frequency band as shown in fig-20.

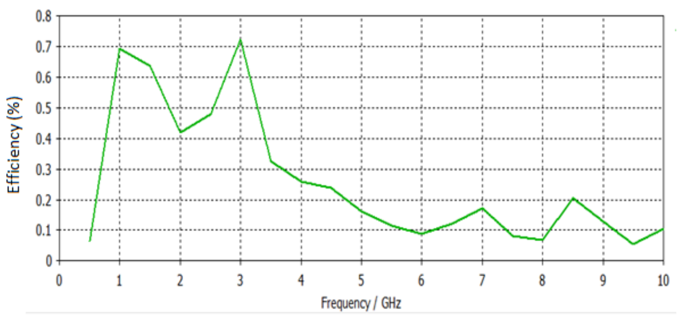

Fig-19: Efficiency graph of antenna design-II with triangular shape dual ridges

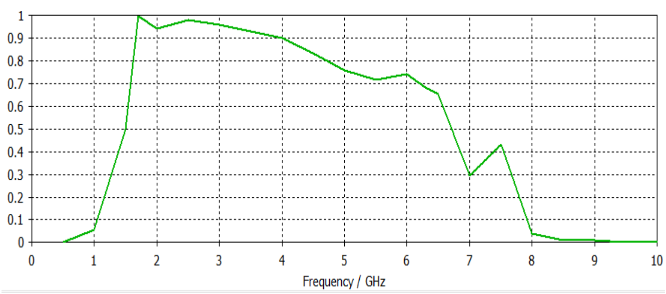

Fig-20: Efficiency graph of DRH antenna design-II

Gain of simple horn antenna design-II: The below fig-21 shows the gain graph of antenna design-II for 1 GHz to 1.8 GHz bands. It is 8 dB for 1 GHz frequency. The fig-22 shows the gain graph of antenna design-II for 1.6 GHz to 5 GHz bands. It is 12 dBi for 1.6 GHz frequency and 13 dBi for 5 GHz respectively..

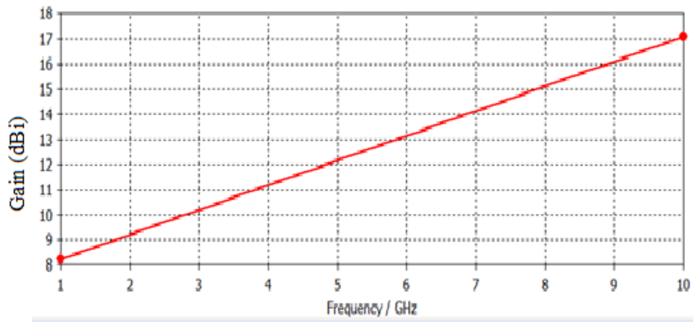

Fig -21: The gain of simple horn antenna design-II

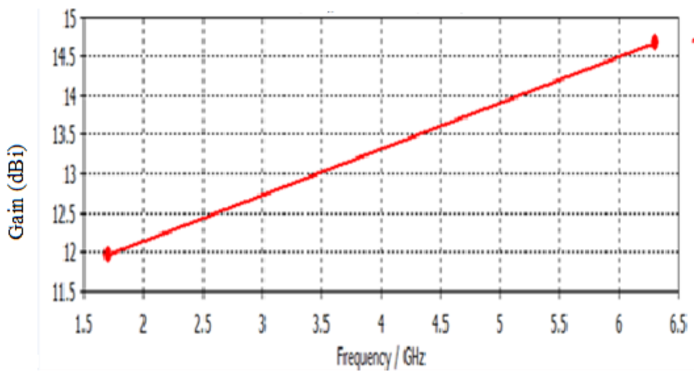

Fig-22: The gain of horn antenna with triangular shape dual ridges

2D radiation pattern of simple horn antenna design-II: In fig-23, the 2-D radiation patterns for simple horn antenna design-II are shown. The values of θ for proposed bands are shown in figure. In fig-24 the 2-D radiation patterns for horn antenna with triangular shaped dual ridges is shown

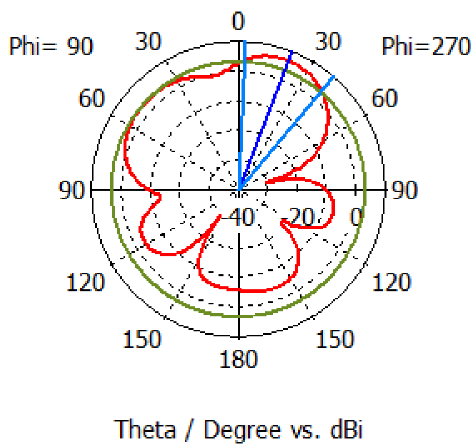

Fig-23: 2D radiation pattern of simple horn antenna-II

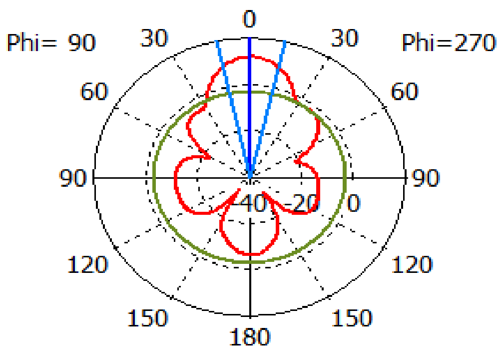

Fig-24: The2-D radiation pattern of antenna-II.

Table 2: Comparative analysis of antenna-II without ridge and with triangular shaped ridge

Parameters	Antenna-II (without ridge)	Antenna-II (with triangular shape ridge)
Frequency	1 GHz to 1.8 GHz	1.6GHz to 5GHz
Return loss	-15 dB	-30 dB
VSWR	1.75	1.6
Bandwidth	1 GHz	3.5 GHz
Gain	8 dBi at 1 GHz	12 dBi at 1.6 GHz
	11 dBi at 4 GHz	13 dBi at 5GHz
Efficiency	70%	87%

Table 2 depicts the comparison of proposed antenna-II without ridge and with triangular shaped ridges. After inserting the triangular ridges in the pyramidal horn section usable bandwidth of antenna is increased from 1GHz to 3.5 GHz. Also it shows better performance in gain and efficiency parameters.

Lastly antenna design-I and design-II results comparison is carried out to find out best design which gives good result.

Table 3: Comparative result analysis of antenna design-I and design-II

Parameters	Antenna design-I	Antenna design- II
Frequency	1.5GHz to 6.5GHz	1.6GHz to 5GHz
Return loss	-30dB	-30dB
VSWR	1.5	1.6
Bandwidth	4.8 GHz	3.5 GHz
Gain	13 dBi at 1.6 GHz	12 dBi at 1.6 GHz
	14.8 dBi at 6.3GHz	13.9 dBi at 5GHz
Efficiency	97 %	87%

Table 3 depicts the comparison of proposed antenna-I and antenna-II. The antenna-I have good bandwidth, efficiency and gain etc. This antenna can be used in EMC testing application etc. Whereas the antenna-II have less bandwidth, gain and efficiency as compare to antenna-I. After analyzing the results of both the antenna design found that antenna-I is giving better result as compare to antenna -II. Hence we decided to go for fabrication of antenna design-I.

6. HARDWARE AND MEASURED RESULTS OF ANTENNA DESIGN-I

The photographs of fabricated antenna-I testing setup is shown in fig-25. Antenna is made up of aluminum material with a thickness of 1 mm. A 50Ω coaxial cable is connected to antenna. The antenna is tested using ZVA 8 vector network analyzer. The range of analyzer is from 300 KHz to 8GHz. The following fig-26 shows the side view of antenna design-I and fig-27 shows the front view of antenna design-I.

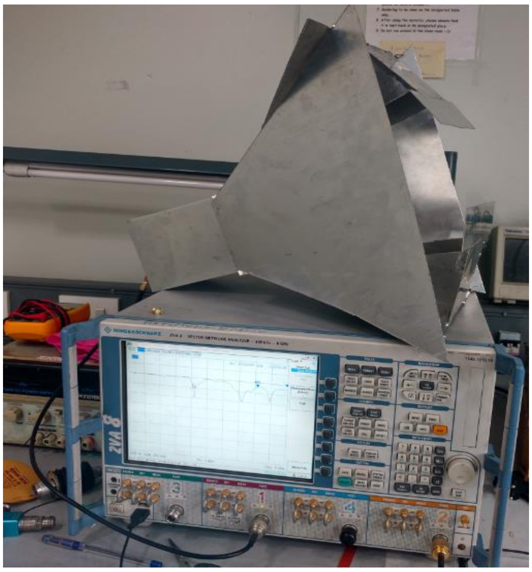

Fig-25: Photograph of fabricated antenna-I and testing setup.

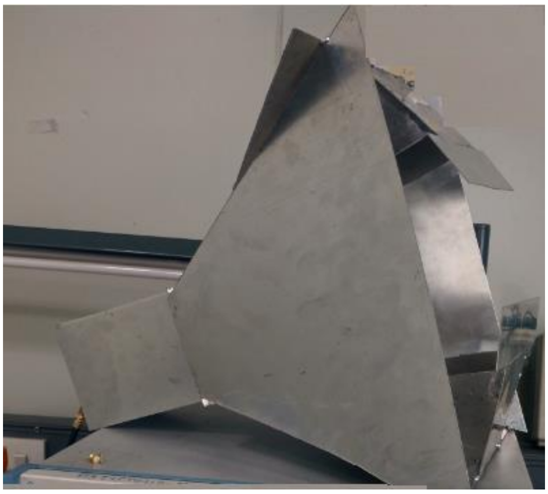

Fig-26: Side view of antenna-I

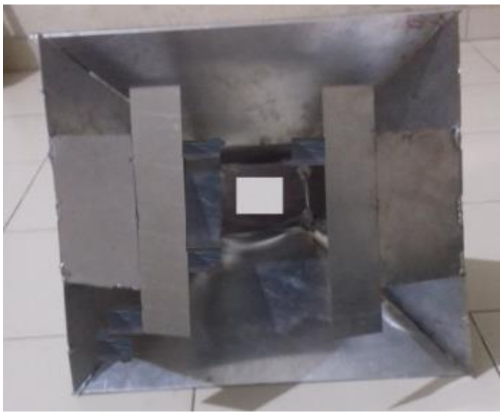

Fig-27: Front view of antenna-I

The fig-28 depicts the measured result of return loss for antenna –I. The antenna is tested on vector network analyzer for 1.5 GHz to 6.5 GHz frequency range. The marker M1 and M2 are positioned on the tips of the wave on -10dB. Frequency band from 1.5 GHz to 6.3 GHz showing the return loss values of -30 dB. The fig-29 depicts the measured result of VSWR for antenna –I.

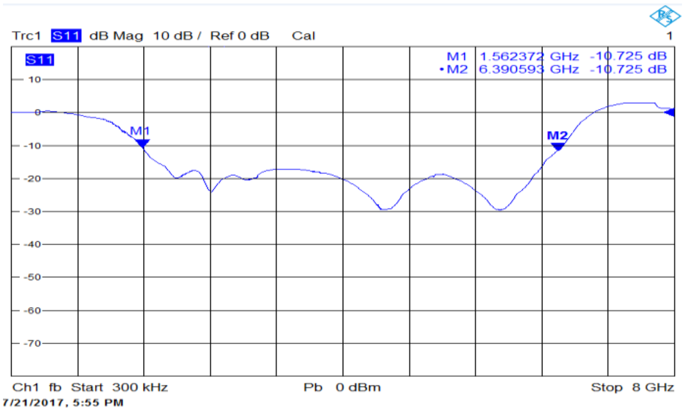

Fig-28: The measured return loss of antenna-I

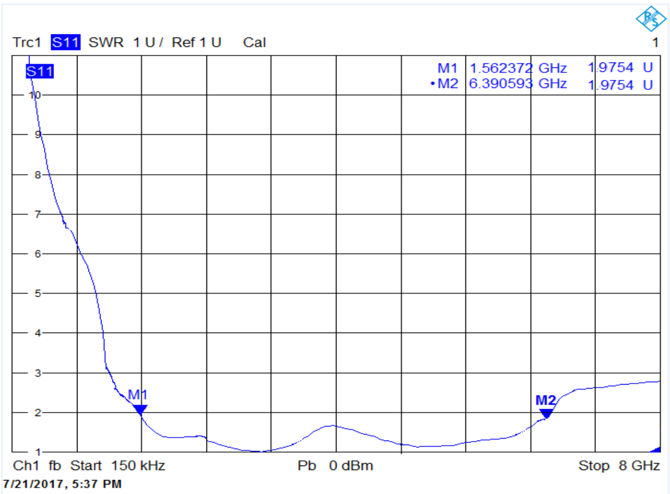

Fig-29 Measured VSWR of antenna-I

The antenna is tested on vector network analyzer for maximum frequency of 7GHz. The marker M1 and M2 are positioned on the tips of the wave on 2, showing the VSWR values of 1.7 for 1.5GHZ to 6.39 GHz band.

Table 4: Comparison of simulated and tested results of antenna design-I

Parameters	Simulated	Measured
Frequency	1.5 to 6.5 GHz	1.56 to 6.39 GHz
Bandwidth	4.8 GHz	4.8 GHz
Maximum return loss over the frequency band	-30dB	-30dB
VSWR	1.5	1.7

From the above table it is shown that the simulated and measured values of reflection coefficient, VSWR and frequency bands are approximately same. The results obtained shows a perfect matching between simulation and testing results for the required frequency band in terms of antenna parameters such as return loss and VSWR.

7. CONCLUSION

In this paper, the dual ridge horn antenna for EMC testing application is presented. The antenna is designed for 1.5 GHz to 6.5 GHz frequency band. The advantage of dual ridge horn antenna is; bandwidth of horn increases when ridges are inserted into the flared section of the antenna .The results obtained shows a perfect matching between the simulation and testing results for the required frequency band in terms of antenna parameters like return loss and VSWR.

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