Mini Double Ridge Horn Antenna for Free Space Measurement

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Abstract. This paper presents the design of a double ridge horn antenna (DRHA) with an operating frequency of 2.4 GHz to 9.8 GHz for free space measurement. The DRHA is designed using CST Studio Suite. The DRHA is built with metallic grid sidewalls, ridges, the shield of coax, cavity back, and bell section. Furthermore, the DRHA exhibits improved radiation patterns with a maximum E-plane beamwidth of 102 degrees and H-plane beamwidth of 92 degrees, and maximum gain up to 16.3 dBi. The simulated results were analyzed and discussed in this paper. This double ridge horn antenna exhibits improved radiation patterns and gains. This shows that the double ridge horn antenna can fulfill the higher demands in antenna applications and in free space material measurement. The antenna presents desirable results throughout the operating frequency.

Keywords- Free space measurement, Double ridge horn antenna

I.INTRODUCTION

Applications of horn antennas is important in many scopes such as satellite and radar applications [1]. Horn antennas mostly used for free space material measurements applications in determining the dielectric properties of materials. Nowadays, the demand for double ridge horn antenna (DRHA) is high as they able to produce wider bandwidth, high gain and low voltage standing wave ratio [2]. The DRHA comprises of flared section, cavity and coax-to-ridged waveguide transition [3]. It is well known that double ridge horn antenna useful in biomedical imaging applications which is able to detect breast or lung cancer [4]. Microwave Imaging (MWI) method through DRHA able to detect breast cancer through screening [5].

Double ridge horn antenna also plays crucial role in dielectric characterization of materials and in free space measurement applications. Double ridge horn antenna consists of flared section, feed section and waveguide section. It is found that the ridges are used in the design of horn antenna so that the bandwidth could be increased. Also, some horns are designed with lens such as parabolic lens and hemispherical lens [6],[7]. The use of lens is to reduce the diffraction effects and to maintain the gaussian beam. The dielectric focusing lenses in horn antenna design is to bundle electromagnetic energy at a certain region. To overcome the limitations in designing the horn antenna, metallic grid sidewalls was used in the design and optimization of parameters was done. Also, some improvements were done on the feeding part and waveguide section. The gain, VSWRs and radiation patterns of the design were obtained and analyzed. In this paper, a detailed explanation on the antenna design and the results are being reported.

II. THE DESIGN OF THE DOUBLE RIDGE HORN ANTENNA

The design of horn antenna comprises of waveguide section, feed section and the flared section. For the antenna feeding SMA connector is used. The outer conductor which acts as the protective layer of the coax connects to the upper ridge and the inner conductor which is the pin is connected to the lower ridge of the antenna. Coaxial probe to waveguide transition is necessary to enhance the performance of the antenna. The inner conductor passes through the first ridge, then connected to the other ridge. The bell section is also connected to the lower ridge of the antenna. The bell section is created with the 3D polygon curve which consists of the bell, bell circle, pin thickening and pin thickening curve. The purpose of the cavity back in the design is to get a better result of S_{11} parameter and to prevent back radiation. This DRHA antenna is smaller in size and able to produce higher gain when compared with the commercial one. Figure 1 shows the design of the double ridge horn antenna with coax connector and metallic grid sidewalls. Figure 2 presents the cutting plane view of the antenna which includes the cavity back, the ridges, bell section, coax connector and inner conductor. Table 1 below shows the antenna specifications.

TABLE 1. Antenna Specifications

Antenna Specification	Value
Frequency Range	2.4 GHz – 9.8 GHz
Antenna type	Double Ridge Horn Antenna
Radiation	Directional
Gain	5.97 dBi – 16.3 dBi
E-plane beamwidth(degree)	23 – 102
H-plane beamwidth(degree)	23– 92

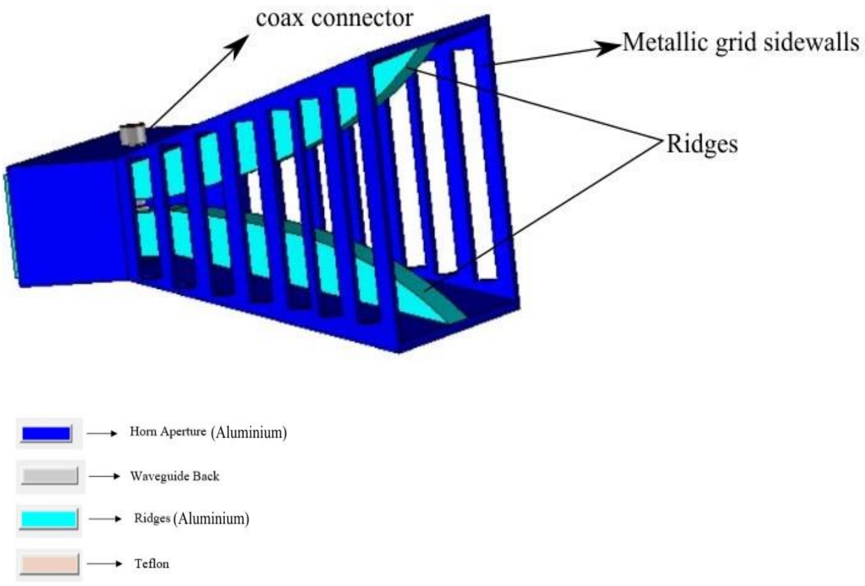


FIGURE 1. The design of the double ridge horn antenna

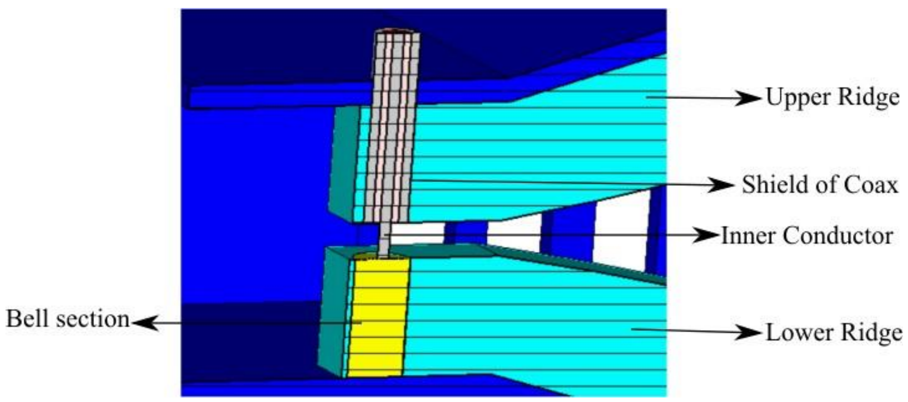


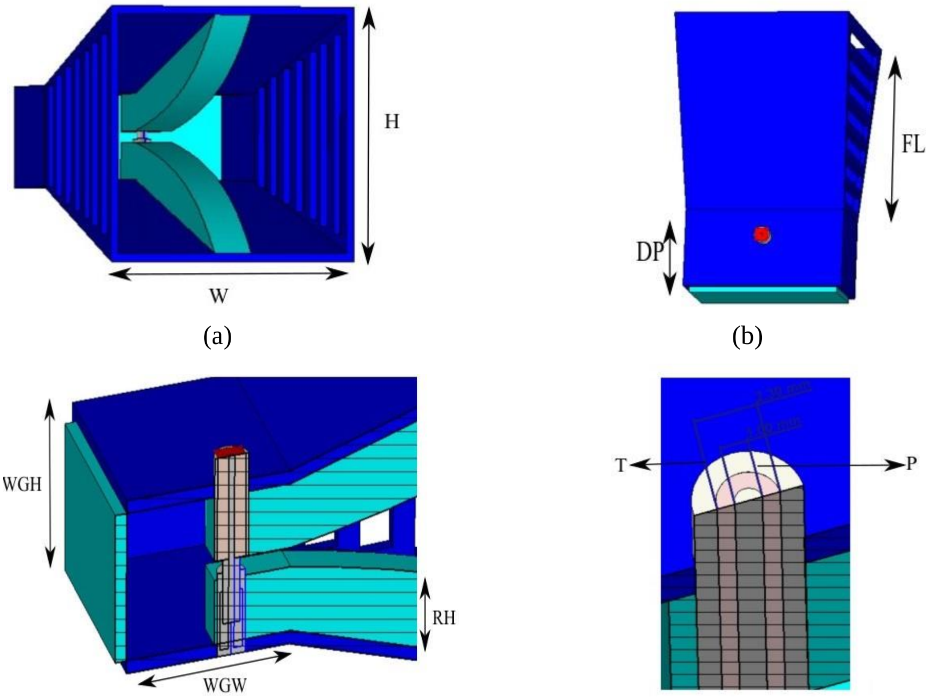
FIGURE 2. Cutting plane view of the antenna

A. Dimensions of the proposed double ridge horn antenna

Figure 3 shows the double ridge horn antenna dimensions. Important parameters such as distance of the pin, radius of the pin, radius of Teflon and ridge height also affects the simulation results significantly. Distance of pin refers to the distance of the coax connector from the waveguide section. Ridge height refers to the spacing between the ridges. The closer the spacing between the ridges, the better the results. Table 2 presents the parameters of the antenna that was designed.

TABLE 2. The parameters of the antenna

Parameters	Symbols	Values (mm)
Height of the horn aperture	H	66
Width of the horn aperture	W	66
Focal length of the horn	FL	70
Waveguide width	WGW	56
Waveguide height	WGH	23
Distance of pin	DP	18.5
Diameter of the pin	P	1
Diameter of the Teflon	T	2.3
Ridge height	RH	10



(c) (d)

FIGURE3. Double Ridge Horn Antenna Dimensions, (a) front view, (b) top view, (c) cross section view inside the horn, (d) horn inner feed

III. SIMULATION RESULTS

In this part, the results obtained from the simulation of the design were analyzed. Figure 4 below shows the S_{11} parameter results obtained from 2 GHz-10 GHz. The bandwidth for the DRHA starts from 2.4 GHz to 9.8 GHz which is the operating frequency. The S_{11} results obtained was at below -10 dB. By optimizing certain parameters for the coaxial part and its inner conductor, the S_{11} was obtained. Figure 5 shows the VSWR result while Fig.6 shows the maximum gain over frequency results for the horn antenna. From 2 GHz to 10 GHz, the VSWR obtained was less than 2. Throughout the operating frequency, VSWR is less than 2. VSWR less than 2 shows that the antenna has good matching. Moreover, the gain has shown increase at certain frequencies which is from 2 GHz to 7 GHz and sudden drop at 8 GHz and start to increase again at 9 GHz. Among the operating frequency, at 9.98 GHz attained the highest gain and at 2.4 GHz is the lowest gain. There are no large fluctuations in the gain curve. The peak gain is 13.4 dBi at 7 GHz. The higher the frequency, the higher the gain except at 8 GHz.

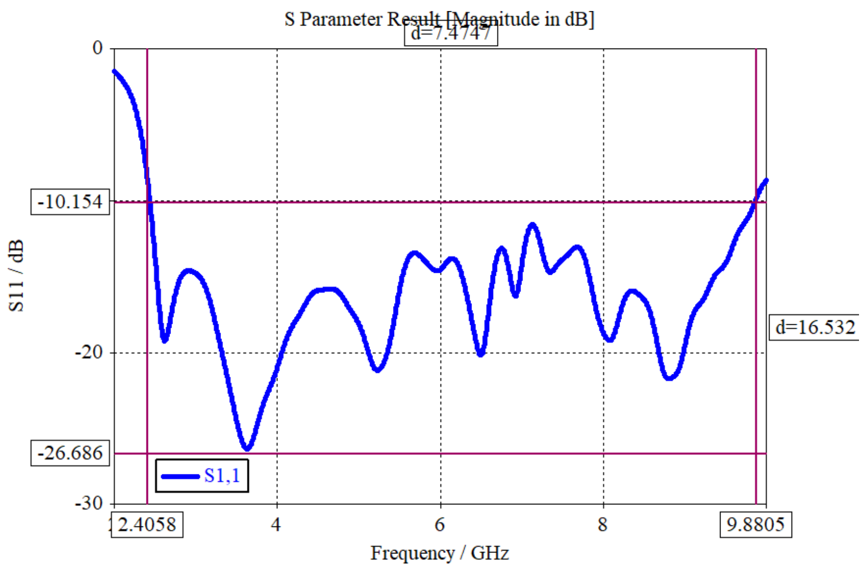


FIGURE 4. S parameter result

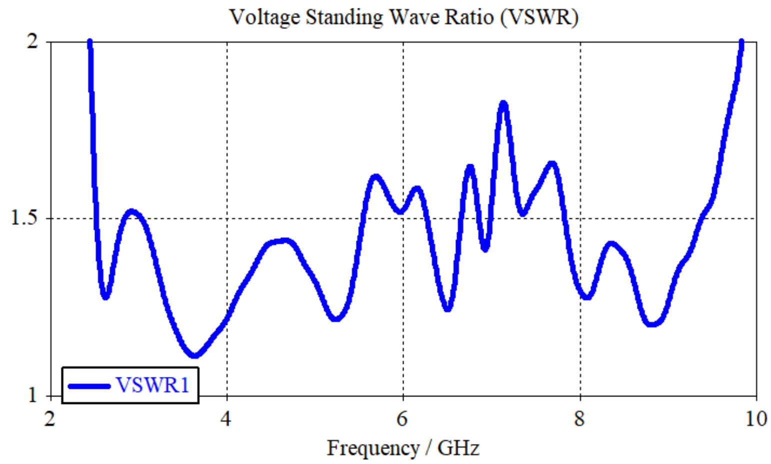


FIGURE 5. VSWR result

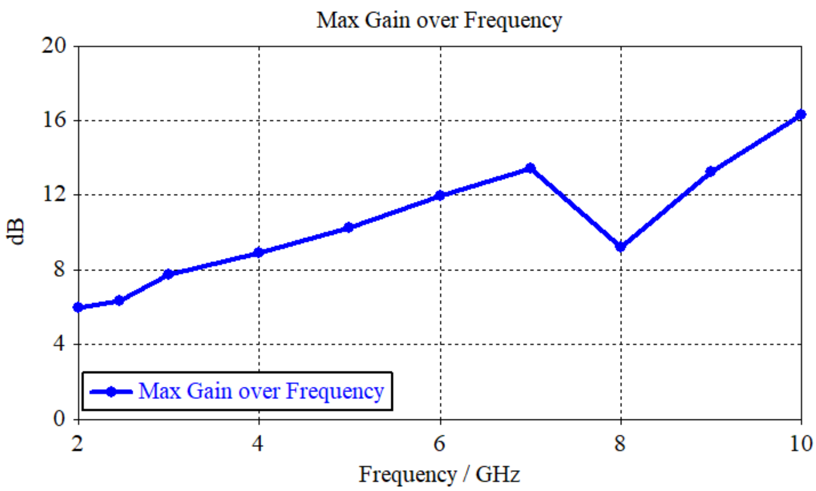


FIGURE 6. Maximum gain over frequency result

Figure 7 below shows the surface current distribution at 3 GHz, 7 GHz, 8 GHz and 9 GHz respectively. At 7 GHz, the surface current distribution is higher compared to the surface current distribution at 3 GHz. The highest gain obtained was at 7 GHz which is 13.4 dBi. Higher amount of current at surface of the antenna has produced higher gain. At 7 GHz the current density is higher compared to 3 GHz and 8 GHz. The gain at 3 GHz is 7.77 dBi and increases up to 13.4 dBi at 7 GHz, drops to 9.21 dBi at 8 GHz and increases again to 13.3 dBi at 9 GHz. The gain drop at 8 GHz is due to the fact that the antenna is radiating less and changes in the antenna beam. It is proven that as the frequency increases, the surface current distribution looks more concentrated. At higher frequencies, the surface current distribution is higher which results in higher gain as can be seen from the radiation pattern.

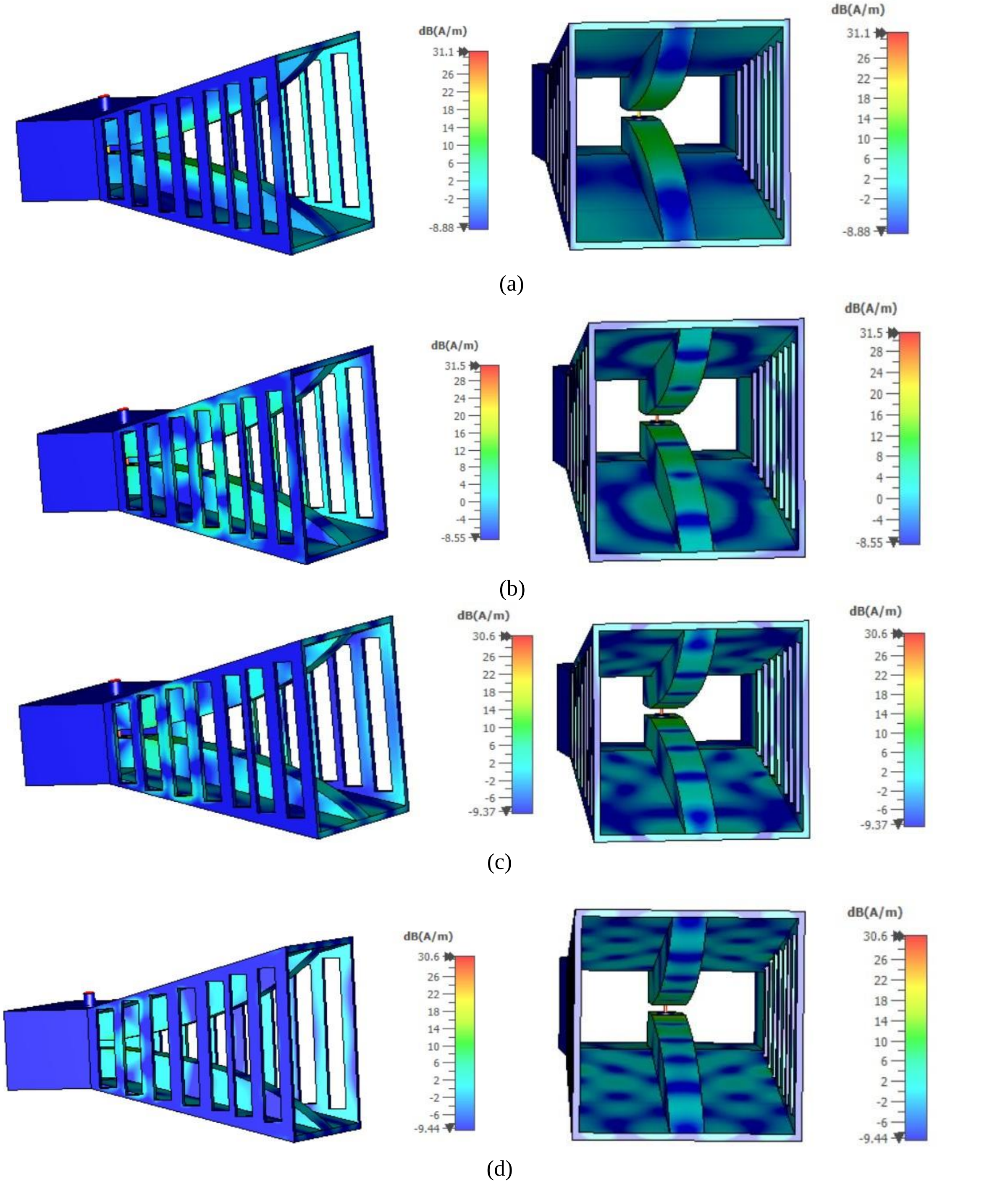
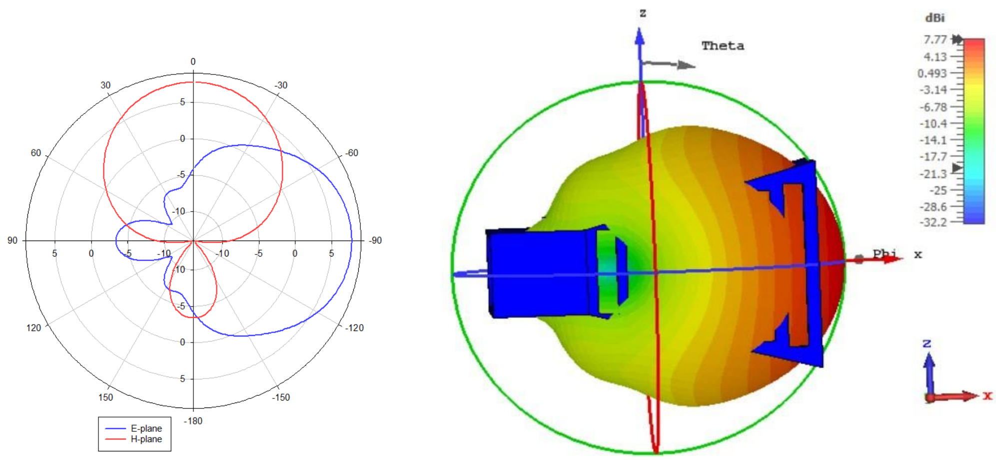


FIGURE 7. Surface current distribution of the double ridge horn antenna at (a) 3 GHz (b) 7 GHz (c) 8 GHz (d) 9 GHz

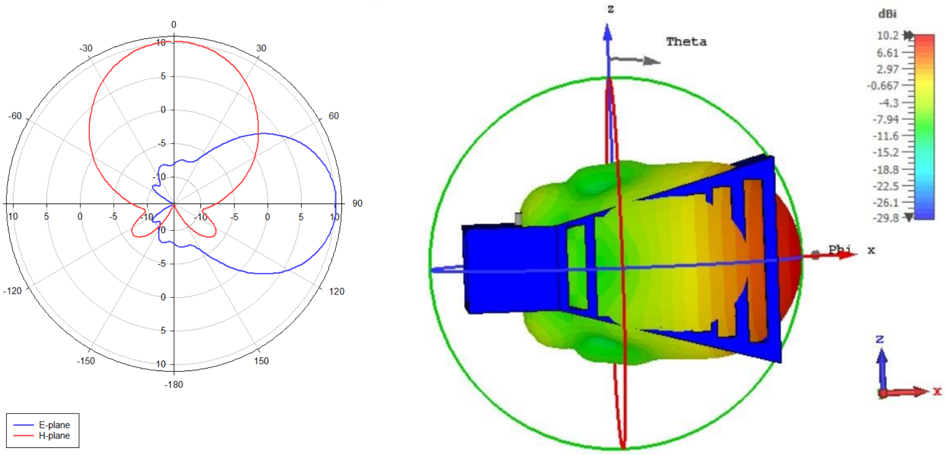
Table 3 below shows the radiation pattern results of the horn antenna. The peak gain is found to be 13.4 dBi at 7 GHz. The gain shows increase from 7.75 dBi to 13.1 dBi from 2 GHz to 7 GHz. At 8 GHz the gain shows sudden drop to 9.46 dBi and increases again to 13.3 dBi at 9 GHz. Higher gain obtained at 7 GHz which is 13.4 dBi among the operating frequencies.

TABLE 3. Radiation pattern results of the horn antenna

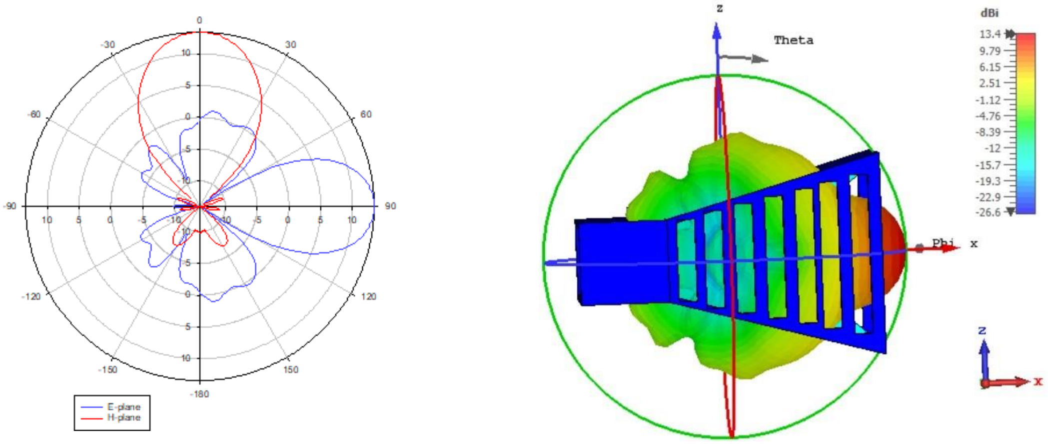
Frequency	Gain(dBi)	E-plane angular width (3 dB) in degrees	H-plane angular width (3 dB) in degrees
2GHZ	5.97	101.6	92.4
3GHz	7.77	72	71.3
4GHz	8.94	60	65.4
5GHz	10.2	49	59.5
6GHz	12	40.2	50
7GHz	13.4	29	36
8GHz	9.21	100.3	44.9
9GHz	13.3	31.3	35.2
10GHz	16.3	22.7	23.3



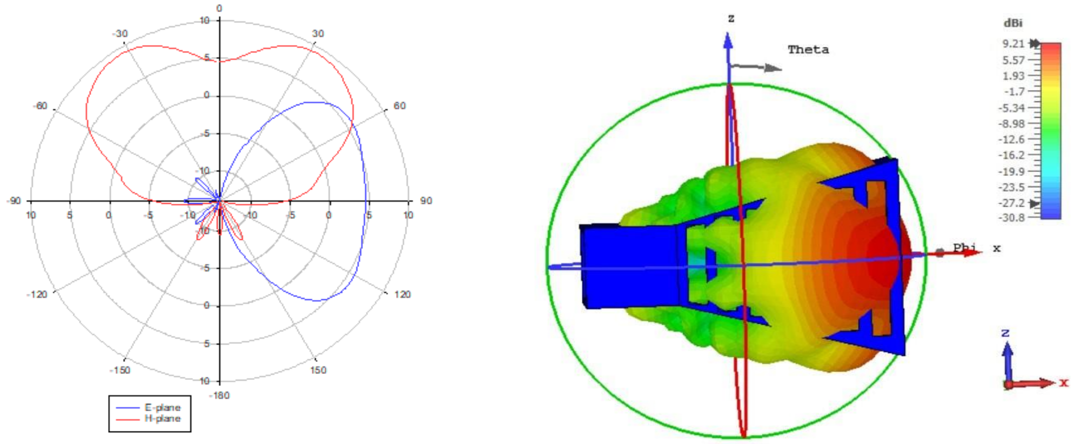
(a) Frequency = 3 GHz



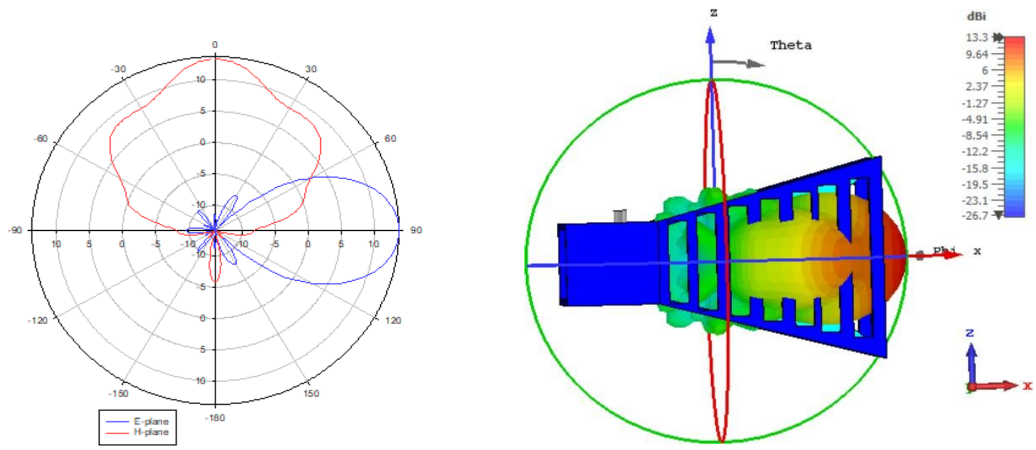
(b) Frequency = 5 GHz



(c) Frequency = 7 GHz



(d) Frequency = 8 GHz



(e) Frequency = 9 GHz

FIGURE 8. Radiation pattern results

IV. CONCLUSION

From the results obtained, it is found that the DRHA produced good results which is suitable for free space material measurement applications. It has been examined that the coaxial probe, its inner conductor and other parameters plays a significant role in determining the antenna performance which would be helpful in future antenna applications. The VSWR, gain and S_{11} obtained was good at operating frequency from 2.4 GHz to 9.8 GHz and the peak gain obtained was 13.4 dBi. A continuation for this research can be used of the same method but consider the problems has been mentioned earlier. For the future work, use of dielectric lens is prompted in designing the DRHA for the further improvement in results.

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