Parametric Analysis and Optimisation of a 8–18 GHz Quad-ridged Horn Antenna

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Abstract— In this paper, parametric analysis and optimization of a 8–18 GHz ultra wide band (UWB) quad-ridged horn (QRH) antenna is presented. As an initial configuration a horn antenna is designed with boxed dimensions of $5.4 \times 5.4 \times 8$ cm as defined in [1]. The gain of the antenna varies between 10 dBi–13 dBi over the entire bandwidth. The co-polarization and cross polarization graphics are presented. It's expected that, the variation of physical dimensions affects the antenna parameters. To analyze these effects the parametric analysis simulations are performed with ANSYS HFSS software.

1. INTRODUCTION

Ultra wide band antennas with high gain are required to meet the requirements of today's telecommunication sector. Parabolic reflector antennas are probably the most widely used for this purpose in the microwave region. Horn antennas can be used as a feed and provide high gain, low VSWR, relatively wide bandwidth. To extend the maximum practical bandwidth of a horn, ridges are introduced in the flared part of the antenna. The radiation phenomenon is based on the wave impedance transition from waveguide line to the impedance of free space through ridges. One of the most preferred methods to increase the bandwidth and gain of horn antennas is to use double or quad ridges [2, 3].

In this paper, the parametric analysis and optimization of a QRH antenna is presented. The antenna is fed by from either one port or double port. At each analysis the fed type is described. Simulations are performed by ANSYS HFSS. HFSS offers multiple state-of-the-art solver technologies based on finite element, integral equation or advanced hybrid methods to solve a wide range of microwave applications. The QRH antenna is simulated by Finite Element Method, FEM.

The organization of this paper is as follows. Section 1 is introduction. In Section 2, the design parameters of the antenna are explained. A QRH is designed as defined in [1] as an initial configuration. The antenna is analyzed and the return loss, gain pattern, co-polarization and cross polarization of the antenna are given for the entire band width. The variations on physical dimensions of the antenna are implemented and the effects on antenna parameters are presented in Section 3. It has been observed that the dimension variation effects may differ for upper or lower frequencies. The conclusion is given at Section 4.

2. INITIAL CONFIGURATION QRH ANTENNA

A QRH antenna is designed based on the design explained in [1]. The dimensions of the antenna are described in Figure 1. The physical sizes of the antenna are given in Table 1. The horn fed by coaxial cable.

Table 1: The physical sizes of QRH antenna for initial configuration.

Parameter	Length (cm)	Parameter	Length (cm)
A	1.6	$L1$	4
B	1.6	$L2$	4
$A1$	5.6	$d1$	0.3
$B1$	5.6	w	0.14

The return loss value and gain of QRH antenna is presented in Figures 2(a) and 2(b) respectively. In 8–18 GHz frequency band, the gain varies between 10.67 to 12.37 dBi.

The gain pattern of the antenna is given at Figure 3(a) and E-field inside of the horn is given at Figure 3(b). The 3D beam pattern of QRH antenna at 8 GHz and 18 GHz are presented at Figures 3(c) and (d) respectively.

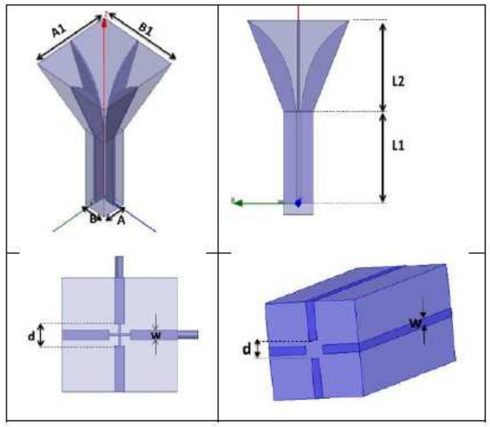


Figure 1: The description of horn antenna's dimensions.

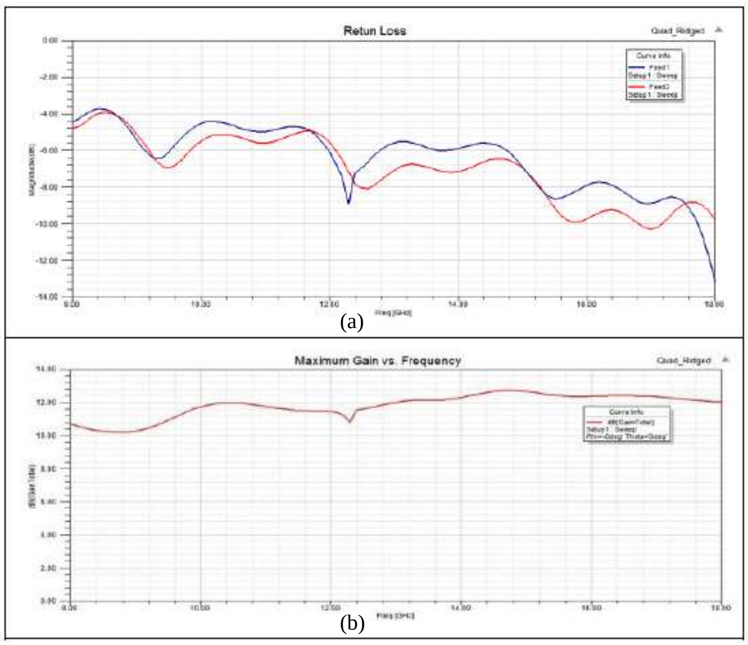


Figure 2: (a) Return loss. (b) The gain at 8–18 GHz.

The co-polarisation and cross polarization pattern are given at Figure 4(a) E-plane for 8 GHz, (b) H-plane for 8 GHz, (c) E-plane for 18 GHz and (d) H-plane for 18 GHz respectively.

3. PARAMETRIC ANALYSIS

For parametric analysis, the dimensions of the horn antenna is parametrised. As a first analysis, the outer dimensions $A1$ and $B1$ is selected to be equal and the values are given in Table 2.

Table 2: The parametric variation $A1$ and $B1$.

Case 1	$A1 = B1 = 2.6$
Case 2	$A1 = B1 = 4.1$
Case 3	$A1 = B1 = 5.6$
Case 4	$A1 = B1 = 7.1$
Case 5	$A1 = B1 = 8.6$

The analysis are performed for five cases. The gain patterns for five cases are given for 8 GHz, and 18 GHz at Figures 5(a) and (b) respectively. The beamwidth and gain varies with parametric change of outer dimensions as presented at Figure 5.

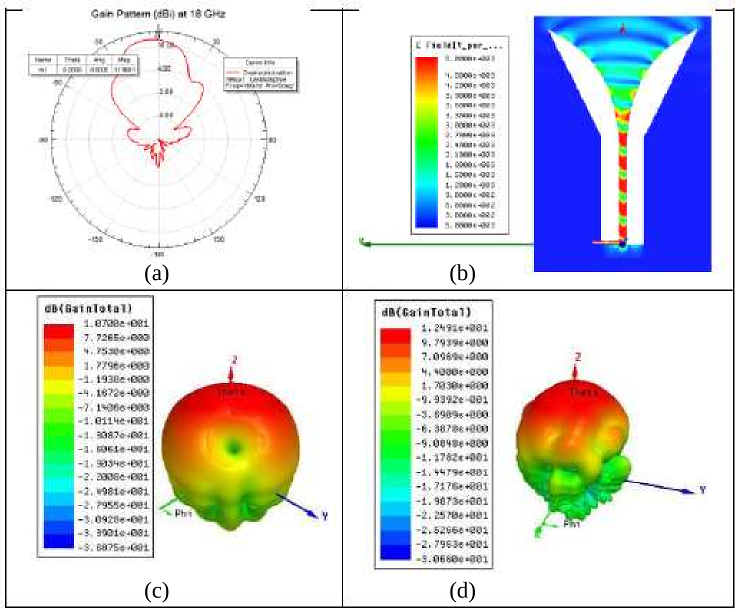


Figure 3: At 18 GHz (a) at 18 GHz, (b) E-field at 18 GHz, (c) 3D radiation pattern at 8 GHz, (d) 3D radiation pattern at 18 GHz.

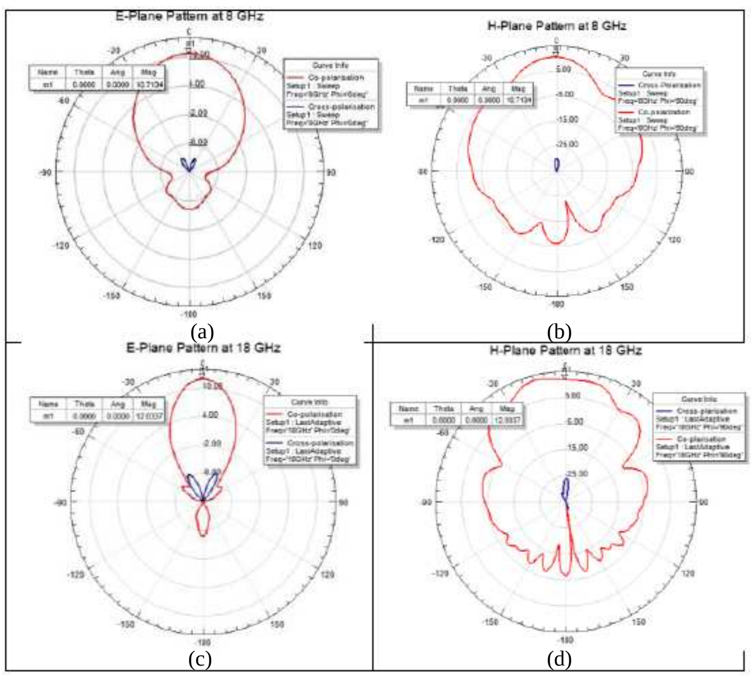


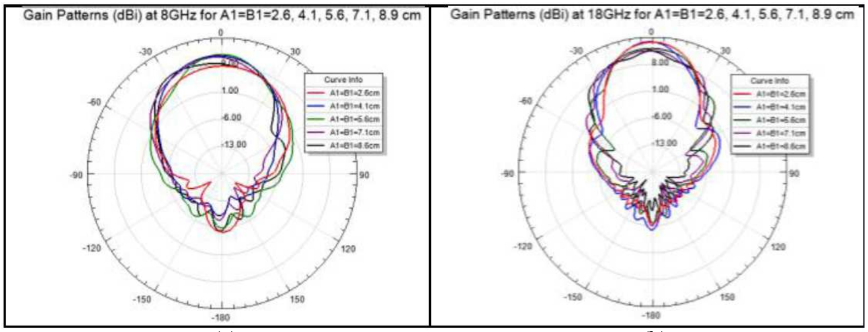
Figure 4: Co-polarisation and cross polarization pattern (a) E-plane for 8 GHz and (b) H-plane for 8 GHz and (c) E-plane for 18 GHz and (d) H-plane for 18 GHz.

The maximum gain for cases are simulated for entire band width.When the outer dimensions are increased it is observed that the gain decrease due to increasing beamwidth. The dimensions are varied from 2.6 cm to 8.6 cm. The numerical values of gain are presented at Table 3 and graphic is presented at Figure 6.

The advantage of this type of parametric analysis is mainly to find the optimal values for each parameter. At this parametrical analysis, it's observed that the gain is maximized for $A1 = B1 =$ 4.1 cm. The parametrical sweep can be repeated with smaller steps to find the maximum gain while the outer dimensions vary from 4.1 cm to 5.6 cm.

This analysis is repeated while $A1 = 5.6$ cm and constant, $B1$ is varying from 2.6 cm to 8.6 cm. The numerical values of gain are presented at Table 4.

The graphic for gain vs frequency is presented at Figure 7.



(a) (b)

Figure 5: Gain pattern for (a) 8 GHz. (b) 18 GHz.

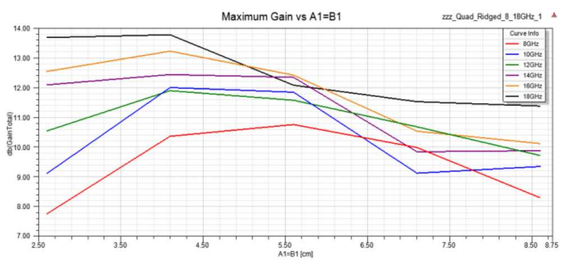


Figure 6: Gain pattern for varying dimensions.

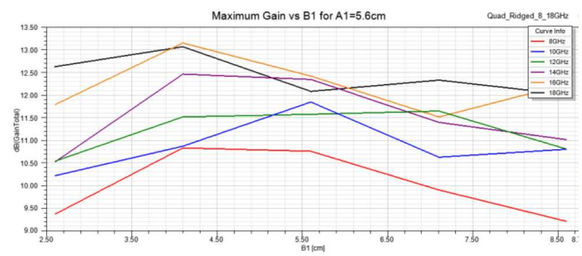


Figure 7: Gain pattern for varying $B1$ dimensions.

In this case to obtain the maximum gain, $B1$ can be selected around 5.6 cm, while $A1$ is constant.

The 3D Beam Pattern of antenna at 18 GHz is presented at Figure 8(a) for $B1 = 2.6$ cm and Figure 8(b) for $B1 = 8.6$ cm respectively. The $3D$ patterns indicate that beamwidth increases as $B1$ increases.

For the varying dimensions of $B1$ the E plane and H plane radiation patterns are presented at Figure 9 for 8 GHz and 18 GHz. It is also observed that beamwidths are increased as long as $B1$ increases.

The parametric analysis are performed also for d and w parameters as they were described at Figure 1.

The w parameter is selected to vary from 0.1 cm to 0.16 cm. This variation has almost no

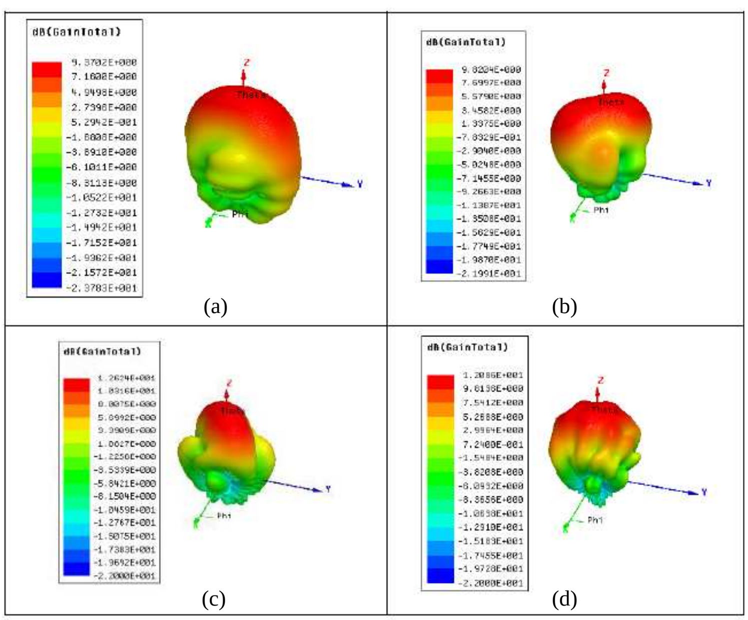


Figure 8: 3D beam pattern of antenna at 8 GHz. (a) $B1 = 2.6$ cm. (b) $B1 = 8.6$ cm and at 18 GHz. (c) $B1 = 18$ GHz. (d) $B1 = 8.6$ cm.

Table 3: Gain vs dimensions for $A1 = B1$.

	Freq [GHz]	A1=B1=2.6cm	A1=B1=4.1cm	A1=B1=5.6cm	A1=B1=7.1cm	A1=B1=8.6cm
1	8.00	7.76	10.37	10.76	9.99	8.30
2	10.00	9.11	12.00	11.84	9.13	9.35
3	12.00	10.54	11.90	11.57	10.68	9.72
4	14.00	12.09	12.44	12.34	9.84	9.88
5	16.00	12.54	13.22	12.42	10.54	10.12
6	18.00	13.68	13.77	12.08	11.53	11.38

Table 4: Gain vs dimensions for $A1 = 5.6$ cm.

	Freq [GHz]	B1=2.6cm	B1=4.1cm	B1=5.6cm	B1=7.1cm	B1=8.6cm
1	8.00	9.37	10.83	10.76	9.91	9.21
2	10.00	10.22	10.87	11.84	10.63	10.80
3	12.00	10.54	11.52	11.57	11.65	10.80
4	14.00	10.52	12.46	12.34	11.40	11.01
5	16.00	11.79	13.15	12.42	11.52	12.24
6	18.00	12.62	13.06	12.08	12.33	12.01

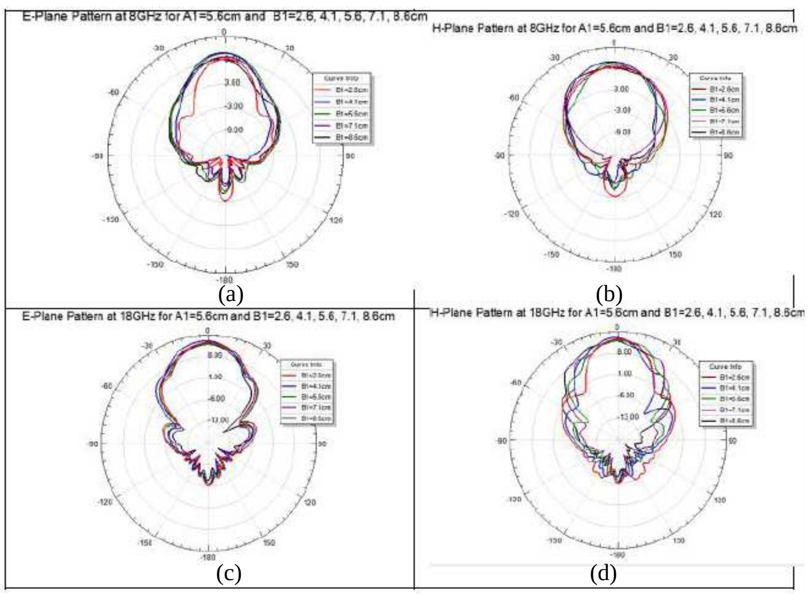


Figure 9: (a) E plane pattern at (b) H plane pattern at 8 GHz. (c) E plane pattern at 18 GHz. (b) H plane pattern at 18 GHz.

influence on gain at the entire bandwidth as can be seen at Figure 10.

With a similar approach, the parameter is selected to vary from 0.2 cm to 0.4 cm. The gain graphic shows that the optimum parameter of $d = 0.30$ cm as can be seen at Figure 11.

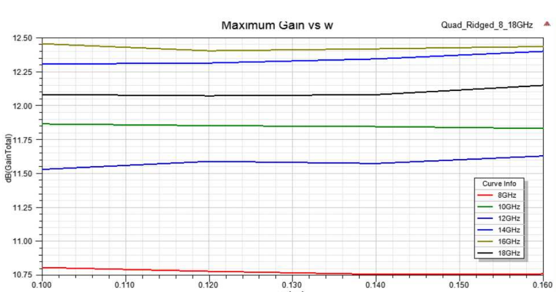


Figure 10: Gain vs w parameter.

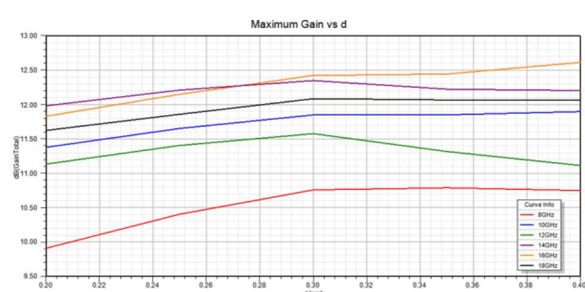


Figure 11: Gain vs d parameter.

4. CONCLUSION

In this paper, the quad ridged horn antenna design is performed, parametric analysis are simulated and the results are presented. The simulation tools are very useful for this kind of parametric analysis. With the help of such tools the best performance of the antenna can be achieved.

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