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A NOVEL DUAL-POLARIZED DOUBLE-RIDGED HORN ANTENNA FOR WIDEBAND APPLICATIONS

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Abstract—Dual-polarized antenna is widely used in communication systems such as ECM and DF systems. In this paper a novel double-ridged horn antenna with dual polarizations is introduced for frequency range of 8–18 GHz. Common double ridged horn antennas have single polarization over the operating frequency. We have used five layers polarizer to provide dual polarizations performance of the double-ridged horn antenna.

In order to achieve dual polarizations the strips width, strips spacing and layers distances are optimized. It is worth mentioning that the corresponding VSWR of the antenna during the optimization process should be maintain below a certain value (VSWR < 2).

Simulation results show that the proposed antenna yields dual polarizations performance and low VSWR over the operating frequency. We have used CST software for antenna simulation which is based on the finite integral technique.

1. INTRODUCTION

The utilizing of double-ridged horn (DRH) antennas continues to increase. These systems are commonly employed in different fields such as reflector feeds, radar, electronic warfare, detection systems, EMC testing and satellite tracking systems [1, 2]. These numerous applications are made possible due to the particular characteristics of these antennas such as versatility, easy excitation, relatively simple construction, high gain and directivity performance [3–5]. To extend the maximum practical bandwidth of horns, ridges are introduced in the flared part of the antenna. This is commonly done in waveguides to decrease the cutoff frequency of the dominant propagating mode (TE_{10}) and thus expands the single-mode range before higher order modes occur [6–8]. Spreading of higher order modes arises from power division between the modes and due to various field distributions, they influence the desired radiation patterns and especially the main lobe deteriorates for higher frequencies. A detailed investigation on 1 to 14 GHz broadband electromagnetic compatibility DRGH Antenna was reported by Botello, Aguilar and Ruiz [9]. A detailed investigation on 1–18 GHz broadband double-ridged horn antenna was reported in [10]. An improved design of the double-ridged horn antenna was presented in [11]. In [12], a quad ridged horn antenna on the 2–26.5 GHz bandwidth with VSWR < 3.1 has been used to achieve dual-polarized performance over the wideband frequency range. Another design of the double-ridged horn antenna in 1–18 GHz range with redesigned feeding section was presented in [13] where several modifications are made in structure of a conventional double ridged guide horn antenna in order to overcome the deterioration of its radiation pattern at higher frequency.

In this paper, a novel configuration of double ridged horn antenna including a five layers polarizer at the horn aperture is proposed providing wideband and dual polarizations performance. Using the commercially available software package CST, simulation results of VSWR, far-field radiation patterns and gain of the designed antenna over the frequency band 8–18 GHz is presented.

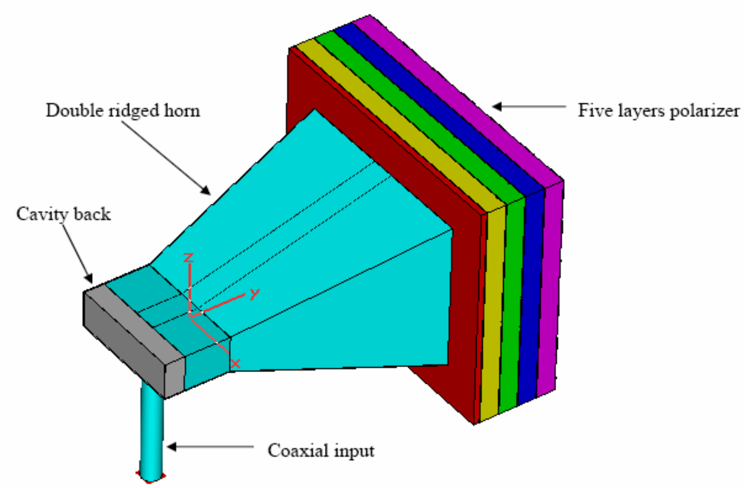


Figure 1. The proposed dual-polarized DRH antenna.

2. DUAL-POLARIZED DOUBLE-RIDGED HORN ANTENNA STRUCTURE

The proposed antenna is shown in Fig. 1. The dual-polarized DRH antenna is composed of three parts: The feeding section, tapered section and five layers polarizer. The design process of each part is investigated completely in the next sections.

2.1. Design of the Tapered Part

Usually ridged and double ridged waveguides are used for provision of single mode propagation in wide band frequency range. Also, ridges vary the impedance of the guide from $50\,\Omega$ at the feeding point (double-ridged waveguide) to $377\,\Omega$ at the aperture of the horn antenna [14]. The ridges have exponential taper with respect to y, the distance from the waveguide aperture. The design of the double ridged waveguide in the tapered section is the most significant part in the antenna design, Fig. 2. The dimensions and geometrical view of the proposed DRH antenna are illustrated in Table 1 and Fig. 3, respectively.

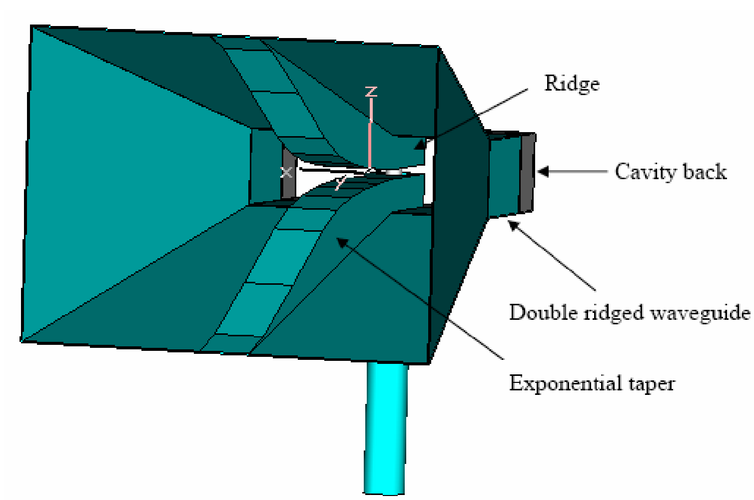


Figure 2. DRH antenna models.

The impedance variations in the tapered part is as Eq. (1):

$$Z(y) = z_0 e^{ky}, \qquad (0 \leq y \leq l) \tag{1}$$

wherein y is the distance from the waveguide aperture. In the designed

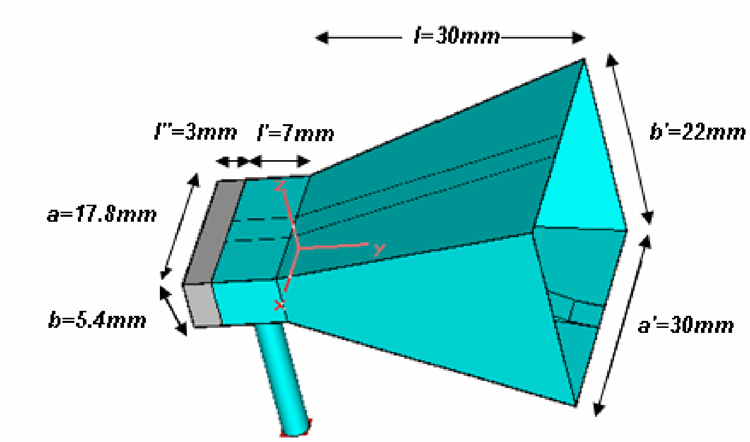


Figure 3. Geometrical view of the DRH antenna.

double-ridge horn antenna $l = 30$ mm. The k is calculated as follow

$$k = \frac{1}{l} \ln \left(\frac{Z_L}{Z_0} \right) \tag{2}$$

in which Z_0 and Z_L are characteristic impedance of double-ridged waveguide and free space, respectively.

The axial length of the horn opening (l) is divided into eight sections. Now we have 8 double-ridged waveguides. Characteristic impedance of each section can be calculated by Eq. (1) (Table 1).

Table 1. The dimensions of the proposed DRH antenna.

a, width of the waveguide aperture (mm)	17.8
b, height of the waveguide aperture (mm)	5.4
a', width of the horn aperture (mm)	30
b', height of the horn aperture (mm)	22
l, axial length of the horn opening (mm)	30
l', length of the ridged waveguide (mm)	7
l'', length of the cavity back (mm)	3
w, width of the ridges (mm)	3.6
d, Spacing between the ridges of waveguide (mm)	0.66

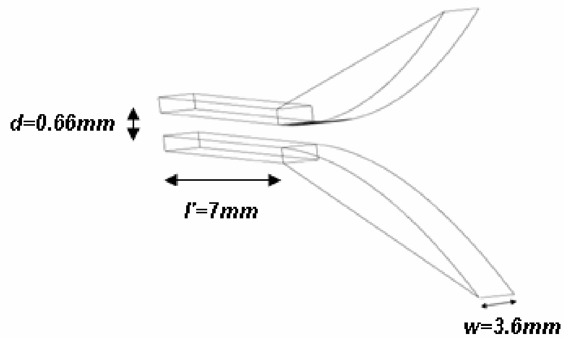


Figure 4. Configuration of the ridges.

By using the optimization process, the height of ridges and spacing between them are obtained for each section. It can be seen that at first, the height of ridge increases and then decreases (Fig. 4). HFSS software is used for the optimization process and impedance synthesis in each section. The detail design dimensions of tapered section are shown in Table 2.

Table 2. Detail design dimensions of tapered part.

#waveguide	distance from waveguide aperture (mm)	Characteristic impedance (Ω)	width of the waveguide aperture (mm)	height of the waveguide aperture(mm)	height of the tapered ridge (mm)	distance between the ridges (mm)
1	0	50.00	17.80	5.40	2.37	0.66
2	3	61.19	19.01	7.06	3.00	1.05
3	6	74.89	20.24	8.72	3.60	1.52
4	9	91.66	21.46	10.38	4.00	2.37
5	12	112.18	22.68	12.04	4.10	3.83
6	15	137.29	23.90	13.70	3.60	6.49
7	21	205.08	26.34	17.02	1.80	13.42
8	27	308.03	28.78	20.34	0.20	19.94

2.2. Coax to Double-Ridged Waveguide Transition

The transition between coaxial probe and the double-ridged waveguide is important to the return loss performance of the horn antenna. Principal goal is obtaining low levels of VSWR throughout transformation of TEM- mode in coaxial to TE-mode in waveguide. Muenzer [15] proposed technical solution that allows improving

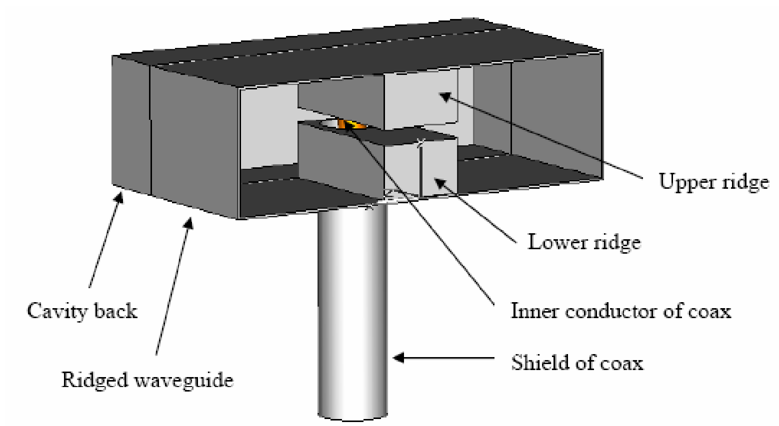


Figure 5. Configuration of the designed coax to double-ridged waveguide transition.

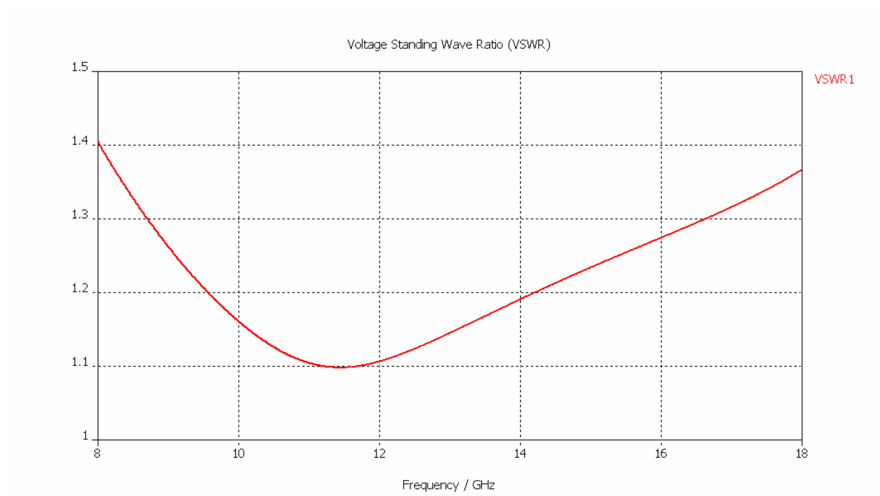


Figure 6. VSWR of the coax to double-ridged waveguide transition.

characteristics (bandwidth and return loss) of coax to double-ridged waveguide transition.

In order to achieving low VSWR, cavity back dimensions and probe spacing from the ridged edge should be optimized. The proposed transition is shown in Fig. 5 with more details. As illustrated in Fig. 6 the designed transition yields VSWR less than 1.4 in the entire frequency band.

2.3. Design of Five Layers Polarizer

In this section we study the five layers polarizer that added to the DRH antenna for providing dual polarizations in the frequency range of 8–18 GHz. Fig. 7 presents the configuration of the five layers polarizer. The polarizer size is $h_1 = 42\,\text{mm}$, $h_2 = 13\,\text{mm}$ and $h_3 = 34\,\text{mm}$ along the x, y and z axes respectively. As shown in Fig. 1 the polarizer is located at the front of the DRH antenna. The configuration of proposed polarizer as presented in Fig. 7 is composed of five layers dielectric and five layers of parallel strips. In order to achieve dual polarizations performance the outgoing wave from the polarizer should be slant. According to the Amitay and Saleh [16] article, incoming and outgoing wave polarizations should be perpendicular to the direction of the first and the last strips layer of polarizer respectively. We use five layers polarizer for providing broadband performance over the frequency of 8–18 GHz. The angle between each layer of strips is 11.25 degree (Fig. 8). To receive dual polarizations the strips width, strips spacing and layers distances are optimized. It is worth mentioning that the corresponding VSWR of the antenna during the optimization process should be maintain below a certain value (VSWR < 2). The designed broadband polarizer specifications are illustrated in Table 3.

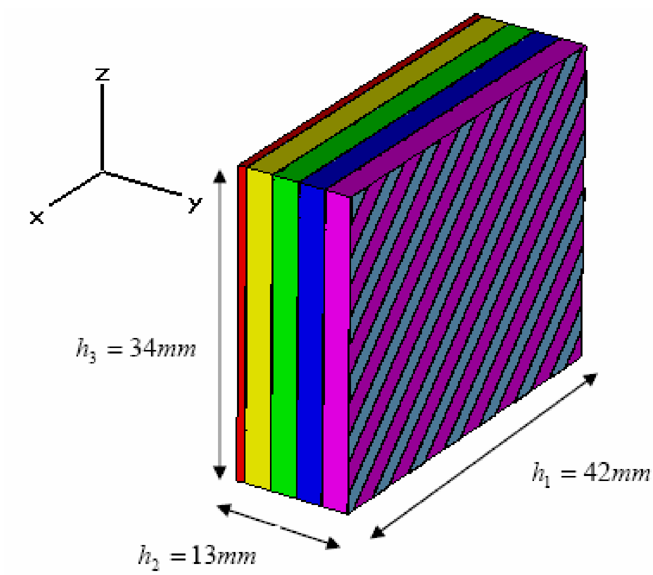
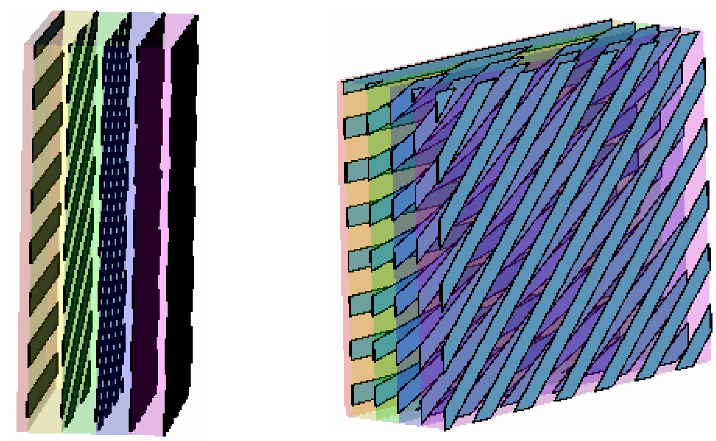


Figure 7. Five layers polarizer model.



(a) (b)

Figure 8. Configuration of the five layers strip of the polarizer. (a) side view (b) overall view.

Table 3. Specifications of broadband polarizer.

First layer dielectric thickness (near the antenna aperture)	0.9 mm
Other dielectrics thickness	2.9 mm
Strips thickness	0.1 mm
Spacing between strips	2.25 mm
Strips width	2 mm
Dielectric material	Styrofoam
Dielectric constant	1.03

3. SIMULATION RESULTS

In this section simulations results of the dual-polarized DRH is presented. The deigned antenna is analyzed by CST software. CST software which is based on finite integral technique is very useful for analysis of UWB antenna. After a time domain simulation, frequency domain response can be obtained over the desired frequency range by

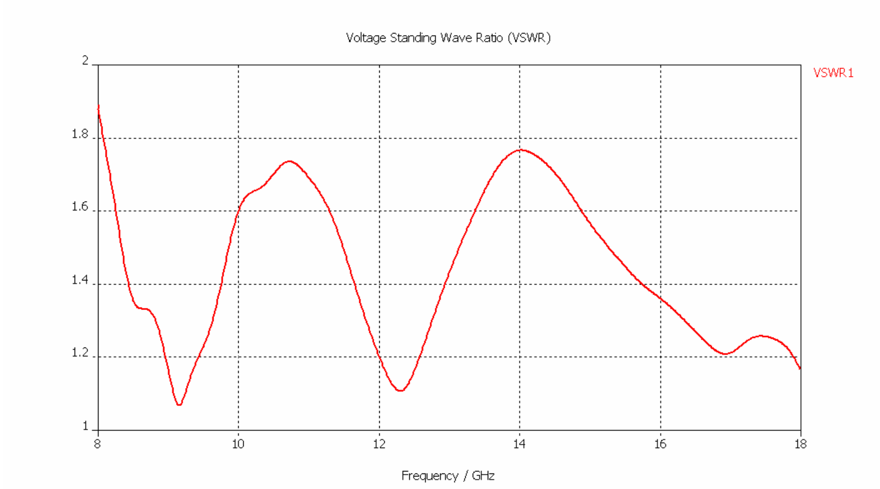


Figure 9. VSWR of dual-polarized DRH antenna.

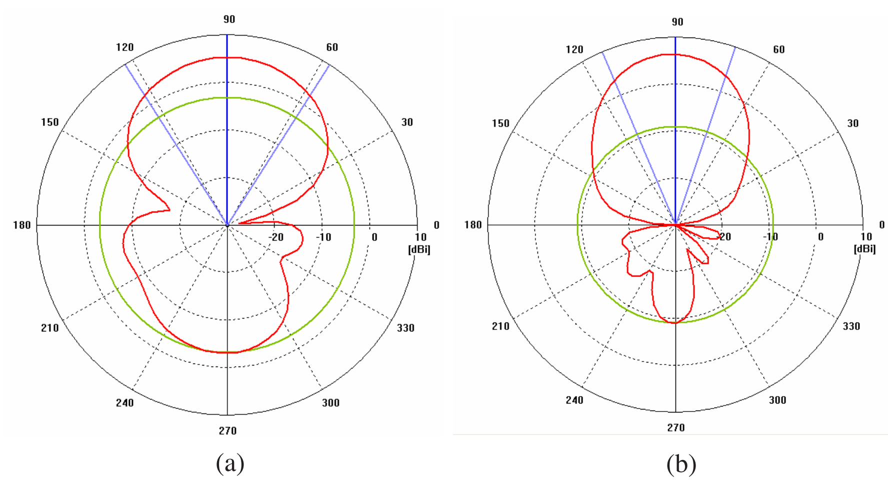
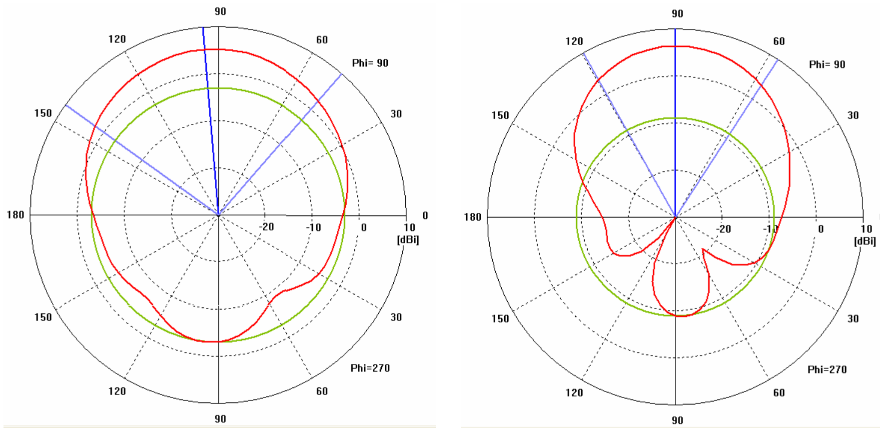


Figure 10. Radiation pattern of dual-polarized DRH antenna in the x-y plane at 8 GHz. (a) E_θ pattern, (b) E_φ pattern.

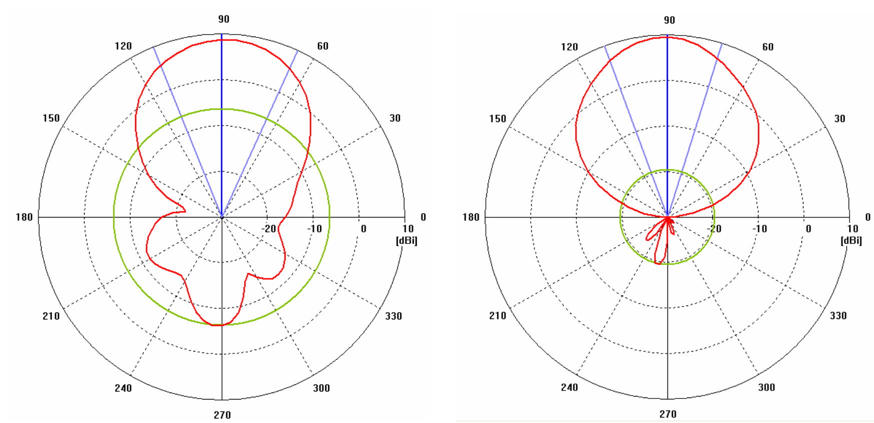
using discrete Fourier transform.

Antenna VSWR is presented in Fig. 9. As shown, the maximum value of the VSWR is less than 2 over the operating bandwidth. The E_θ and E_φ patterns of the antenna for the x-y plane and the y-z plane for various frequencies (8, 13, 18 GHz) are shown in Figs. 10–15. As shown in these figures, proposed antenna yields good performance for



(a) (b)

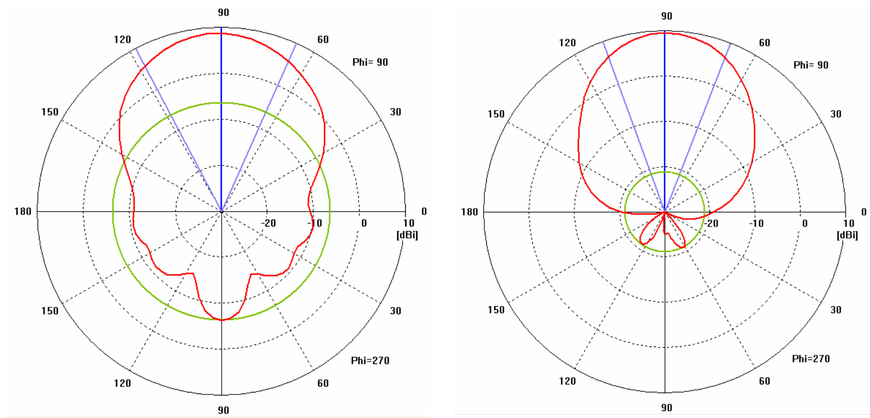
Figure 11. Radiation pattern of dual-polarized DRH antenna in the y-z plane at 8 GHz. (a) E_θ pattern, (b) E_φ pattern.



(a) (b)

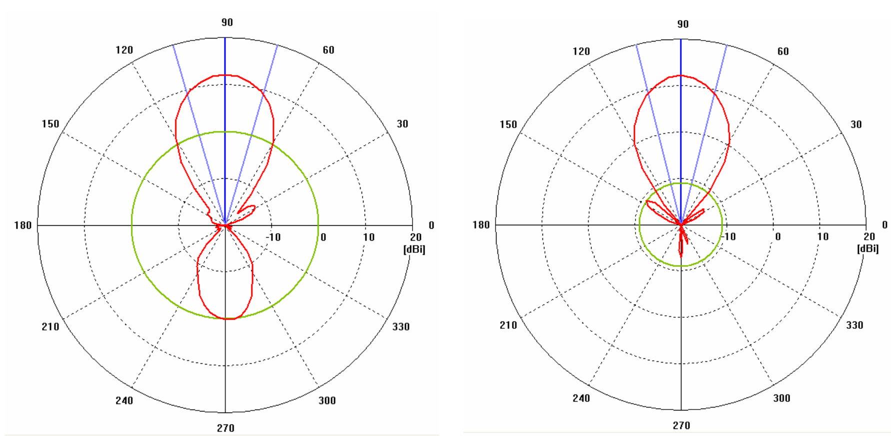
Figure 12. Radiation pattern of dual-polarized DRH antenna in the x-y plane at 13 GHz. (a) E_θ pattern, (b) E_φ pattern.

dual-polarized application. E_θ and E_φ pattern represent vertical and horizontal polarization patterns respectively in the x-y plane and vice versa in the y-z plane. The horizontal and vertical gains of the antenna for various frequencies are shown in Fig. 16. The close values of vertical and horizontal gains represent the good performance of the proposed antenna for dual polarizations.



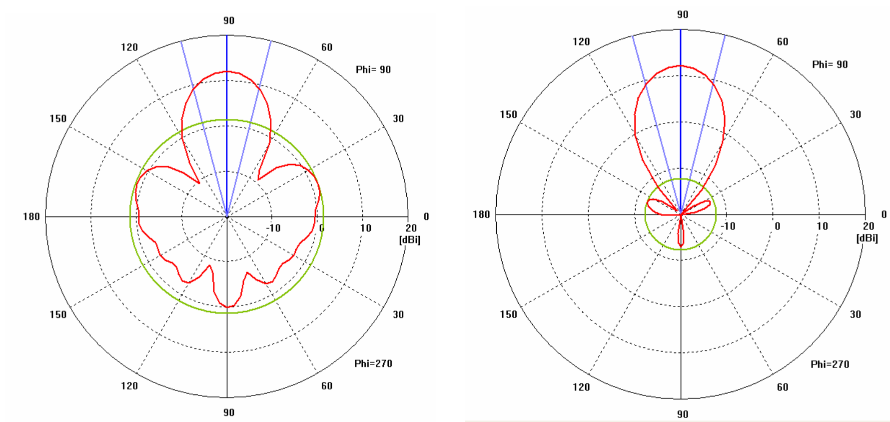
(a) (b)

Figure 13. Radiation pattern of dual-polarized DRH antenna in the y-z plane at 13 GHz. (a) E_θ pattern, (b) E_φ pattern.



(a) (b)

Figure 14. Radiation pattern of dual-polarized DRH antenna in the x-y plane at 18 GHz. (a) E_θ pattern, (b) E_φ pattern.



(a) (b)

Figure 15. Radiation pattern of dual-polarized DRH antenna in the y-z plane at 18 GHz. (a) E_θ pattern, (b) E_φ pattern.

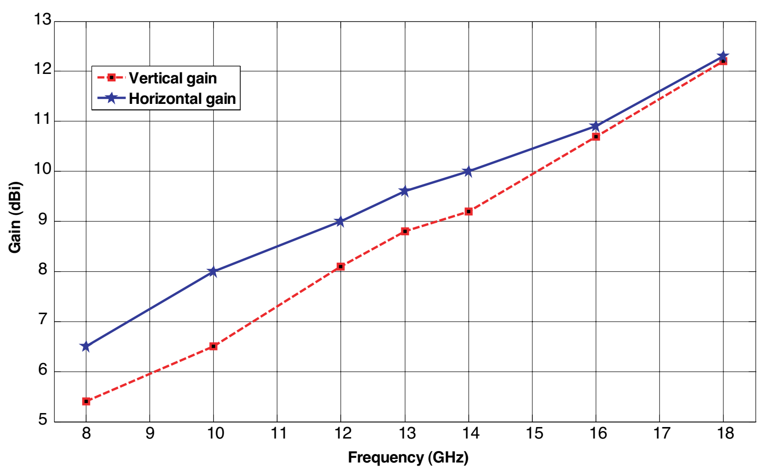


Figure 16. The horizontal and vertical gain of the designed antenna.

4. CONCLUSION

Dual-polarized antenna is widely used in communication systems such as ECM and DF system. In this paper a novel double-ridged horn antenna with dual polarization was introduced for 8–18 GHz. We have used five layers polarizer to provide dual polarizations performance of the double-ridged horn antenna. In order to achieve dual polarizations the strips width, strips spacing and layers distances were optimized. CST software was used for analysis of the designed antenna. The E_θ and E_φ pattern of the designed antenna for the x-y plane and the y-z plane for various frequencies show that, the proposed antenna yields good performance for dual-polarizations application. More over, the antenna VSWR is less than 2 over the operating frequency band which is necessary for UWB application.

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