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Symmetrical Dual Step Finite Partial Ground Notch Truncated RMSA for Ultra Wideband Communication System Applications

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Abstract:

The designed antenna proposed in this paper for UWB wireless communication application is a simple dual symmetrical step finite partial ground notch truncated at the center rectangular microstrip antenna. The desired features of the proposed antennas are wide bandwidth, nearly omni directional radiation patterns, compact in size and simple geometry. Its operating frequency range is from 1.22 to 11.82 GHz with four resonant frequencies centered at 1.66 GHz, 6.51 GHz, 9.21 and 10.78 GHz of respective impedance BW of 162.57% with bandwidth ratio 6.48:1 which is more than the bandwidth ratio of 3.4:1 of UWB allotted by FCC. The overall printed circuit board dimensions are 23.3×24×21.3 mm^3 designed on 50×50 mm^2 modify epoxy substrate of $\epsilon_r = 4.2$ and thickness 1.6 mm. Study is analyzed using standard commercial electromagnetic simulation software Ansys HFSS. Vector Network Analyzer (VNA) is used to validate the simulation results. Very good agreement is observed in simulated and measured results. The antenna can be used for various indoor and outdoor positioning wireless communication applications.

Keywords: Symmetrical, Dual step, Finite partial ground plane, Notch truncated, RMSA

1. Introduction

Since FCC (Federal Communication commission) approved the 3.1-10.6 GHz band for unlicensed radio frequency applications. The UWB technology with high data rate transmission and low power consumption receives much attention in research to design UWB antenna [1-5]. Also, the design of compact, low profile, cost effective and efficient antennas for UWB applications is not an easy task. It is a challenging task for researchers. At the same time microstrip antenna gains an attention because of light weight, easy to design and low cost features [6-11]. In the last three decades there are many techniques have been reported to reduce size, enhance bandwidth, and to improve feed arrangements. Qing Song and Xue-Xia Zhang [12] in the year 1995 have described a method for increasing the bandwidth by MSA arrays and using gap-coupling patches found that, this method is effective to increase the bandwidth. Herve Legay and L. Shafai [13] in the year 1997 have proposed a novel technique for feeding MSA arrays. They concluded that, by using H-type feed large bandwidth can be exhibited with very stable radiation patterns. K. F. Lee *et al.* [14] in the year 1997 have presented the simulation of the co-axial fed U-slot rectangular patch antenna and studied experimentally. It is found that the U-slot patch on a foam substrate of thickness 0.08λ can be designed to attain 20-30% of impedance bandwidth. B. L. Ooi and C. L. Lee [15] in the year 1999 have investigated the characteristics of a novel rectangular air-filled stacked U-slot patch fed with an off-set L-shaped probe. The top patch and lower U-slot patch are all supported by thin bass woods at the four corners and the height of the lower U-slot patch is 10% of the designed wavelength. An impedance bandwidth of 44.4% is achieved. Keisuke Noguchi *et al.* [16] in the year 2001 have presented a meander line antenna. This antenna consists of two strips, one is fed and the other is grounded at the bottom and is shorted at a point. Later this antenna is applied to a conducting box as handset model which increases the bandwidth of a built-in antenna. S. N. Mulgi *et al.* [17-] in the year 2004 have proposed a method for improving the impedance bandwidth of microstrip antenna by incorporating a common parasitic element which is gap-coupled to the radiating edges of rectangular patches. They have optimized the size of parasitic element and gap between the driven and parasitic element for maximum impedance bandwidth. They have verified the theoretical and experimental impedance bandwidth and input impedance for the proposed configurations. They conclude that, the proposed antenna can be conveniently used as an array element in phased array radars and mono pulse antennas. J. Chen *et al.* [18] in the year 2010 have presented a novel broadband circular patch antenna. Electromagnetic coupling feed technology, shorting pins and matching network designed by means of genetic algorithm optimizers are used simultaneously to broaden the bandwidth of the circular patch antenna. An impedance bandwidth of 65% at VSWR<2.3 is obtained by them. All these techniques presented in the past are useful but complicated in design and are not suitable for UWB wireless communications and also cost effective. To fulfill the demands such as compactness, enhanced bandwidth, low cost suitable for UWB range in this study a compact simple in design MS antenna is designed and proposed. The proposed designed geometry is a symmetrical dual step corner truncation on rectangular patch with monopole feed arrangement and finite partial ground plane. The results shows that the antenna radiates for more than UWB allotted by FCC, operating frequency range is from 1.22 to 11.82 GHz with four resonant frequencies centered at 1.66 GHz, 6.51 GHz, 9.21 and 10.78 GHz of respective impedance BW of 162.57% with bandwidth ratio 6.48:1 which is more than the bandwidth ratio of 3.4:1. Actual size reduction achieved is 6% on patch and 57.4 % on ground plane. Modify epoxy substrate material is used to designed the antenna. The antenna is suitable for WiMAX (3.3-3.7 GHz), C-band (3.7-4.2 GHz), IEEE 802.1a/b/g WLAN (5.15-5.35 GHz and 5.725-5.825 GHz), HIPERLAN/2 (5.15-5.35 GHz and 5.47-5.725 GHz), X – band International maritime satellite communication system (7.25-7.7.75 GHz),ITU band (8.01-8.5 GHz) etc.

1. Antenna Geometry and Design

The optimized geometry of the proposed symmetrical dual step finite partial ground notch truncated RMSA (SDSFPGNTRMSA) and respective dimensional values in mm is as shown in Fig. 1. It is clearly seen in this figure that, L and W are the length and width of the rectangular patch of 24 mm and 31 mm. The bottom part of the rectangular patch is modified into dual symmetrical steps denoted by *S1* and *S2* of length 2mm and width 5mm. The modified rectangular patch is fed by 50Ω microstripline feed of length Lf=23.3 mm and width Wf=3.2 mm etched on top layer of the substrate. The finite partial ground plane of length Lg=21.3 mm on which a rectangular notch is truncated at the center of dimensions a and b. The length and width of the notch is 5 mm which is etched at the back surface layer of substrate. The parameter g is the gap between patch and ground plane. The optimized value of 2 mm which is fixed at this better impedance matching is achieved from parametric analysis. The photograph of fabricated antenna is as shown in Fig. 2.

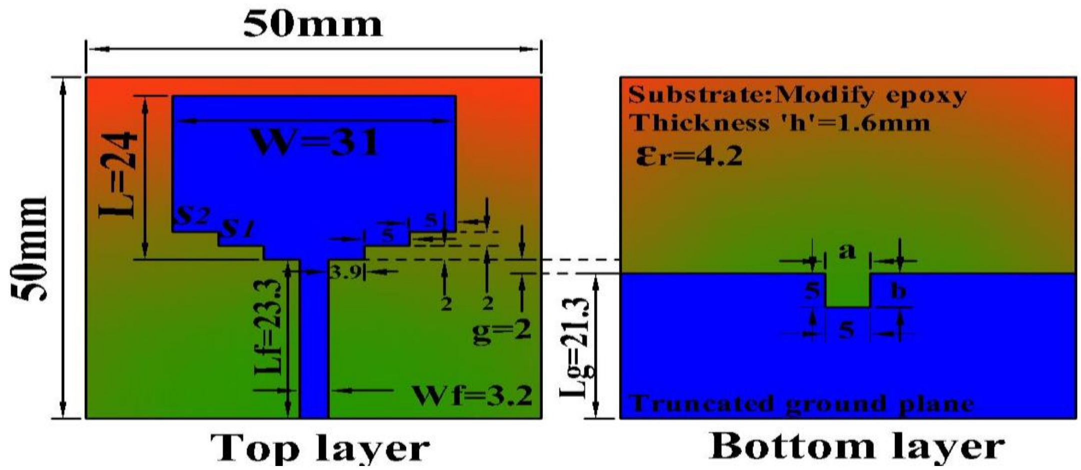


Fig1. The geometry of UWB SDSFPGNTRMSA

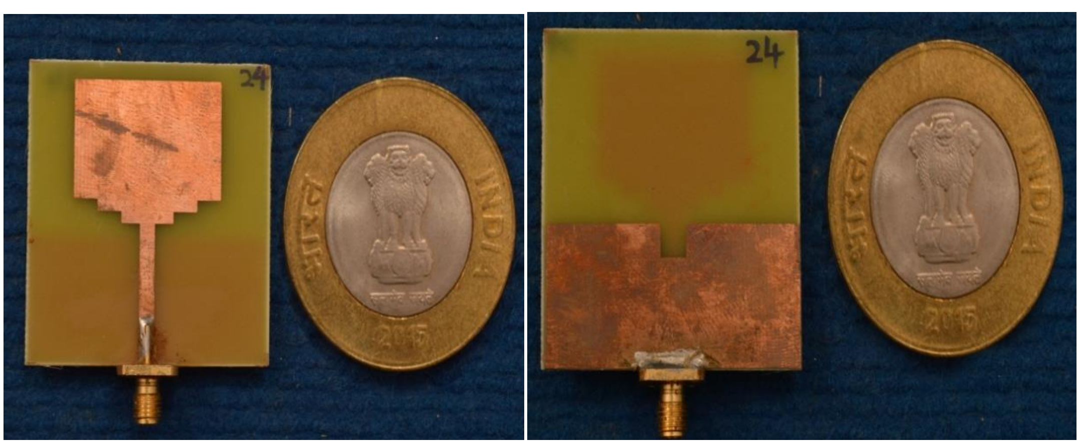


Fig. 2 Photographs of the fabricated SDSFPGNTRMSA

1. Results and Discussion

The simulated work is carried out using HFSS and measured with VNA (ZVK-1127.8651 model). The antenna parameters are discussed to validate the results of the designed antenna. Figure 3 shows the variation of measured and simulated return loss versus frequency plot of SDSFPGNTRMSA. From this figure it is clear that, the antenna exhibits a return loss curve which is less than -10 dB lies from 1.22 to 11.82 GHz (BW=162.57%) with bandwidth ratio of 6.48:1 which is more than the bandwidth ratio of 3.4:1 of UWB allotted by FCC with four resonant frequencies centered at 1.66 GHz, 6.51 GHz, 9.21 and 10.78 GHz respectively. From this figure it is also clear that, there is a very well agreement is achieved between the measured and simulated results. The desired enhanced ultra-wideband is produced due to modified partial truncated ground plane structure i.e. by creating a rectangular notch cut and for the better performance of the impedance matching the gap (g) between radiating patch and the ground plane which is kept constant at 2 mm.

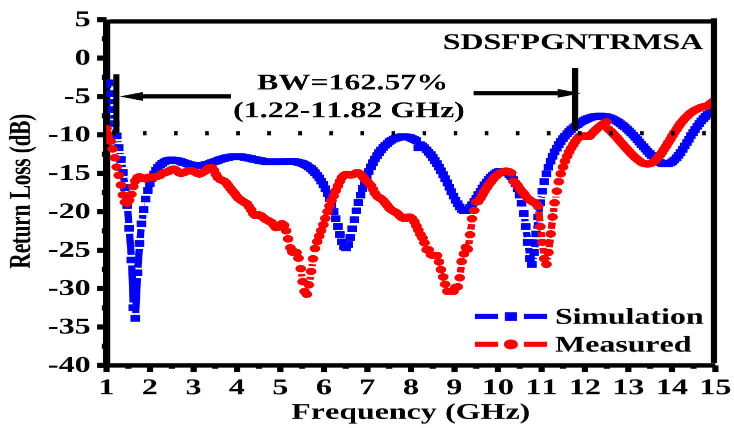
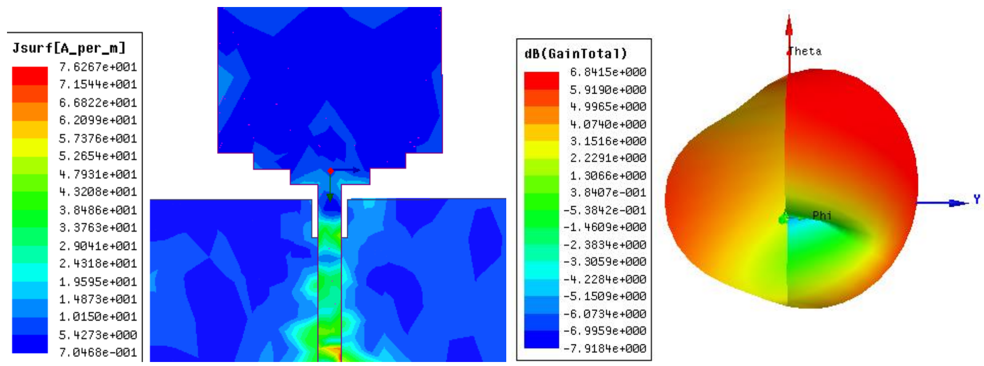


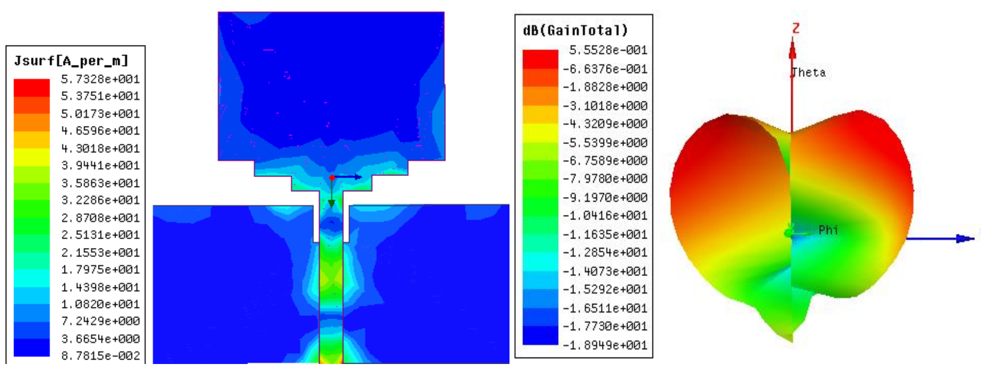
Fig. 3 Variation of measured and simulated return loss versus frequency curve of

SDSFPGNTRMSA

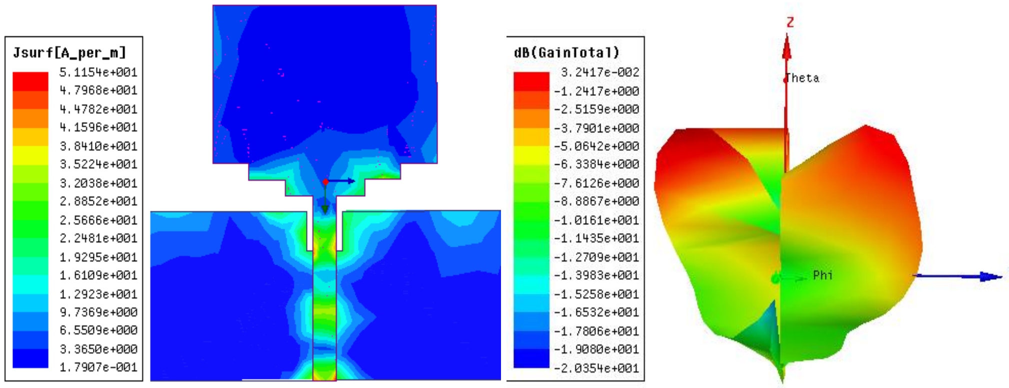
The simulated current distribution on radiator and ground plane to understand the antenna electromagnetic characteristics and 3D radiation patterns of SDSFPGNTRMSA are studied using ANSYS HFSS-3D electromagnetic simulator and depicted in Fig. 4 (a) to (d) observed at frequencies 1.66, 6.51, 9.21 and 10.78 GHz for the optimal design parameters. From Fig. 4 (a) it is observed that, the current is distributing across the feed line that gives the fundamental first resonant frequency and large surface current density is observed along the microstripline feed, ground plane and at the edges of radiator in figures 4 (b) and (c) and overlapping of current distribution results a single band more than UWB range resonating frequency band response. At the first (i.e 1.66 GHz) and second (i.e 6.51 GHz) resonant frequencies nearly omni-directional 3D-radiation patterns are obtained but at third (i.e 9.21 GHz) and fourth (i.e 10.78 GHz) resonant frequencies the corresponding pattern is losing its omnidirectional characteristics due to ground plane involvement to this resonance and surrounding reflections which is more at higher frequencies.



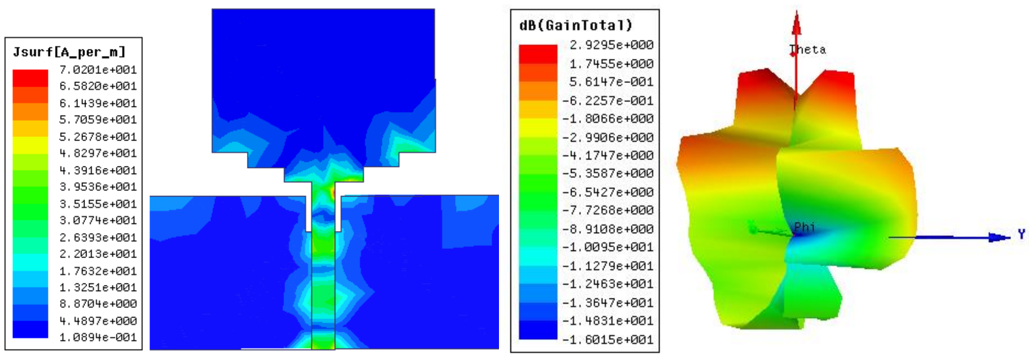
(a)



(b)



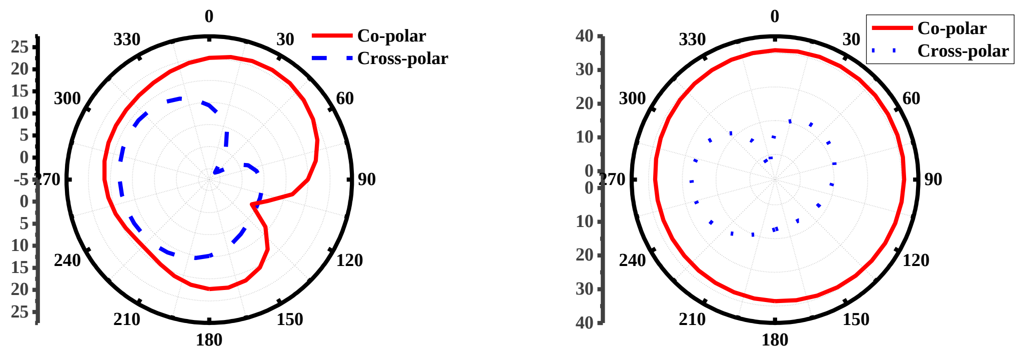
(c)



(d)

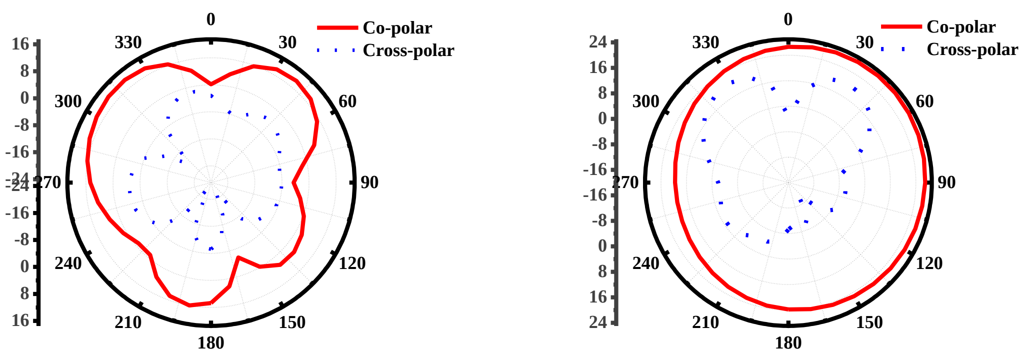
Fig 4. Surface current distributions and 3D radiation patterns of SDSFPGNTRMSA observed at (a) 1.66 GHz, (b) 6.51 GHz, (c) 9.21 GHz and (d) 1078 GHz

The typical radiation patterns of SDSFPGNTRMSA measured in E- and H-planes at 1.66, 6.51, 9.21, and 10.78 GHz are shown in Fig.5 (a)-(d) respectively. From these figures it is clear that, the antenna gives nearly omnidirectional radiation characteristics in its operating band from 1.22-11.82 GHz. However, at the higher frequencies, the radiation patterns are slightly distorted due to surrounding reflections which is more at higher frequencies.



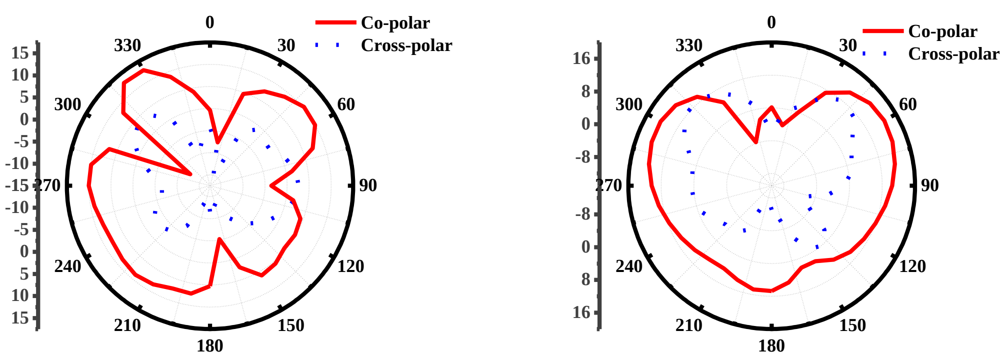
E-plane H-plane

(a)



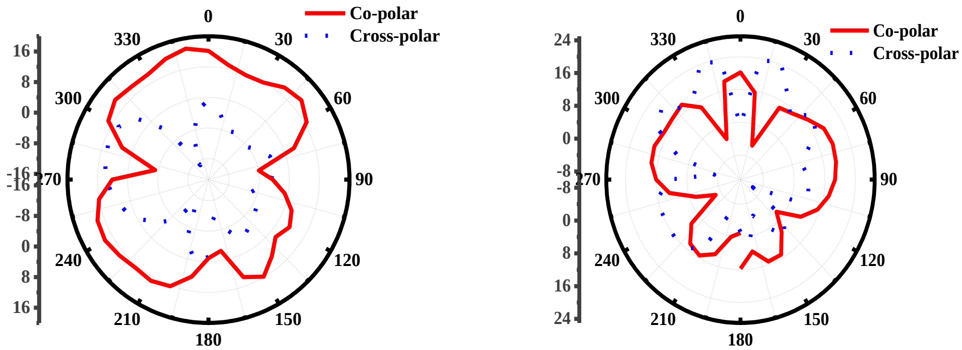
E-plane H-plane

(b)



E-plane H-plane

(c)



E-plane H-plane

(d)

Fig. 5 Typical radiation patterns in E- and H-plane of SDSFPGNTRMSA measured at (a) 1.66 GHz, (b) 6.51 GHz, (c) 9.21 GHz and (d) 10.78 GHz

The variation of measured gain versus frequency of SDSFPGNTRMSA plotted from 1 to 20 GHz which is as shown in Fig.6. From this figure, it is observed that, over the UWB operating band from 1.22 to 11.82 GHz the stable gain of 2 - 5 dB is observed. The maximum gain of 5.17 dB is observed at 1.66 GHz. This shows that, the proposed antenna is highly directive at low frequency resonating band.

The variation of VSWR versus frequency of SDSFPGNTRMSA measured over -10dB return loss bandwidth of antenna from 1.22 to 11.82 GHz resonating band of proposed this antenna is as depicted in Fig. 7. It is clearly observed in this figure that the VSWR<2 stable response over the operating band which is one the good characteristics of the proposed antenna.

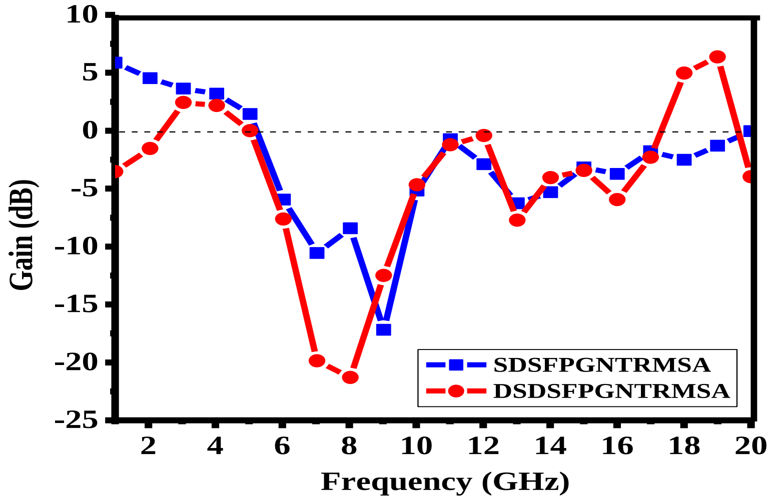


Fig. 6 Variation of gain versus frequency of SDSFPGNTRMSA

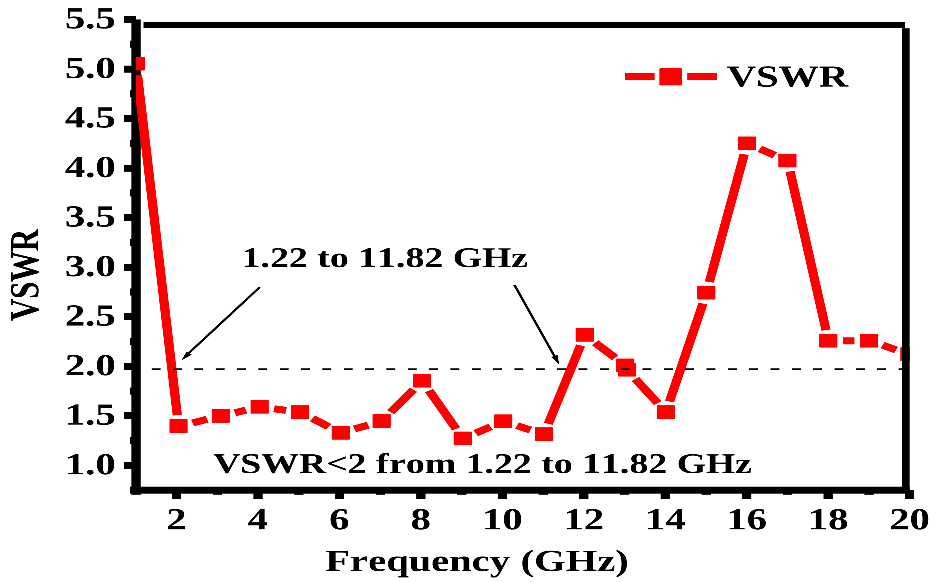


Fig. 7 Variation of VSWR with respect to frequency of SDSFPGNTRMSA

1. Conclusion

In this paper dual symmetrical slot rectangular MSA with finite partial ground with slit at the center is proposed. Its operating frequency range is from 1.22 to 11.82 GHz with four resonant frequencies centered at 1.66 GHz, 6.51 GHz, 9.21 and 10.78 GHz of respective impedance BW of 162.57% with bandwidth ratio 6.48:1 which is more than the bandwidth ratio of 3.4:1 of UWB allotted by FCC. It is also clear that, there is a very well agreement is achieved between the measured and simulated results. The maximum gain of 5.17 dB is observed at 1.66 GHz. This shows that, the proposed antenna is highly directive at low frequency resonating band. Nearly omnidirectional patters are achieved. The antenna can be used in indoor and outdoor UWB wireless communication networks.

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