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Research Paper

Bandwidth enhanced CPW fed elliptical wideband antenna with slotted defected ground structure

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Abstract

In this article, a simple curved elliptical coplanar wave guide fed antenna is proposed for wideband applications. An elliptical shaped model of multiband antenna is converted as notch band antenna with placement of slots in the radiating structure and by incorporating defected ground structure, bandwidth enhancement is attained in the proposed model. In short, the multiband antenna is modelled in to wideband antenna with bandwidth of 17.8 GHz and impedance bandwidth of 67%. By placing defected ground structure adjacent to feed line on the ground plane, additional resonant frequencies are raised and enhancement in the bandwidth is obtained. The measured results are providing excellent correlation with simulation results obtained from HFSS and CST tools.

Keywords: *Bandwidth, Coplanar Waveguide Feeding (CPW), Defected Ground Structure (DGS), Elliptical Monopole.*

1. Introduction

Modern communication modules require compact printed wideband antennas with moderate gain. Demand for high bandwidth antennas are increasing day by day with advancements in the RF-technology. Various techniques and models are proposed by the researchers to match the current technology with advanced modules in the field of microwaves and antennas [1-2]. There is a trade off between bandwidth and gain because of gain bandwidth product of unity. By placing advanced techniques like DGS, EBG's and met material concepts in the design of antenna models, we can attain good bandwidth with considerable gain [3-4]. Most of the antenna feeding techniques has advantages and disadvantages with respect to connection, impedance matching and placement in compact space. Coplanar wave guide feeding helps to get the radiating element and ground on the single side of the substrate with easiness in the excitation [5-6].

Compact size with simple structure and Omni-directional radiation pattern are the attracting features for the wideband antennas, especially for indoor applications. Most of the slot models are designed in the literature for improving the lower frequency of the band [7-8]. Many designs in the literature for monopole antenna with multiband characteristics are employing slots and slits in the radiator, ground plane and in the feeder. Numerous models are designed by the researchers with compact size, improvement in bandwidth and resonance mode realization [9-10]. Different types of feeding methods are available to excite the antenna with good impedance matching. Probe fed method, microstrip line fed method, aperture coupled fed method, proximity coupled fed method and CPW fed method are the popular methods used by many engineers in the design of modern antennas [11-12].

Among these feeding techniques, coplanar wave guide feeding has several advantages over other techniques [13-14]. Slot antennas exhibit wider bandwidth, lower dispersion, and lower radiation loss than microstrip antennas, and CPW also provides an easy means of parallel and series connection with active and passive elements that are required for matching and gain improvement, and with ease of integration with monolithic microwave integrated circuits [15].

2. Antenna Geometry & Design

A novel curved elliptical monopole antenna is proposed here with simple elliptical shaped slot patch to enhance the impedance bandwidth. In this model, by employing a pair of ellipse-shape-combined design a proper control on the lower and higher frequencies of the band is achieved. By this combination in the patch, additional resonances are excited, and hence the bandwidth is increased, especially at higher band. The multiband characteristic of the basic curved elliptical antenna is modified with slots in the radiating element and defected ground structure in the semi-circular ground. The basic CPW fed antenna structure to defected ground model are presented in Fig 1. The proposed antenna complete dimensions are presented in Table 1. Dielectric constant of the substrate material will play a major role in the design of antenna. The effective dielectric constant ε_{eff} can be calculated from ε_r

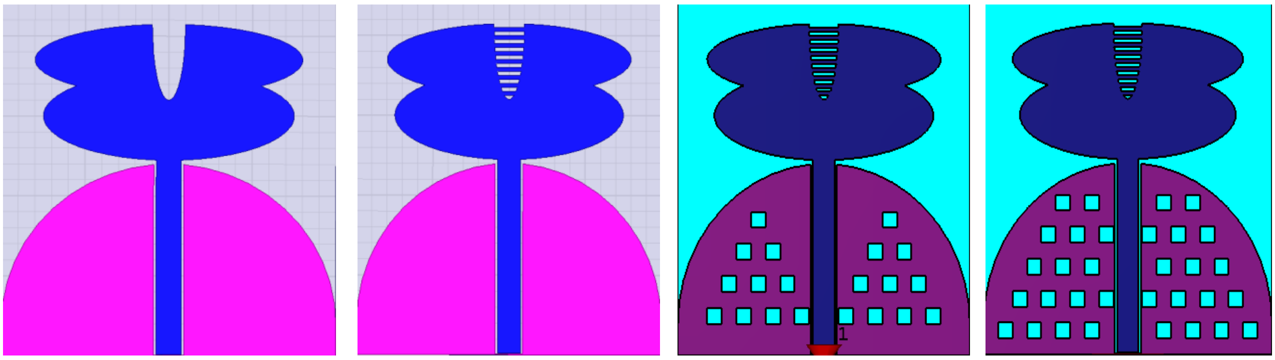


Fig. 1: Wideband CPW Fed Curved Elliptical Antenna Iterations, (a) CPW Fed Curved Elliptical Antenna, (b) CPW Fed Curved Elliptical Antenna with slots, (c) CPW Fed Curved Elliptical Antenna with DGS, (d) CPW Fed Curved Elliptical Antenna with Modified DGS

Table 1: Antenna dimensions in mm

Antenna Parameter	W_s	L_s	R_1	R_2	L_f	W_f	W_{sg}	L_{sg}	S_l	h
Dimension in mm	40	44	16	15	24	3	2	2	3.9	1.6

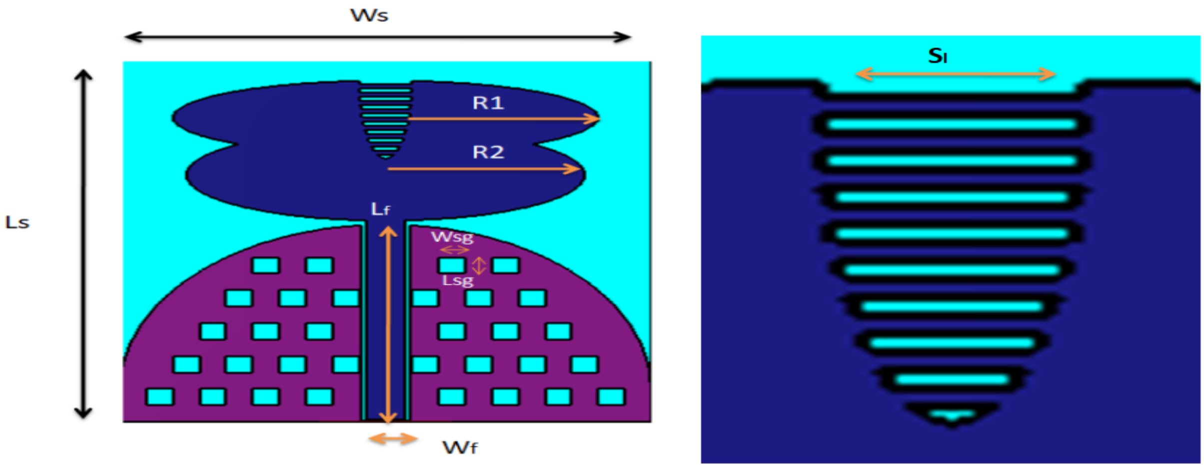


Fig. 2: Proposed Curved Elliptical Antenna with Modified DGS

The length of the 'S_l' has decay of 0.2 mm from top to bottom as shown in Fig 2. This change in slot length variation will provide different electrical lengths when antenna is radiating.

$$\varepsilon_{eff} = (\varepsilon_r + 1)/2 \quad (1)$$

$$P_v = C / \sqrt{\varepsilon_{eff}} \quad (2)$$

Where 'P_v' is the phase velocity and the characteristic impedance 'Z_o' can be calculated from phase velocity.

$$Z_o = (1 / CP_v) \quad (3)$$

3. Results and Discussion

To examine the proposed design, electromagnetic simulation tool CST microwave studio has been used in this work. The S_{11} of all the iterations are plotted and presented in this section. Initially curved elliptical antenna and curved elliptical antenna with slots are designed. The reflection coefficients of these two models are shown in Fig 3. Compared to basic curved elliptical monopole antenna, antenna with slots is providing better impedance bandwidth characteristics. These two models are giving multiband characteristics with slight variations in the bandwidth, but to enhance the bandwidth the defected ground structures are introduced in these models. The modified models of DGS are examined for reflection coefficient and the corresponding plots are presented in Fig 4. The antenna model 3 is providing dual notch band characteristics in the operating band of 2-20 GHz, but model 4 is providing complete wideband in this range. The electromagnetic coupling with periodic slots in the ground plane playing the major role in the broad band characteristics of the antenna model 4. An impedance bandwidth of 67% is achieved from the proposed antenna model 4. The electromagnetic coupling between patch and the ground plane is adjusted in this structure to improve the impedance bandwidth without any other alternative techniques. The bandwidth of zero order reference determined from the shunt inductance 'Ls' and shunt capacitance 'Cs' [16].

The fractional bandwidth $F_B = G\ Ls/Cs$ ----- (4)

The shunt inductance is increased by the placement of more number of periodic slots in the ground plane of the proposed antenna, which in turn improved the impedance bandwidth.

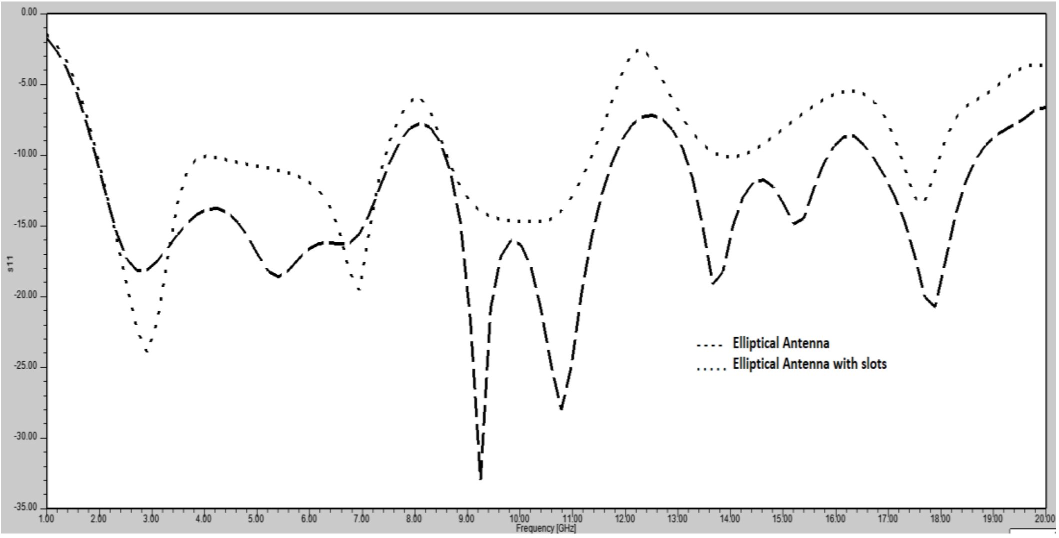


Fig. 3: Reflection Coefficient of Antenna Model 1 and 2 without and with slots in the elliptical structure

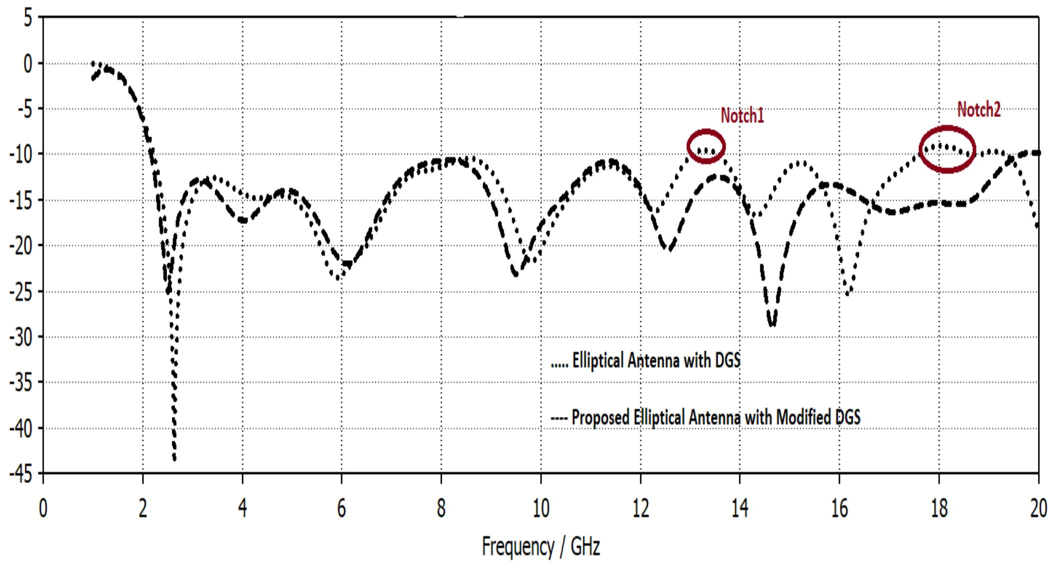


Fig. 4: Reflection Coefficient of Antenna Model 3 and 4 with DGS and Modified DGS

The strong current distributions around stub/slots at the notched frequency leads to near field radiation counteracted, due to which high energy is reflected to the input port and the band-notched characteristics achieved. Fig 5 shows the voltage standing wave ratio of the proposed antenna. Good impedance matching characteristics in the operating band also can be observed from Fig 6.

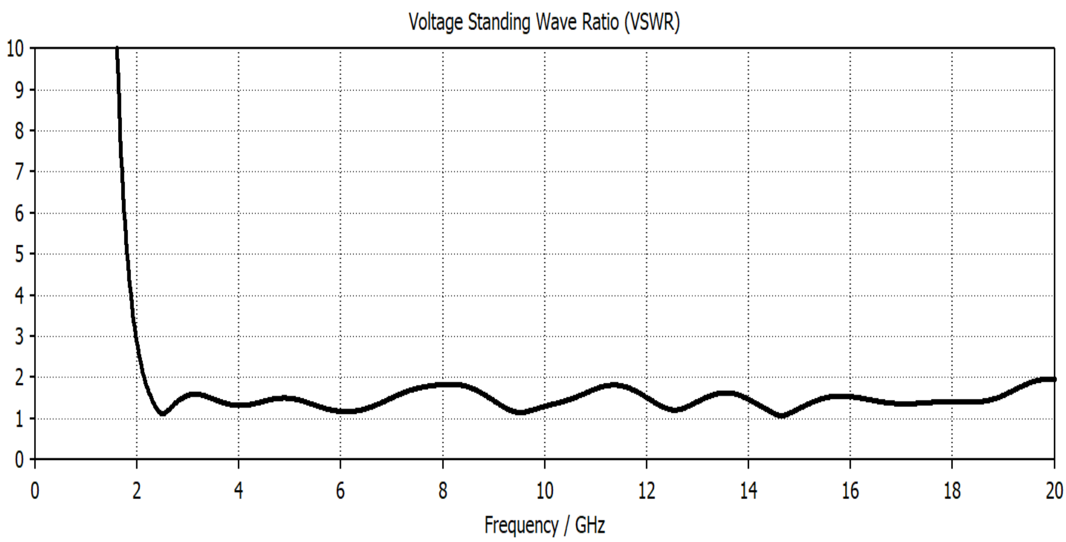


Fig. 5: VSWR of proposed curved elliptical antenna with modified DGS

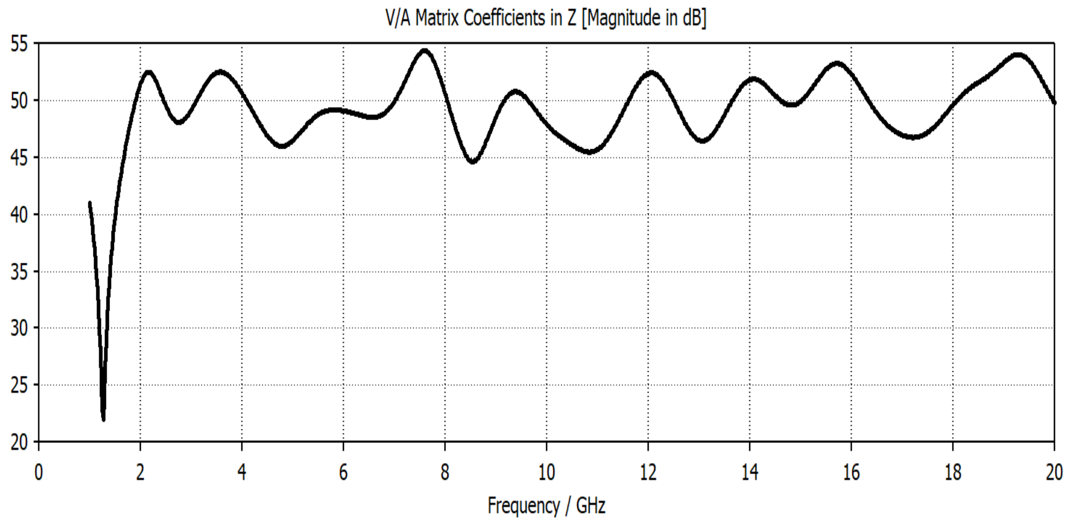


Fig. 6: Impedance plot of proposed curved elliptical antenna with modified DGS

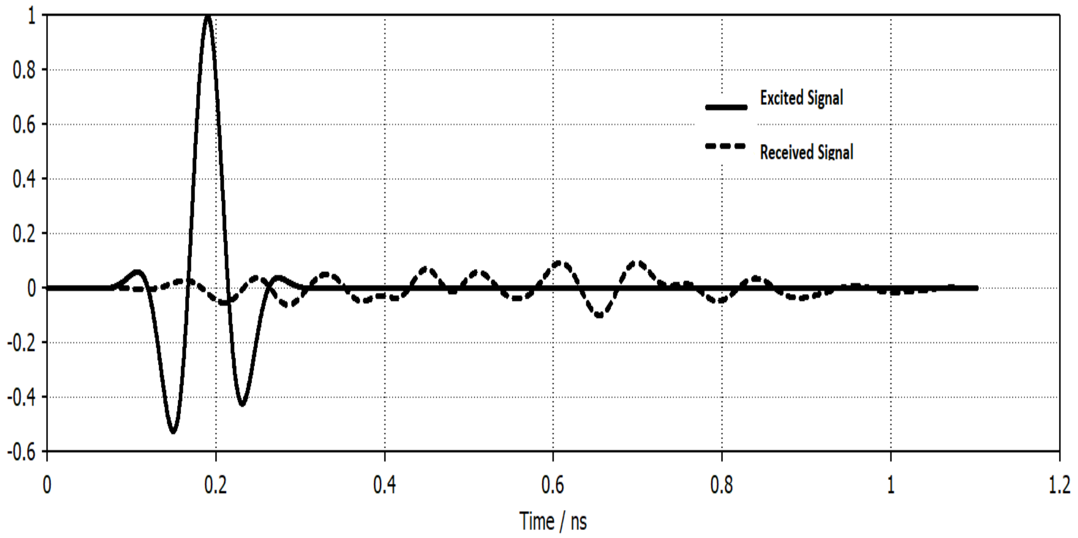
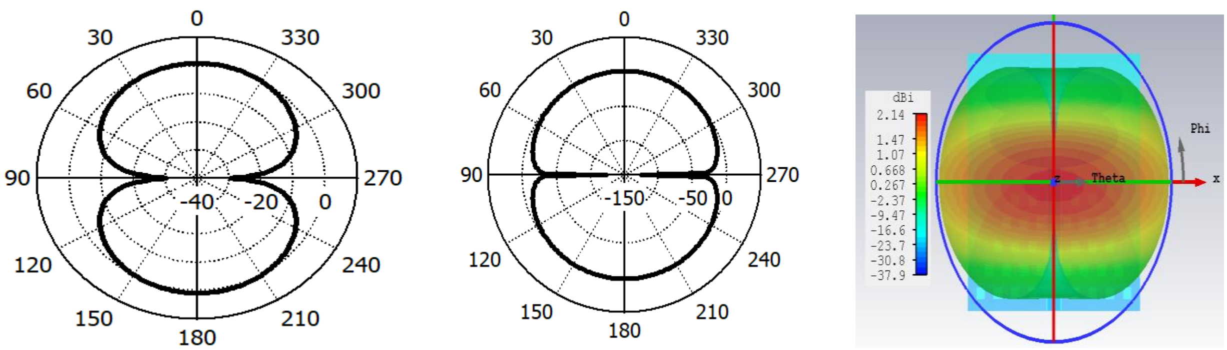


Fig. 7: Time domain analysis of proposed antenna

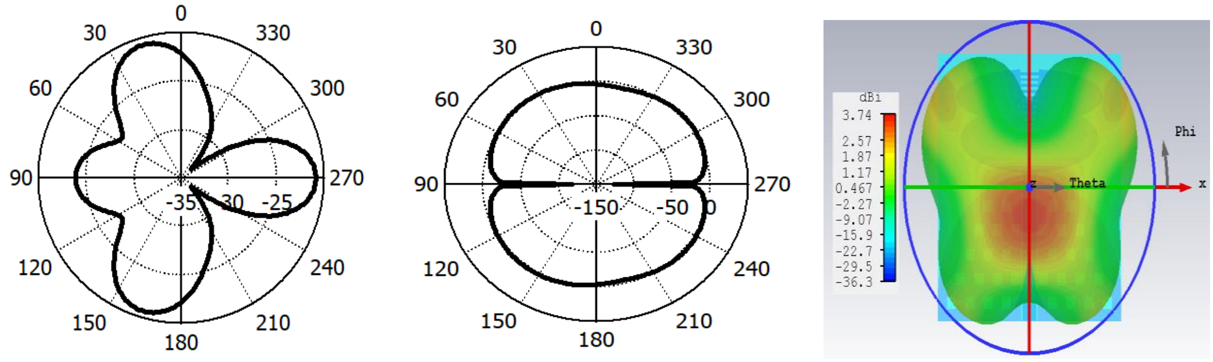
The simulated input signal and impulse response for the proposed antenna is shown in Fig 7. Pulse distortion which is one of the characteristics of wideband signals is essentially determined by their wide bandwidth. To minimize reflection loss and to avoid pulse distortion good impedance match must be maintained throughout the operating band. The main reason between the signal distortion as shown in Fig 7 is due to mismatch between source pulse and the antenna. To evaluate this wave form distortion, generally correlation factor will be calculated between input at transmitting end antenna to the output at receiving end antenna. The general equation for calculating correlation factor with s1(t) as input and s2(t) as received signal.

$$\rho = Max\left\{\frac{\int s1(t)s2(t-\tau)dt}{\sqrt{s1^2(t)}\sqrt{s2^2(t)dt}}\right\} \tag{5}$$

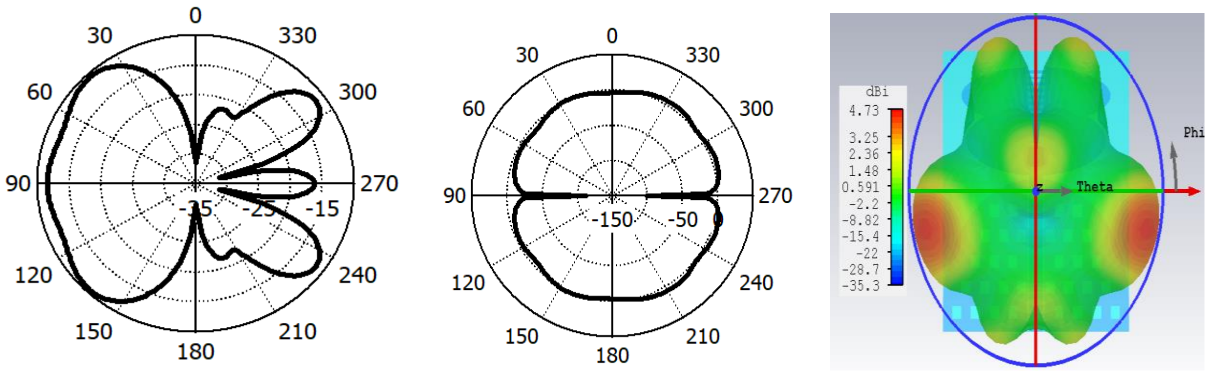
Where ‘τ’ is the delay



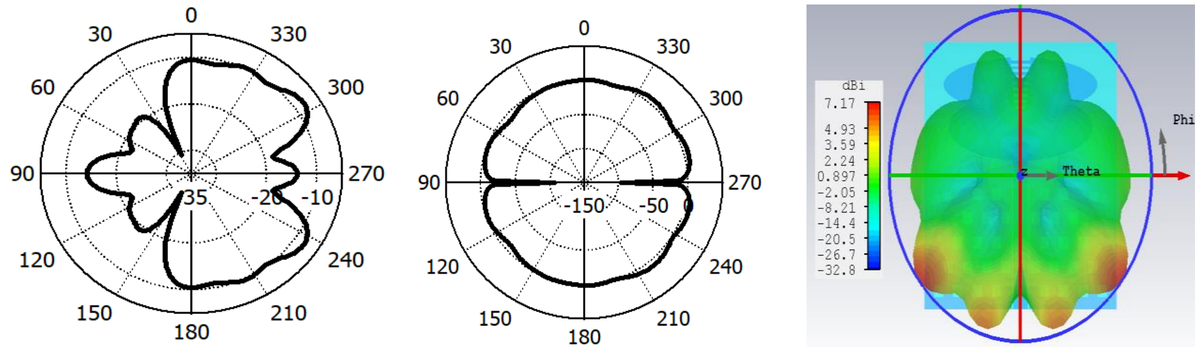
(a) At 2.4 GHz



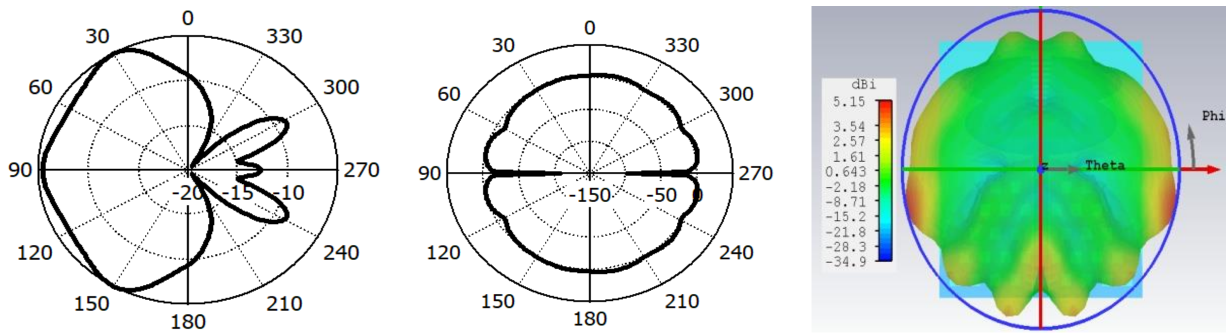
(b) At 5.8 GHz



(c) At 9 GHz



(d) At 12 GHz



(e) At 14 GHz

Fig. 8: Radiation Pattern of the proposed antenna model at different operating bands in E-plane, H-plane & in 3D, (a) 2.4 GHz, (b) 5.8 GHz, (c) 9 GHz, (d) 12 GHz, (e) 14 GHz

The radiation characteristics of the proposed antenna were measured in anechoic chamber by placing antenna on mount. To distort the back radiation, a small ferrite ring was covered at antenna's cable connection. A signal source was connected to transmitting horn antenna at one end and prototyped antenna was placed on other side in the anechoic chamber. The measured radiation pattern was plotted from the readings obtained from the setup and simulation characteristics also correlated for validation. Fig 8 shows the radiation pattern of the antenna at different operating bands and their corresponding peak realized gains at corresponding frequency in three-dimensional view.

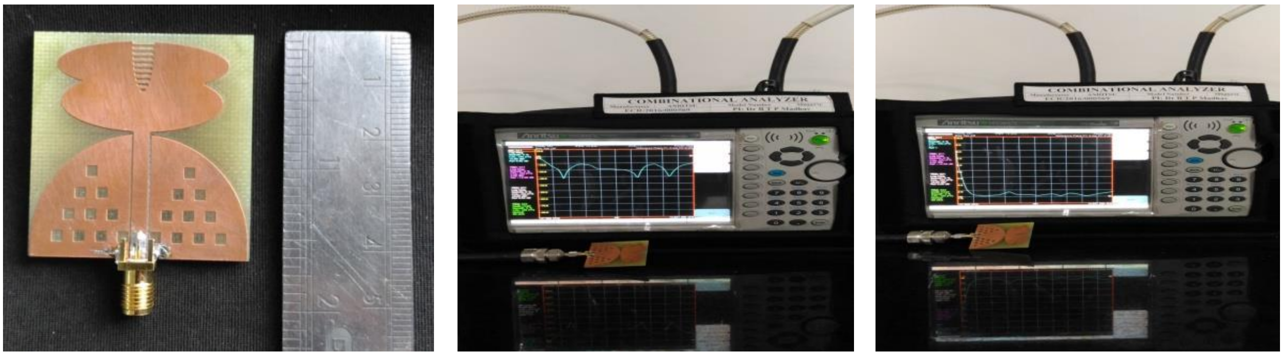


Fig. 9: Elliptical Antenna with DGS (a) Prototyped curved elliptical antenna with DGS, (b) Return loss Measurement on VNA, (b) VSWR Measurement on VNA

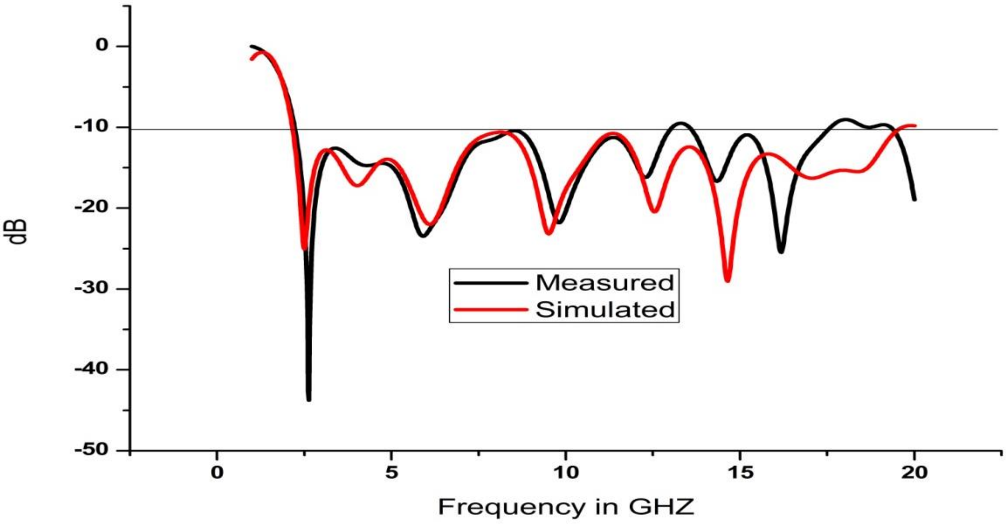


Fig. 10: Measured and Simulated Reflection coefficient

Fig 9 shows the prototyped antenna model on FR4 substrate, corresponding reflection coefficient and VSWR measurement results on vector network analyzer. Fig 10 is providing the evidence of correlation between measured results on VNA with simulation results obtained from HFSS tool. A small mismatch in the higher operating band is due to the connector loss related impedance mismatching. Antenna is providing good gain and efficiency in the wideband, which is reflecting in the Fig 11. A peak realized gain of more than 7.1 dB and efficiency more than 85%.

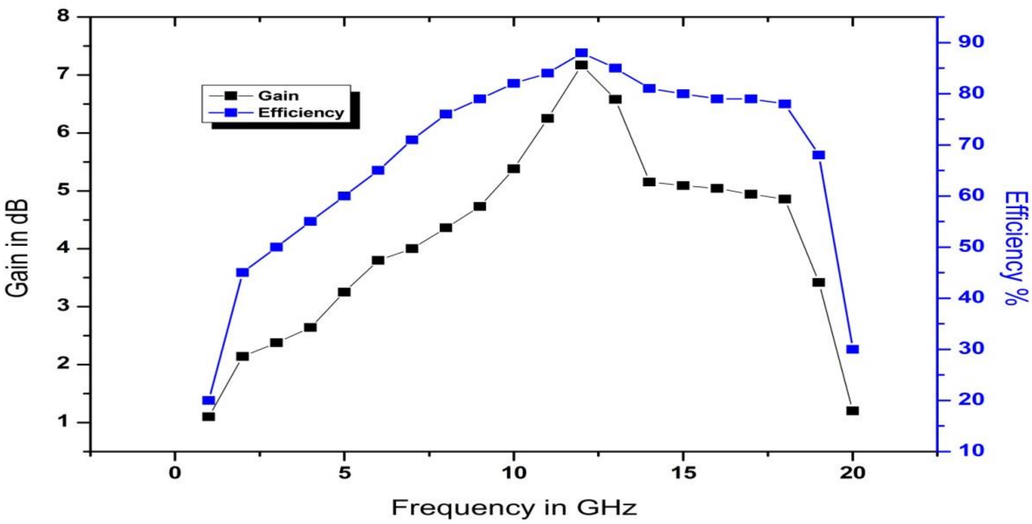


Fig. 11: Frequency Vs Gain and Efficiency

4. Conclusion

A curved elliptical monopole antenna with defected ground structure is proposed in this work to enhance the bandwidth. A multiband antenna is modelled in to wideband antenna with bandwidth of 17.8 GHz and impedance bandwidth of 67%. By placing defected ground structure adjacent to feed line on the ground plane, additional resonant frequencies are raised and enhancement in the bandwidth is obtained. The proposed antenna is providing excellent radiation characteristics with peak realized gain of 7.17 dB and peak efficiency 85%. The simulation results of

HFSS are in good matching with measurement results of aniritsu combinational analyzer.

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