

Multiband Microstrip Antenna Design and Performance Analysis for Wireless Applications

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Abstract - The design of a fork-type planar antenna with microstrip feeding for Bluetooth, WLAN, and WiMAX communications is discussed in this paper. The antenna configuration considered here includes a microstrip feeding line with a fork-shaped radiating patch etched on one side of the dielectric substrate is printed with the radiating patch and the other side has a Defected Ground Plane (DGS). The fork radiator includes two circular shaped side arms along with a rectangular central arm. In order to increase the impedance bandwidth as well as impedance matching at the lower operating band, an inverted T-shaped ground plane incorporating rectangular slots in the central arm is employed.

In order to verify the performance characteristics of the proposed antenna, fabrication and experimental analysis were carried out on the prototype. The results reveal that the antenna operates in dual-frequency bands which can cover both WLAN and WiMAX bands completely. The lower band has an impedance bandwidth of 410MHz between 2.26 and 2.67GHz and the upper band has a bandwidth of 3.78GHz between 3.0 and 6.78GHz.

Index Terms – Antenna, Microstrip, Multiband, WLAN, WiMAX

I. INTRODUCTION

The radio and wireless communication systems are meant to transmit messages over short and long distances without using any physical wires. Messages can be communicated by means of devices like pagers, cellular phones, computer terminals, PDAs, and many other wireless communication gadgets. The term telecommunication is described as the sending of signals across a distance for the purpose of communication. Communication in early times was done through smoke signals, drumbeats, flag signaling, semaphore, and heliograph, where flashes of light were transmitted using the sun's reflection.

Multiband antennas are important in the present-day wireless communication system, since they assist in meeting the demands of wireless service. WiMAX technology operates in the frequency bands 2.50-2.69 GHz, 3.40-3.69 GHz and 5.25-5.85 GHz. All of these wireless communication services have found broad application in portable gadgets like handheld computers and 4G.

Recently, scientists have been paying special attention to the development of multiband antennas that have the ability to work at different frequencies, possessing certain features like compactness, small sizes, simple construction, and omnidirectional radiating properties. Furthermore, there is much interest in gaining an independent frequency band control feature for all of the operational frequency bands.

This proposal is concerned about the advancement of multiband antenna which is minimized and simple profile that can work on multiple bands for wireless communication systems and assessing its execution. This work plans to perform fundamental research on improving the structure and organization of multi band antenna. The essential objective of the present work is to structure such antenna that can cover the range of numerous wireless applications with a reflection coefficient of $|S_{11}| < -10\text{dB}$.

The antenna exhibitions have been assessed to meet the particular wideband targets after attempting few upgrading techniques of different antenna parameters. Two design approaches were considered in this present work. The first is a modified adaptation of planar antenna and the second is a defected ground to adjust the wideband exhibitions. The two structures show wide bandwidth to cover the lower and upper wireless bands. Another design concept was presented for Planar inverted-T antennas to dismiss the WLAN inside the wideband antenna operation by introducing rectangular slot on feeding plate of the PITAs components. A parametric study was performed to check and approve the design concept in terms of the gain and group delay. This article proposes a new dual band forked shape patch antenna using defect in the ground plane for Bluetooth, WLAN, and WiMAX bands. In this paper, the design

of this new antenna comprises the microstrip feed line along with the forked shape radiator patch on one side of the dielectric layer and defective ground plane on the other side of the dielectric layer. The forked shape radiator includes two circular shaped arms along with a rectangular arm located in the middle position. Defect in the ground plane has been incorporated through an inverted T-shape ground plane having a rectangular slot in its middle portion. This paper addresses in detail the geometric design and parametric analysis of this newly proposed antenna. The antenna design is given in Section II, the parametric study of antenna parameters is given in Section III and the conclusions are summarized in Section IV..

II. ANTENNA STRUCTURE & DESIGN

Microstrip patch antenna has been widely utilized due to their unique properties like lightweight, small size. But this kind of antenna additionally has a few vulnerabilities like low efficiency, poor polarization properties, and narrow bandwidth. So Researcher's are performing different test on this sort of antenna. Herem we will be designing a fork shaped planar antenna for Bluetooth, WLAN and WiMAX applications. A frequency band of 1–15 GHz is considered in the process of designing the antenna. This antenna uses a Multiband Antenna to enable multiple communication services to share the same antenna in a single device, such as WLAN and WiMAX applications. Operating frequency/bands of this antenna is 2.02 GHz, 2.97 GHz, 5.39 GHz, 7.95 GHz, and 10.23 GHz. In this antenna, we utilize a Penta band which is obtained by defected ground structure. Antenna is comprised of a Microstrip feed line, fork-shaped patch having rectangular slots in its middle arm and two stubs in its monopole antenna on one side and a defected ground plane on the opposite side of the dielectric substrate. The design of the ground plane is based on an inverted T-type design where there is a rectangular cutout in the middle arm. This improves the bandwidth as well as impedance matching at low frequencies..

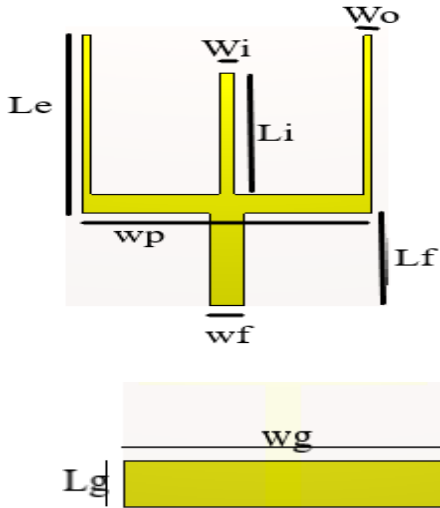


Fig. 1 Proposed Antenna Geomotery

g. 1 shows the structure of the proposed antenna designed on one 1.6mm-thick FR4 substrate having a relative permittivity of 4.4 and loss tangent of 0.02.. The suggested design of the antenna includes a planar I-shaped monopole antenna along with two branches whose outer and inner radii are denoted as R1 and

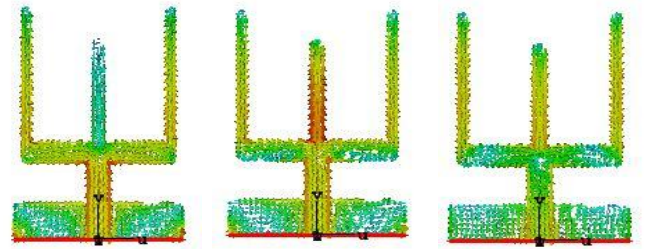
R2, respectively. Furthermore, the upper section of the annular ring is designed with a circular cut having a radius of R3

. The two branches act as the monopole antenna radiator operating in the low band frequency range, whereas they also operate as a resonator being excited by the I-shaped monopole to generate radiations in the high frequency range. The addition of the two paths of the surface current decreases the resonant frequency. The total electrical length of the two paths is equal to 32.11 mm, and this equals to quarter-wavelength resonance at a frequency of 2.26 GHz. The structure is excited by a 50 Ω microstrip feed line with a dimension of 2.2 mm in width (Wf) and 12.5 mm in length (Lf), which is etched on one side of the substrate material. The other side is made up of an inverted T ground plane, where a rectangular slot is present within the T shape.

Table 1: Parameters used for Design of Proposed Antenna

Parameters	Unit(mm)	Parameters	Unit(mm)
L_p	13.90	L_g	2.0
W_p	4.40	L_{g1}	7.0
L_f		W_g	18.0
R_1	11.5	W_{g1}	13
R_2	8.9	W_{g2}	4
R_3	4	W_{g3}	2.5
H_s	1.6	T_c	0.035

The surface current distributions obtained at 2.58, 3.23 and 5.38 GHz are illustrated in Fig. 2, which correspond to the respective figures of Figs. 2(a)–2(b). As seen in Fig. 2(a) the surface current is primarily along the entire radiating patch and along the feed line. It is also noted that the lower frequency mode resonance is produced by the circular arm of the fork-shaped radiator at 2.58 GHz. As shown in Fig. 2(b), the surface current density mainly flows around the center arm of the fork-shaped radiator and the center part of the ground plane at the resonance frequency of 3.23 GHz. At the 3rd resonant frequency of 5.38GHz, the distribution of surface currents in Fig. 2(c) indicate that currents are mainly concentrated along the feed line , the lower section of the circular arm of the fork shaped radiator and the entire ground plane. Therefore, it is clear that the ground



plane is a major contributor towards this resonant mode.

Figure 2: Flow of Surface current at frequency (a) 2.58 GHz, (b) 3.23 GHz and (c) 5.38 GHz

3. RESULTS AND DISCUSSION

The proposed antenna design provided good performance characteristics. In this section all the results like S-Parameter, radiation pattern, VSWR ratio, polarization, efficiency, total radiated power and antenna gain are discussed. Using CST MICROWAVE STUDIO, the proposed antenna with

partial ground structure is simulated. The S parameters and radiation patterns were simulated over the 1-10GHz frequency range and analysed to assess the antenna performance with respect to bandwidth and isolation.

A) Port Signal

In proposed design, the microstrip line feed which is excited at 7.5 GHz is used. This port is of quasi TEM mode having line impedance of 58.57Ω and wave impedance of 264.72Ω .

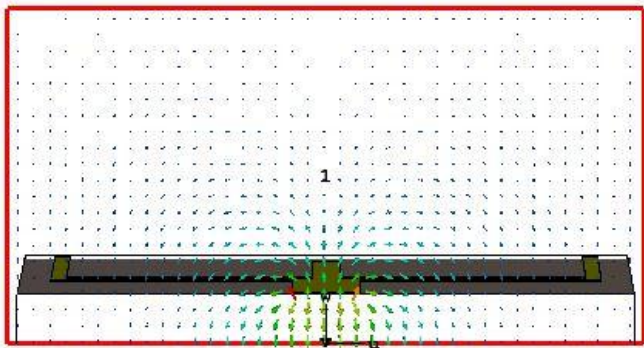


Figure 3: Port mode of proposed antenna

The characteristics of input port signal i1 and output signal o1,1 is shown in figure 4.

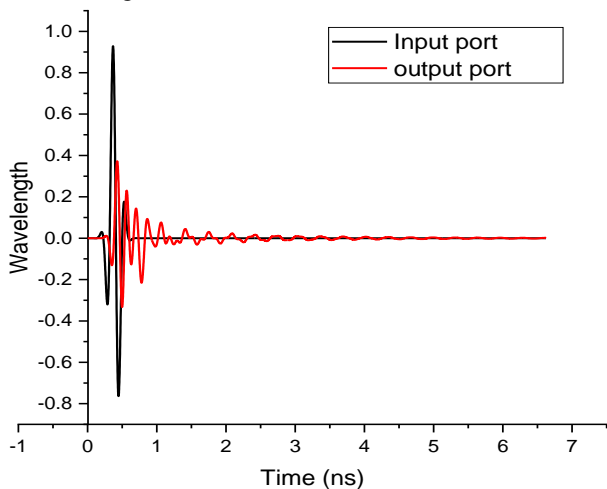


Figure 4: Characteristics curve of input and output port signal

B) S-Parameter

The S-parameter of proposed antenna is calculated. The graph shown in figure 5 indicate the triple band characteristics of microstrip patch antenna. The first two bands come under the category of S-band and the third band comes in C-band category as standardized by ISM (industrial, scientific and medical) standards.

The S-Parameter characteristic of first band is shown in figure 5. This band is having an operating frequency range of 2.32 – 2.83 GHz i.e. the low frequency of this band is 2.32 GHz and high frequency is 2.83 GHz. The resonating frequency of this band is 2.58 GHz. The return loss of this band is -16.7 dB as we can see this on y-axis of the graph above. This band is having a bandwidth of 512 MHz. This band comes in S- band as standardized by ISM and it is used for satellite radio and Wi-Fi applications.

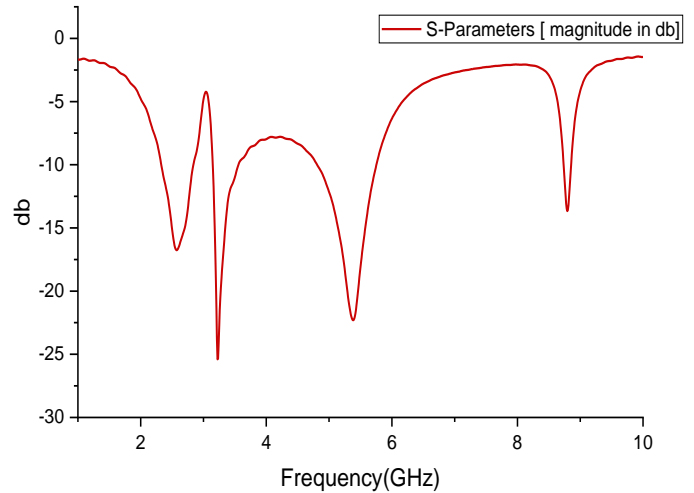


Figure 5: S-Parameter characteristics of proposed antenna

The characteristic of second band is shown above in figure 5. This band is having an operating frequency range of 3.14 – 3.55 GHz i.e. the low frequency of this band is 3.14 GHz and high frequency is 3.55 GHz. The resonating frequency of this band is 3.23 GHz. The return loss of this band is -25.19 db as we can see this on y-axis of the graph below. This band is having a bandwidth of 409.56 MHz. This band is also comes in S- band as standardized by ISM and it is used for WiMAX applications. The S11 characteristic of third band is shown in above figure 5. This band is having an operating frequency range of 4.80 – 5.75 GHz i.e. the low frequency of this band is 4.80 GHz and high frequency is 5.75 GHz. The resonating frequency of this band is 5.38 GHz. The return loss of this band is -22.09 dB. This band is having a bandwidth of 952.59 MHz. This band comes in C-band as standardized by ISM and it is used for Radar (weather) or WLAN applications.

C) Radiation Pattern

The proposed antenna's radiation patterns are obtained within a frequency range of 1-10 GHz. Figure6, Fig7, and Fig8 shows the simulated radiation pattern at 2.58 GHz, 3.23 GHz, and 5.38 GHz frequencies throughout the three main axis at $\phi = 90^\circ$, $\theta = 0^\circ$ and $\theta = 90^\circ$.

The radiation pattern of antenna at 2.58 GHz is found to be omni-directional and its directivity is 2.90 dBi. The proposed antenna at this frequency is having the maximum electric field $E_{max} = 15.43$ dBV/m and maximum magnetic field $H_{max} = -36.09$ dBA/m. The maximum power flow at this frequency is $P_{max} = -13.34$ dBW/m². The polar plot and 3D plot of this radiation pattern is shown in figure 4.5.

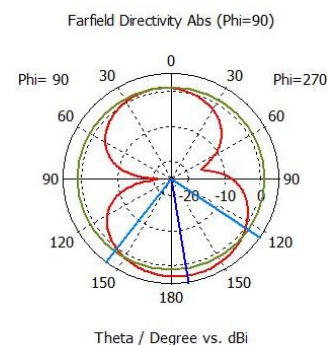


Figure 6: Simulated radiation pattern of proposed antenna at frequency 2.58 GHz

(a) Polar form of radiation pattern, (b) 3D structure of radiation pattern

The radiation efficiency at this frequency is -2.14 dB and total efficiency -2.23 dB.

At 3.23 GHz the radiation pattern of proposed antenna is found to be omni-directional and its directivity is 2.53 dBi. The proposed antenna at this frequency is having the maximum electric field $E_{max} = 15.08$ dBV/m and maximum magnetic field $H_{max} = -36.44$ dBA/m.

The maximum power flow at this frequency is $P_{max} = -13.69$ dBW/m². The polar plot and 3D plot of this radiation pattern is shown in figure 8.

The radiation efficiency at this frequency is -2.21 dB and total efficiency is -2.22 dB.

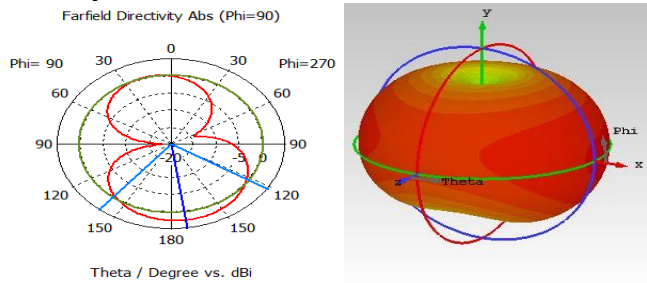


Figure 7: Simulated radiation pattern of proposed antenna at frequency 3.23 GHz (a) Polar form of radiation pattern, (b) 3D structure of radiation pattern

The radiation pattern of proposed antenna at 5.38 GHz is found to be omni-directional and its directivity is 3.86 dBi. The proposed antenna at this frequency is having the maximum electric field $E_{max} = 17.75$ dBV/m and maximum magnetic field $H_{max} = -33.77$ dBA/m.

The maximum power flow at this frequency is $P_{max} = -11.02$ dBW/m². The polar plot and 3D plot of this radiation pattern is shown in figure 9.

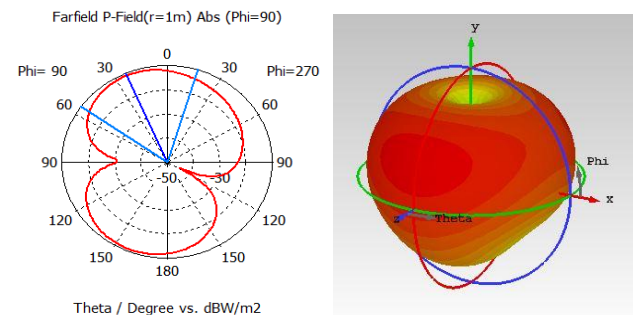


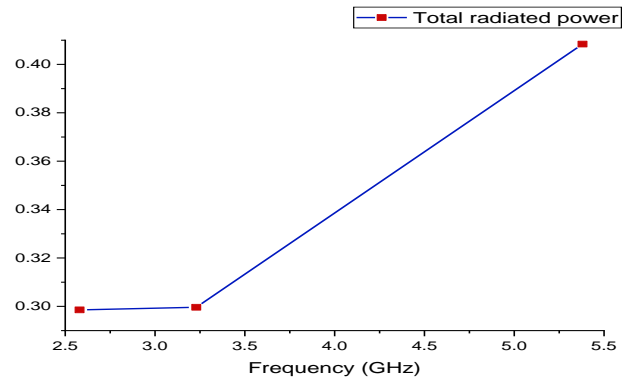
Figure 8: Simulated radiation pattern of proposed antenna at frequency 5.38 GHz (a) Polar form of radiation pattern, (b) 3D structure of radiation pattern

The radiation efficiency at this frequency is -0.85 dB and total efficiency is -0.87 dB.

C) Polarization Characteristics

Polarization of an antenna describes the orientation of the electromagnetic field generated from the antenna in the far-field zone. Depending on the type of electromagnetic field generated from the antenna, it can either be referred to as linearly polarized antennas or circularly polarized antennas, such as right hand circularly polarized antennas. One of the most important factors

in the communication between antennas is polarization since signal transmission and reception can happen effectively if the two communicating antennas share similar polarizations. For example, horizontally polarized antennas cannot effectively communicate with vertically polarized antennas. As per reciprocity theory, an antenna shows identical properties during transmission and reception. This implies that vertically polarized antennas transmit and receive vertically polarized signals. This explains why communication between vertically and horizontally polarized antennas yields extremely weak signal strength or no signal strength at all due to polarization mismatch.



The polarization characteristics of any antenna can be easily found by knowing its axial ratio. If the axial ratio of antenna is less than or equal to 3 dB then it is circularly polarized, if it is between 3 to 10 dB then it is elliptically polarized and if it is greater than 10 dB then the antenna is having linear polarization.

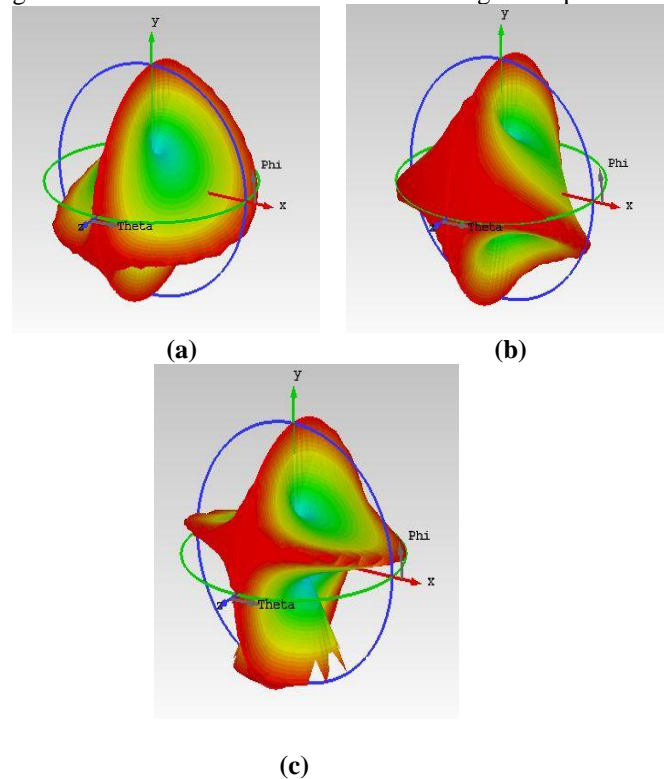


Figure 9: Polarization characteristics of proposed antenna (a) At frequency 2.58 GHz, (b) At frequency 3.23 GHz, (c) At frequency 5.38 GHz.

It is found from the Fig:9 that at operating frequencies 2.58 GHz, 3.23 GHz and 5.38 GHz, the polarization of proposed antenna are obtained to be circularly polarized.

D) VSWR Characteristics

VSWR characteristics graph is shown in Fig:10. All the three resonating bands are having VSWR value less than 2 which is good for an antenna performance. The VSWR value of first band, second band and third band are 1.34, 1.11 and 1.16 respectively.

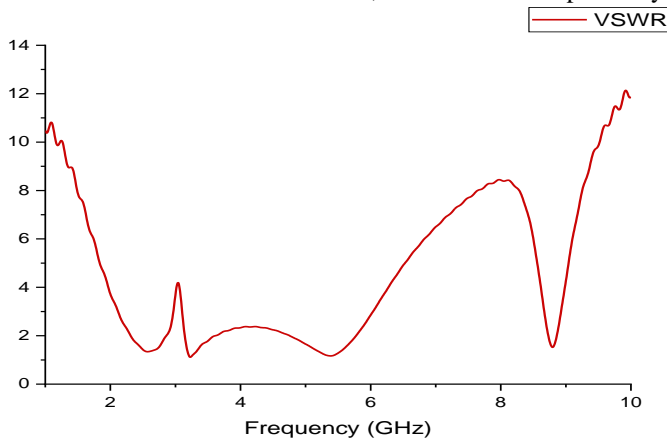


Figure 10: VSWR characteristics curve of proposed antenna

E) Efficiency of Radiation

The radiation efficiency of the designed antenna is shown in Fig. 11. The values for radiation efficiency are -2.14 dB at 2.58 GHz, -2.20 dB at 3.23 GHz, and -0.85 dB at 5.38 GHz

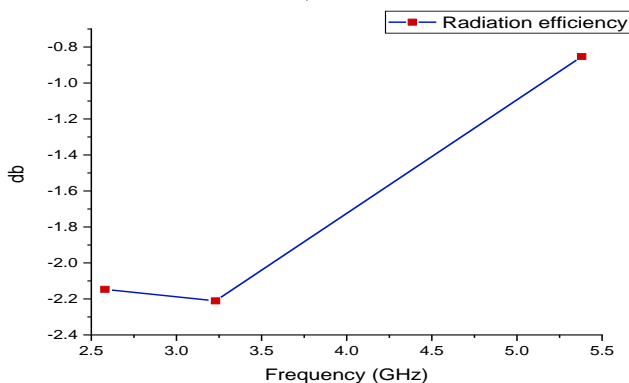


Figure 11: Characteristics curve of radiation efficiency of antenna

F) TOTAL Efficiency

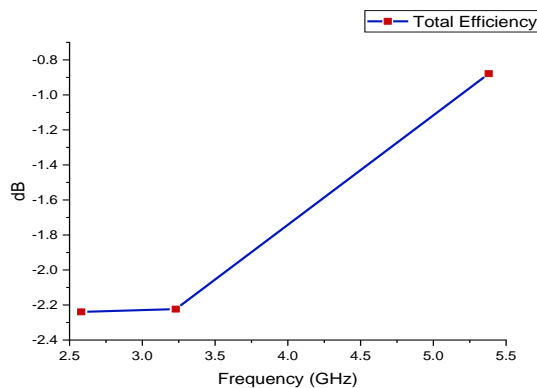


Fig 12. characteristic curve of total efficiency of antenna.

Total efficiency of the presented antenna is given in Fig. 12. Total efficiency values obtained from the analysis are -2.23 dB for 2.58 GHz, -2.22 dB for 3.23 GHz, and -0.88 dB for 5.38

G) Maximum Gain

The maximum gain curve of proposed antenna is shown in Fig:13. From figure we found that the value of gain is maximum at frequency 5.38 GHz. The values of maximum gain over different frequencies are 0.75, 0.33 and 3.00 at frequency value of 2.58 GHz, 3.23 GHz and 5.38 GHz, respectively.

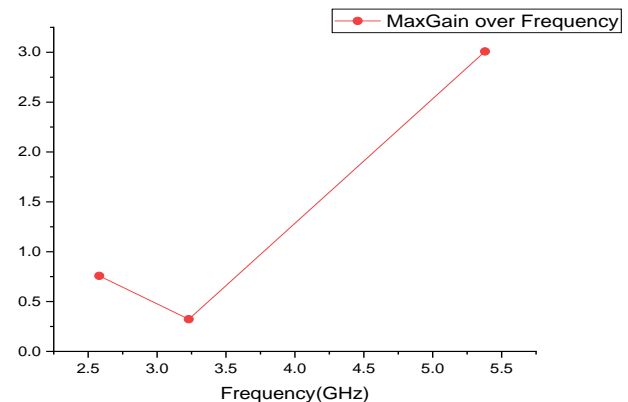


Figure 13: Characteristics curve of Maximum gain over frequency

4. CONCLUSION

In this research work, the performance evaluation of E-shaped antenna with partial ground structure have been done. The different parameters of this antenna like S-parameter, VSWR, radiation pattern, polarisation, efficiency, total radiated power, maximum gain over frequency have been discussed in previous chapter. This is concluded that this antenna operates for three different frequency bands.

The value of resonating frequencies are 2.58 GHz, 3.23 GHz and 5.38 GHz. The first two bands comes in the range of S-band and are used for WLAN, satellite radio, Wi-Fi and other radio or wireless applications. The third band obtained comes in the range of C-band and can be used for RADAR (Weather), WLAN applications or any other application of C-band. The peak gains of this antenna at all the three bands are 0.75 at 2.58 GHz, 0.33 at 3.23 GHz and 3.00 at 5.38 GHz. The gain achieved by this antenna for all three bands made it good for multiple wireless applications.

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