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Slit Loaded Rectangular Shaped Monopole Antenna Design with Band Notched Characteristics for Ultra Wide Band Applications

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ABSTARCT

In this paper a low cost edge fed printed planar monopole antenna is presented for Ultra Wide Band (UWB) applications. The proposed antenna exhibits a notching characteristic at the frequencies 6 GHz to 7.6 GHz and has several rectangular shaped slits which are symmetrical in nature, placed towards the radiating edges of the patch. The two corners of the patch surface has been etched to obtain a notching behavior. The antenna is placed on a 1.6mm low cost FR-4 substrate material of dimension 36 mm x 34 mm and has a partial ground plane below it. The proposed antenna exhibits an Omni-directional radiation pattern and has a wide impedance bandwidth of about 50% in the frequency range 3.6 GHz to 6 GHz and 27.2 % in the frequency range 7.6 GHz to 10 GHz. The proposed antenna has been designed and simulated using an Method of Moment (M.O.M) based Electromagnetic solver, CADFEKO version 5.5. The plots of various antenna parameters like Return loss, Voltage Standing Wave Ratio (VSWR), Gain, Bandwidth etc. of the proposed antenna have been observed.These results clearly indicate that the proposed antenna exhibits Ultra Wide Band behavior.

Key words: Ultra Wide Band, Monopole, Bandwidth, Band Notching.

INTRODUCTION

The Federal Communication Commission (F.C.C.) in the year 2002 has allotted 3.1-10.6 GHz frequency band for Ultra Wide Band applications [1] and has been used by several wireless standards of varying data rate. There are several advantages like high bandwidth, high data rate, more reliability, less power consumption etc. while using in these frequencies [2]. But a main drawback of this system is the interference whichit causes to the various wireless systems such as Wireless Local Area Network (W-LAN) [3]. Several researches have been undertaken to design antennas that operate in these bands. The antennas designed for this purpose should satisfy certain requirements such as low cost, omnidirectional radiation pattern, large bandwidth etc [4-5].Several broadband antennas such as Vivaldi [6], Log Periodic, Bowtie antennas [7] can also be used to support UWB communication but the geometry of such antennas are relatively very large and are not very compact. A planar monopole antenna [8] serves as an ideal candidate for this requirement and many antennas have been designed considering this fact.

Several techniques have been introduced so as to provide a band notching characteristics [9-10]. The most popular among them is achieved by connecting several band-stop filters to the antenna. But this method increases the complexity of the system. Another method to achieve notching is by configuring the antenna to achieve band-stop characteristics. Many antennas have already been developed based on this fact and most of them were focused on notching the WLAN frequencies [11]. UWB antennas that provide notching at more than one frequency are studied. Most of the UWB antennas designed today are non-planar and so this can't be integrated with ICs.Another consideration that should be taken into account is the wide bandwidth while designing an antenna which radiates inless than-10 dB. Generally the radiation efficiency of the antenna should be above 70% to work efficiently and the size of such antennas should be smaller since they are employed for wireless communication devices. A compromise needs to be achieved between size and performance of the antenna.Band notching of Ultra Wide Band antennas have been studied in the literature. A split ring resonator has been placed in the radiating edges so as to obtain UWB behavior [12] and a T-shaped back conductor ground plane has also been proposedin [13]. A UWB antenna with trapezoidal shaped patch for band notching is proposed in [14]. In this paper a broadband Omni-directional monopole antenna with a partial ground plane and rectangular shaped patch with rectangular slits have been proposed, the length of the monopole is at least a quarter of the wavelength. The band notched characteristics have been achieved for the C-band satellite communication frequencies.

MATERIALS AND METHOD

Antenna Design

A partial ground plane which is a Perfect Electric Conductor (PEC) has been introduced at the bottom side of the monopole antenna. The ground plane is of dimension 36 mm x 10 mm. Three symmetrical rectangular slits of dimension 4 mm x 1.5 mm and 2 symmetrical rectangular shaped slits of dimension 2 mm x 1 mm is used for the design as in Fig 1.

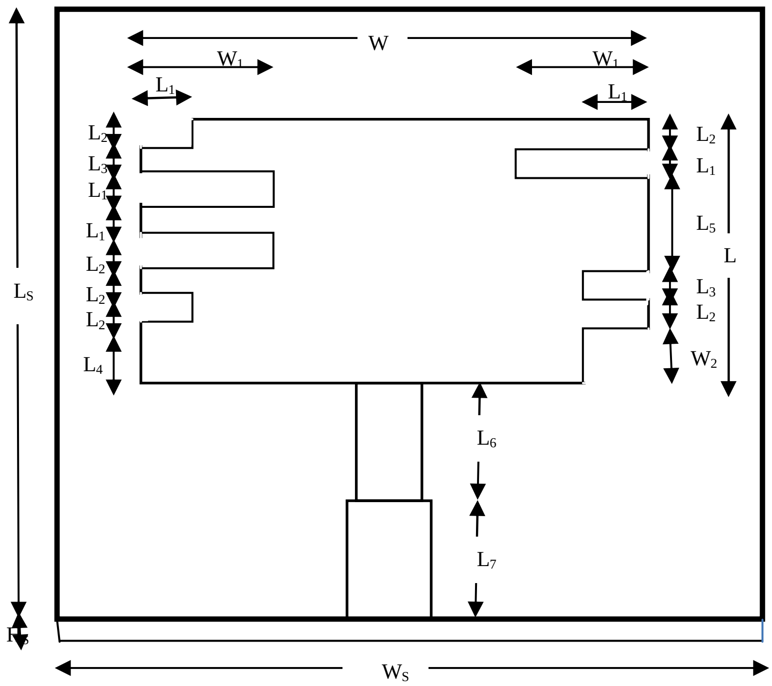


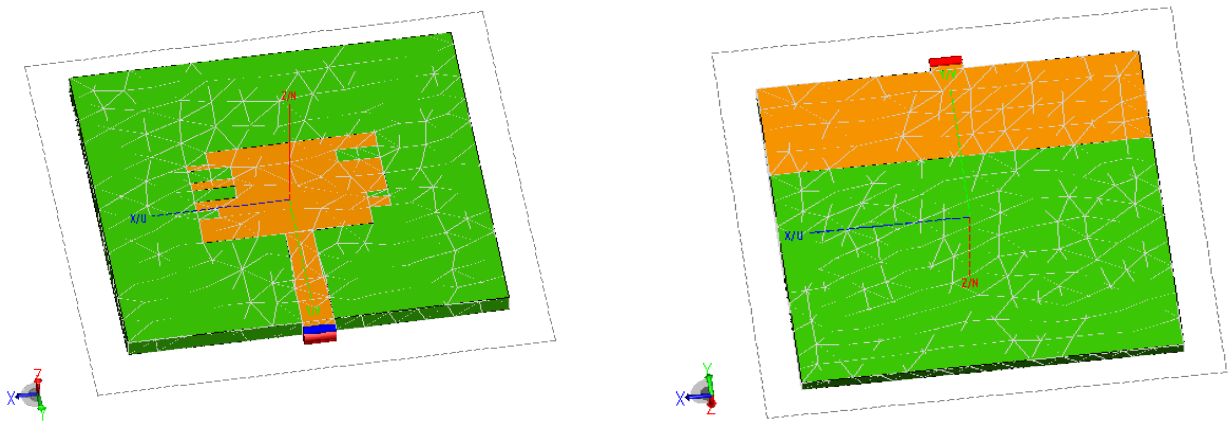
Fig.1.Geometry of Proposed Antenna

An edge feeding technique has been used for the monopole antenna that improves the bandwidth when compared with other feeding methods. The dimensions of the edge fed monopole antenna are given by Table 1.

Table1. Parameters of the Proposed Antenna

Parameters	**Value (mm)**
Length of patch (L)	11.3
Width of Patch (W)	18
Length of substrate (Ls)	34
Width of substrate (Ws)	36
Height of substrate (Hs)	1.6
Length of slits1 (L1)	1.5
Width of slits1 (W1)	4
Length of patch (L2)	1
Width of slits2 (W2)	2
Length of slits3 (L3)	1
Length of patch (L4)	3
Length of patch (L5)	5
Length of feed (L6)	5.6
Length of feed (L7)	6

The antenna has been fabricated on an inexpensive FR4 substrate material with a height of 1.6 mm, permittivity of 4.4 and loss tangent 0.0019. The proposed antenna has several rectangular shaped slits placed on the surface of the patch. Slits causes meandering of the surface current path presented on the patch surface. The top and bottom view of the proposed antenna is shown in Fig 2.



(a) **(b)**

Fig.2. Geometry of the Proposed Antenna, (a) Top view (b) Rear view

The resonant frequency of the design is assumed as

$$F = \left[\frac{C}{2L\sqrt{\varepsilon_{eff}}} \right] \qquad (1)$$

$$\varepsilon_{eff} = \left[\frac{\varepsilon_r + 1}{2} \right] \qquad (2)$$

Where,
ε_r**:**Relative dielectric constant of the substrate
ε_{eff}**:**Effectivedielectric constant of the substrate
*C***:**Velocity of light .i.e. 3×10^8
L**:**Length of the patch

RESULTS AND DISCUSSION

The proposed antenna is simulated using an electromagnetic simulator, CADFEKO and parameters such as Return loss, Bandwidth, Gain, Voltage Standing Wave Ratio (VSWR) are measured. Return loss indicates the amount of power that is lost to the load and does not return as reflection. The Fig 3 shows the variation of return loss with frequency of the slit loaded rectangular monopole antenna and the bandwidth of operation can easily be calculated from this plot. The proposed antenna resonates at frequencies ranging from 3.6 GHz to 6 GHz and 7.6 GHz to 10 GHzand has a return loss of -30 dB at 5.5 GHz and -44 dBat 9.4 GHz. An impedance bandwidth of 2.4 GHz each is obtained for the resonating frequencies below -10 dB.

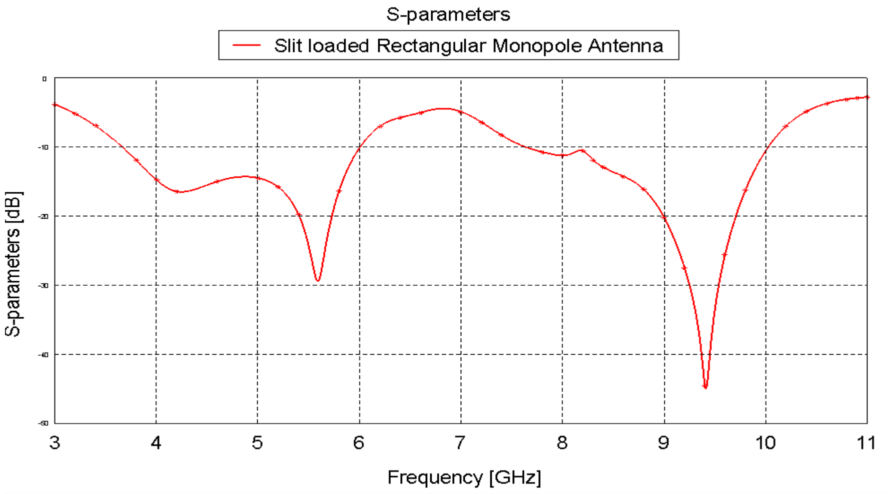


Fig.3. S_{11} curves of slit loaded Rectangular shaped Monopole antenna

VSWR is a parameter that shows the level of impedance mismatch and is always a positive real number. The VSWR ratio of the proposed antenna is 1:1.2 as given in Fig 4 at the frequencies 5.5 GHz and 9.4 GHz.

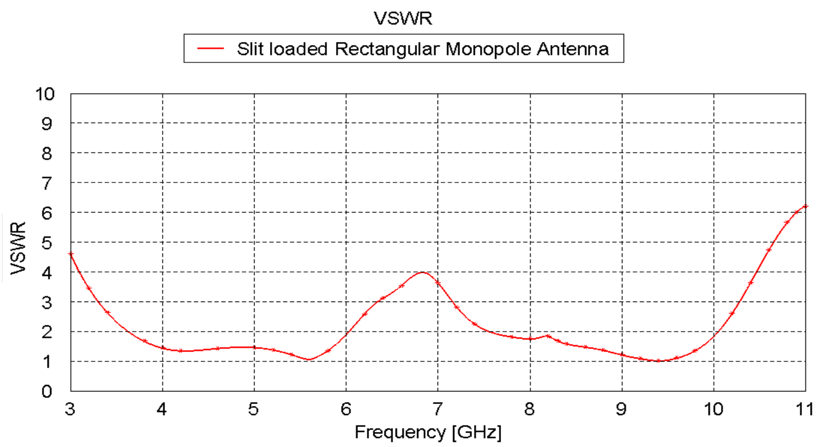
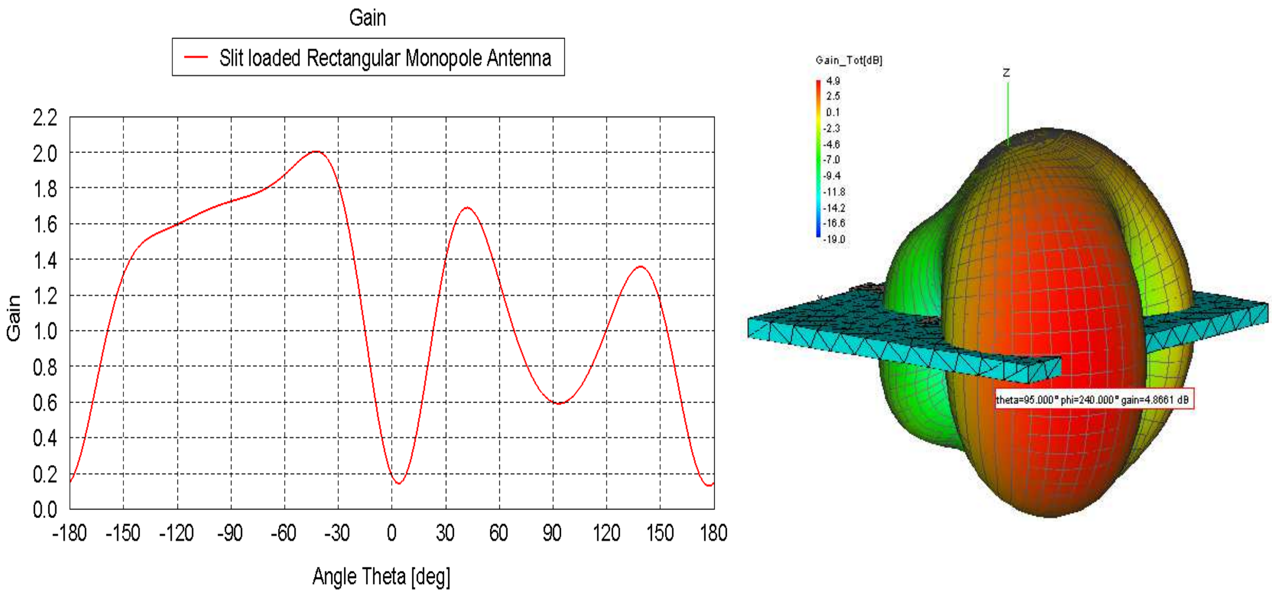


Fig.4. VSWR Curves of slit loaded Rectangular shaped Monopole antenna

Gain is the ratio of radiation field intensity of test antenna to that of the reference antenna. It is usually expressed in dB. The Fig 5(a) shows the simulated antenna gain plot of a slit loaded rectangular monopole antenna with partial ground plane. The 3 D plot of radiation pattern in the far field of the antenna is shown in Fig 5(b). In the 3D plot the regions highlighted with red color indicates the areas with maximum Gain. The observed value of gain of the proposed antenna at resonant frequency of 5.5 GHz is 2 dB. Thus we can conclude that the antenna gain is reduced when slits are loaded into the radiating edges of the patch present on the FR-4 substrate.



(a) **(b)**

Fig.5. Gain plot for Slit loaded Rectangular shaped Monopole antenna (a) 2D at 5.5 GHz (b) 3D at the far fields

The 2-D radiation plot of the proposed antenna at different frequencies is shown in Fig 6. Fig 6(a) shows the 2D plot of radiation pattern at 3 GHz. It is observed that an omnidirectional pattern is observed along the H plane while a bidirectional pattern is observed along the E plane

The shapes of both these patterns get distorted while increasing the frequencies. Fig 6(b) shows the pattern at 5.4 GHz, Fig 6(c) shows the pattern at 6 GHz and Fig 6(d) shows the pattern at 9.4 GHz.

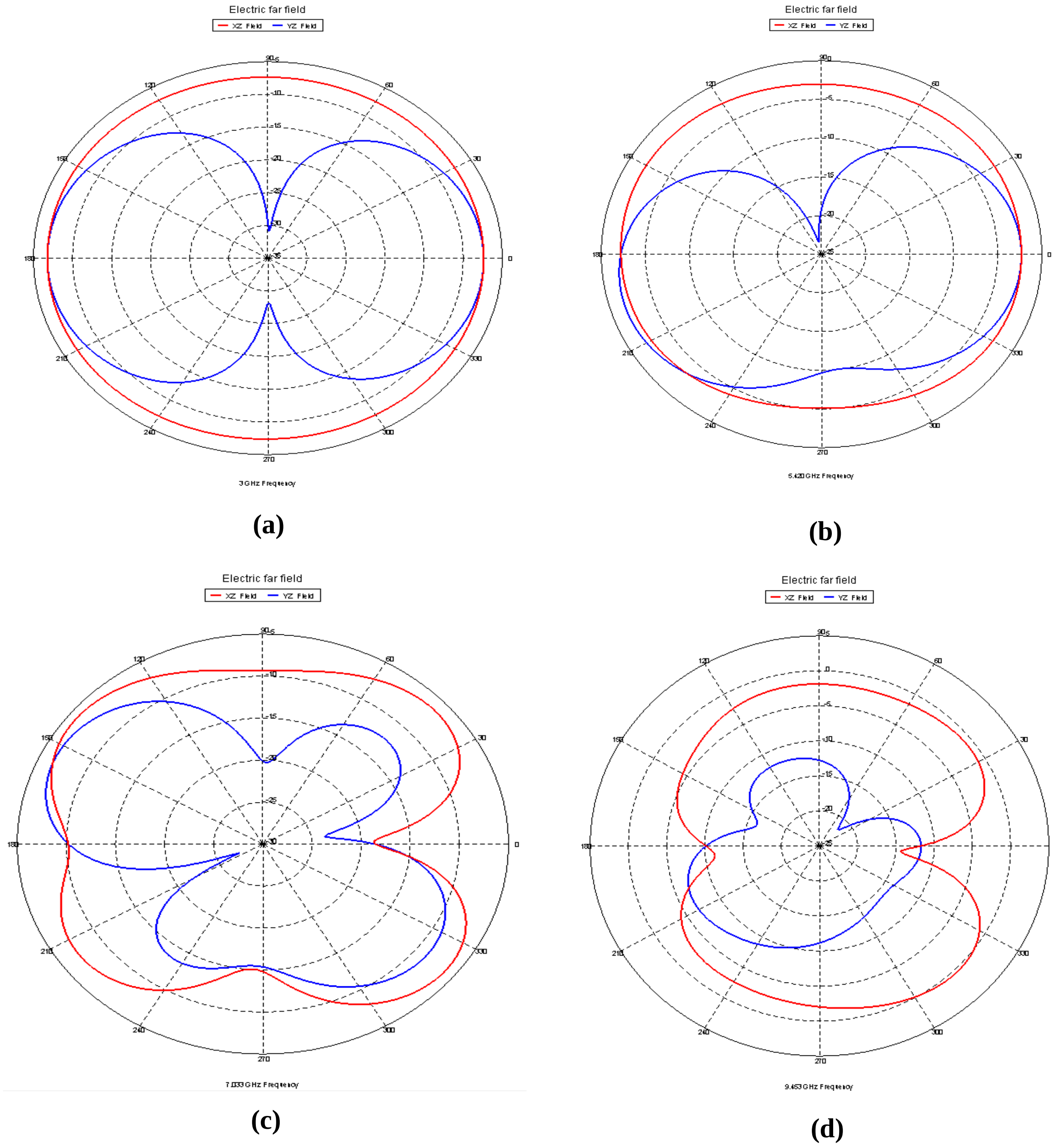
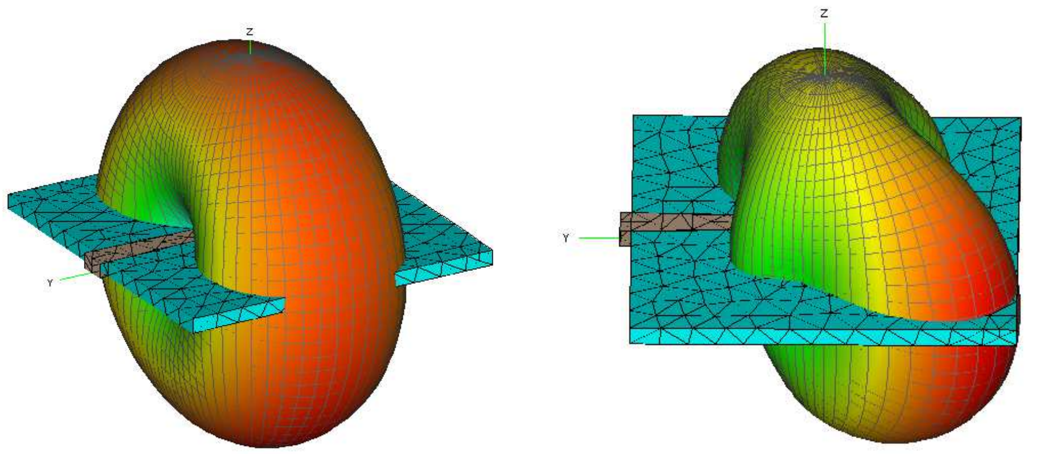
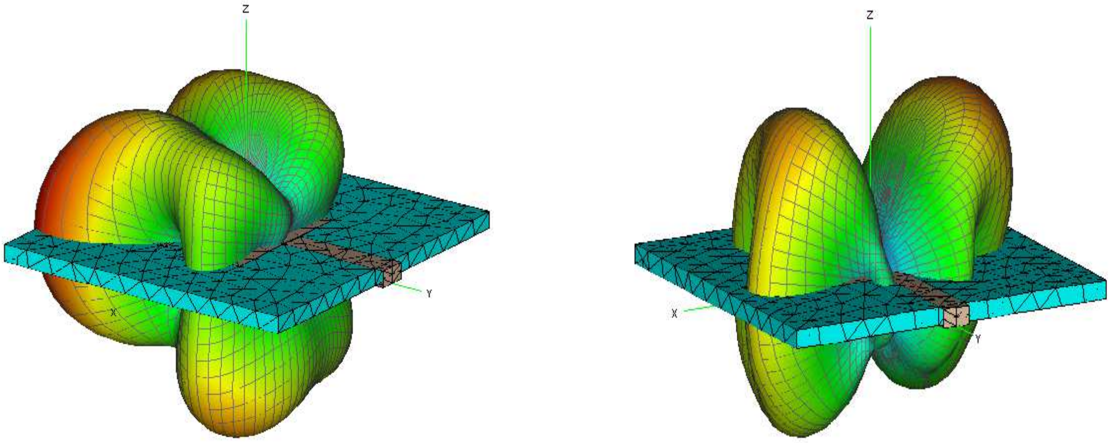


Fig.6.2D Radiation pattern of Slit loaded rectangular monopole antenna at
(a) 3 GHz (b) 5.4 GHz (c) 7 GHz (d) 9.4 GHz

The radiation pattern in 3D is shown in the Fig 7. Fig 7(a) shows the 3D pattern at 3 GHz, Fig 7(b) shows the 3 D pattern at 5.4 GHz, Fig 7(c) shows the 3 D pattern at 7 GHz, Fig 7(d) shows the 3 D pattern at 9 GHz. Here the red color regions indicate those with maximum field intensity.



(a)(b)



(c)(d)

Fig.7. 3D Radiation pattern of Slit loaded Rectangular Monopole Antenna at (a) 3 GHz (b) 5.4 GHz (c) 7 GHz (d) 9.4 GHz

Table II. Comparison ofAntenna Parameters

Antenna Parameters	Proposed Antenna
Resonant Frequency (GHz)	5.5 9.4
Return Loss (dB)	-30, -44
VSWR	1.2
Gain (dB)	2
Bandwidth (MHz)	4800
Impedance Bandwidth (%)	77.2
Application	UWB

The simulated results of proposed antenna are presented in a table as in Table II. From the table we see that the gain is enhanced for the proposed antenna when compared to other antenna

CONCLUSION

In this paper a printed edge fed Rectangular Monopole antenna with a PEC ground plane has been designed and simulated using CADFEKO. The antenna has wide bandwidth, Omni directional radiation pattern and good impedance matching. Such antennas are less fragile and can be integrated with ICs. The antenna resonates in the frequency range 3.6 to 6 GHz and 7.6 to 10 GHz with a bandwidth of 2400 MHz and 2400 MHz respectively with a VSWR less than 2 at both these frequency ranges. The gain of the antenna is 4.9 dB which is satisfactory for wireless systems. The experimental results show that the printed planar edge fed rectangular shaped slit loaded monopole antenna with partial ground plane exhibits a better performance for UWB applications.

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