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DESIGN OF DUAL BAND RECTANGULAR PRINTED ANTENNA FOR BLUETOOTH AND WI-MAX APPLICATIONS

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ABSTRACT

The work represents the designing of the Dual Band Rectangular Printed Antenna. The single band (Bluetooth) antenna is achieved by the finding the proper position of Co-axial feed point and optimizing the width of the patch. Further dual band behaviour of antenna is achieved by embedding a rectangular slot below the Coax feed point on the radiating patch. The dimensions of the antenna are calculated for the frequency of 2.44 GHz. The designed antenna is simulated using EM simulation software CAD FEKO suite (7.0). The proposed antenna is realized on FR-4 dielectric substrate having a dielectric constant of 4.4 and loss tangent of 0.02, with dimensions of 38.60mm x 46.70 mm x 1.6mm. The antenna covers the two bands of operation i.e. Bluetooth (2.4-2.48 GHz) and WiMax (3.44-3.54 GHz) with reflection coefficient -10dB. The antenna exhibits stable radiation patterns for the entire dual band.

Keywords: Dual band antenna, WIMAX, Bluetooth, Coax feed, MSA.

I. INTRODUCTION

The vogue of mobile communication systems has increased extremely during the last decade. As an essential part of these systems, antenna is one of the most important design issues in modern mobile communication units. Even though there are several similar definitions, an antenna can be mainly described as a device, which transforms the electromagnetic waves in an antenna to radiating waves in an unbounded medium such as air in transmitting mode and vice versa in receiving mode. The fast growth of mobile communication systems has forced to the use of novel antennas for base and mobile station applications. Previously, mobile systems were designed to operate for one of the frequency bands of 2G systems, which are Digital Cellular System (DCS), Personal Communications Service (PCS) and Global System for Mobil Communications (GSM) networks. Presently, many mobile communication systems use several frequency bands such as GSM 900/1800/1900 bands (890-960 MHz and 1710-1990 MHz); Universal Mobile Telecommunication Systems (UMTS) and UMTS 3G expansion bands (1900- 2200 MHz and 2500-2700 MHz); and Wi-Fi (Wireless Fidelity)/Wireless Local Area Networks (WLAN) bands (2400-2500 MHz and 5100-5800 MHz) [1].

Typically, because a single antenna cannot operate at all of these frequency bands of Mobile communication, multiple different antennas covering these bands separately should be used. However, usage of many antennas is usually limited by the volume and cost constraints of the applications. Therefore, multiband and wideband antennas are essential to provide multifunctional operations for mobile communication. A multiband antenna in a mobile communication system can be defined as the antenna operating at distinct frequency bands, but not at the intermediate frequencies between bands [9]. Recent vogue in multiband antenna designs used in mobile devices can be divided into three types: slot - type antennas, monopoles antennas and planar inverted-F antennas (PIFA). Multiple resonant modes are achieved through different slots of various geometric cuts onto the radiator and ground plane [1].Slot antenna, with the advantages of compact size, wide bandwidth, and easy integration with other devices is a good candidate for the design of multiband antennas. In the past years, different designs of multiband slot antennas have been proposed [5].

The rapid growth of wireless communication systems (WCS) has forced to the use of antennas for various applications including laptop, mobile, notebook, GPS receivers, PDAs, USB dongles with application bands of GSM, UMTS, GPS, Bluetooth,WiMAX, WLAN, C-bans, X-band and so on. Singular antenna cannot be useful to operate at all these bands of WCS; hence it requires multi antennas for each of these bands. By 1978, the Microstrip patch antenna became more widely well known and used in various communication systems. The numerous advantages of MSA, such as its low weight, small size, and fabrication is easy using printed-circuit technology, led to the design of several configurations for various applications [2]. With increasing requirements for personal and mobile communications, the demand for smaller and low-profile antennas has brought the MSA to the limelight. The telemetry and communications antennas on missiles need to be thin and conformal and are often MSAs. Radar altimeters use small arrays of Microstrip radiators. Other aircraft-related applications include antennas for telephone and satellite communications. Microstrip arrays have been used for satellite imaging systems. Patch antennas have been used on communication links between ships or buoys and satellites. Pagers, the Global System for Mobile Communication (GSM) and the Global Positioning System (GPS) are major users of MSAs. The main drawbacks of the Microstrip patch antennas are narrow bandwidth and low gain. Some approaches have been therefore developed for bandwidth enhancement [2].

In this paper, the Design of Dual Band Rectangular Printed Antenna is proposed for Bluetooth and Wi-max Applications. The designed antenna is realized using co-axial feed on a 1.6mm thick FR-4 dielectric substrate with 38.60mm x 46.70mm surface area and feed by a Co- axial feed of 50Ω. The antenna is designed with full ground having dimensions same as FR-4 substrate. The relative permittivity and loss tangent of the substrate is 4.4 and 0.02 respectively.Equations (1-8) are used for the proposal of rectangular Microstrip patch antenna [4].Co- axial feed is applied to the proposed antenna. First we have designed single band antenna for Bluetooth applications. The position of Co-ax feed point is found in such a way that the Bluetooth band (2.4-2.48 GHz) will resonate with centre frequency of 2.44 GHz. After earning the Single band antenna, surface current distribution is observed at 3.5GHz. It has been seen that there is very less current in the lower region or region below feed point of the radiating patch. A rectangular quarter wavelength slot is etched in to the lower region of the radiating patch to resonate over Wi-Max band (3.4-3.6 GHz) [3].The proposed antenna is simulated using CAD-FEKO EM simulation software of suite 7.0.

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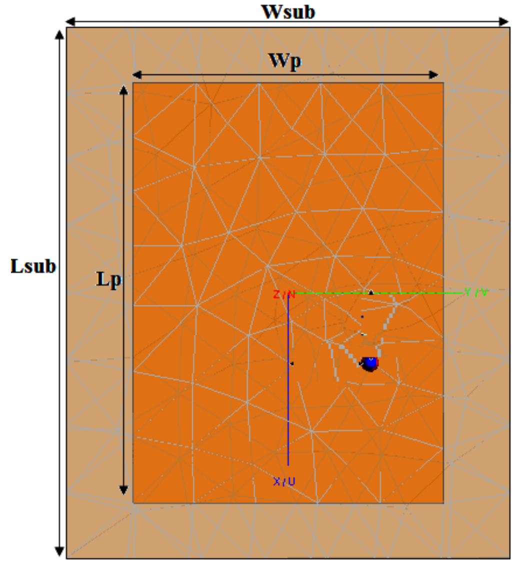
II.ANTENNA DESIGN

The geometry of the single band MSA is as shown in Fig.1. The designed antenna is realized using co-axial feed on a 1.6mm thick FR-4 dielectric substrate with 38.60mm × 46.70mm surface area and feed by a Co- axial feed of 50Ω. The antenna is designed with full ground having dimensions same as FR-4 substrate [7]. The relative permittivity and loss tangent of the substrate is 4.4 and 0.02 respectively. Equations (1-8) are used for the proposal of rectangular Microstrip patch antenna [4].Co- axial feed is applied to the proposed antenna. The position of Co-ax feed point is found in such a way that the Bluetooth band (2.4-2.48 GHz) will resonate with centre frequency of 2.44 GHz as shown in Fig. 2.The dimensions of proposed antenna is shown in the Table 1.



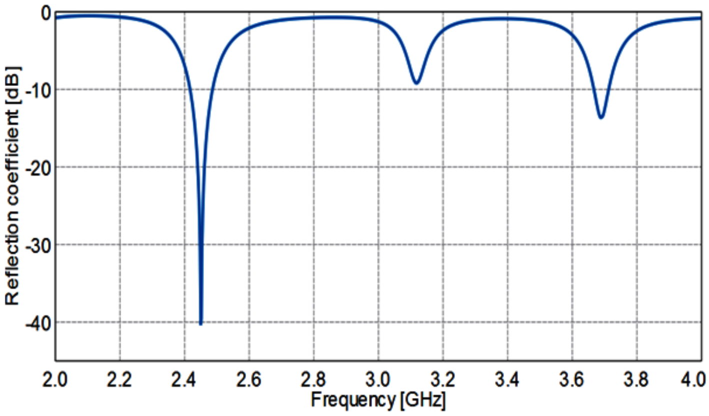


Fig.1 Geometry of Single band antenna.

Fig.2 Graph of its simulated reflection coefficient versus frequency.

Table 1. Dimensions of proposed antenna

Parameters	Calculated Values
Resonant Frequency (f_r)	2.4 GHz
Substrate	FR4
Dielectric constant (ε_r)	4.4
Substrate Height (h)	1.6 mm
Feed	Co-axial
Patch Length (LP)	37 mm
Patch Width (WP)	27 mm
Substrate Length (Lsub)	46.70 mm
Substrate Width (Wsub)	38.60 mm
Length of Ground Plane (Lsub = Lg)	46.70 mm
Width of Ground Plane (Wsub = Wg)	38.60 mm

Distance of feed point from LP (X)	6.12 mm
Distance of feed point from WP (Y)	7.17 mm

The Design equations of antenna are shown below from Equations (1-8).

Width of patch (W_P):

$$W_P = \frac{c}{2*fr\sqrt{\frac{\varepsilon r+1}{2}}} \qquad (1)$$

Where, c is the speed of the light.f_r is the resonant frequency and ε_r is the dielectric constant of substrate.

Effective dielectric constant(ε_{reff}):

$$\varepsilon_{reff} = \frac{\varepsilon r+1}{2} + \frac{\varepsilon r-1}{2\sqrt{(1+\frac{12h}{W})}} \qquad (2)$$

where, ε_{reff} is the Effective dielectric constant ,ε_r is the dielectric constant of substrate,h is the Height of dielectric substrate and W is the Width of the patch.

Effective length(L_{eff}):

$$Leff = \frac{c}{2*fr\sqrt{\varepsilon reff}} \qquad (3)$$

Patch length(ΔL):

$$\frac{\Delta L}{h} = 0.412\left(\frac{(\varepsilon reff+0.3)(\frac{W}{h}+0.264)}{(\varepsilon reff-0.258)(\frac{W}{h}+0.8)}\right) \qquad (4)$$

Length of substrate(Ls):

$$Ls = Lp + 6h \qquad (5)$$

Width of substrate(Ws):

$$Ws = Wp + 6h \qquad (6)$$

Distance of feed point from L_P (X):

$$X = \frac{L_P}{2\sqrt{\varepsilon reff}} \qquad (7)$$

Distance of feed point from W_P (Y):

$$Y = \frac{W_P}{3\sqrt{\varepsilon reff}} \qquad (8)$$

After earning the Single band antenna we have designed dual band antenna for Bluetooth and Wimax applications.The geometry of the dual band MSA is as shown in Fig.3.The antenna design is mainly based on the fact of the surface current distribution.After earning the Single band antenna, surface current distribution is observed at 3.5 GHz. It has been seen that there is very less current in the lower region or region below feed point of the radiating patch.

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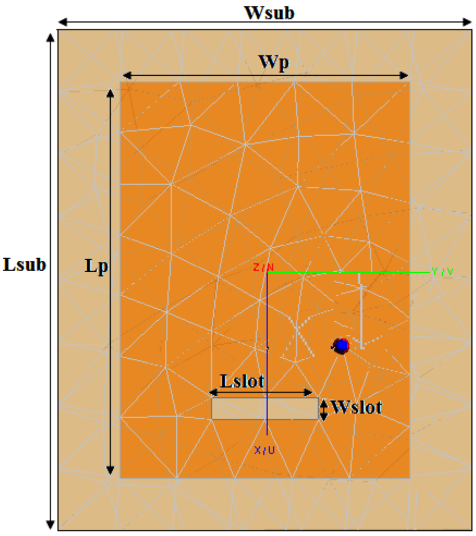

Fig.3 Geometry of Dual band antenna.

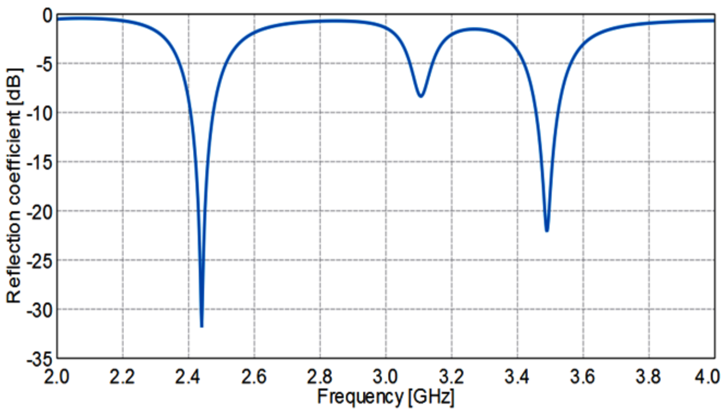

Fig.4 Graph of its Simulated Reflection coefficient versus Frequency.

A rectangular quarter wavelength slot is etched in to the lower region of the radiating patch to resonate over Wi-Max band (3.4-3.6 GHz).The position slot is found in such a way that the Wi-max band (3.4-3.6 GHz) will resonate with centre frequency of 3.5 GHz as shown in Fig.4.For Wi-Max band (3.4-3.6 GHz): centre frequency (f_w) = 3.5 GHz and λ/4 = 12.98mm. where,

$$\lambda = \frac{c}{4fw\sqrt{\frac{(Er+1)}{2}}} \quad (9)$$

III. SIMULATION RESULTS

The antenna designs were simulated in the CAD-FEKO suite 7.0 in order to get the radiation parameters. The parametric analysis is performed to Dual band Antenna. Then achieved simulated results are analyzed. We have considered Reflection Coefficient (S_{11}) versus Frequency to judge the performance of the antenna. Firstly, we have done parametric analysis to single band antenna by varying the feed position of an antenna and by varying the width of the patch.

To achieve a single band operation using Co-axial feed, it is very important that at which point we are feeding to the antenna patch. Hence after performing number of simulations for various feed positions, then at X = 6.12mm and Y = 7.17mm from the Centre of the radiating patch, a Bluetooth band from 2.405-2.475 GHz is achieved. The parametric study of various feed positions is as shown in Fig.5. From the Fig.5 feed position at X = 6.12mm and Y = 7.17mm, a maximum reflection coefficient (S_{11}) of -40dB is achieved. For other feed positions, S_{11} is less than -20dB.

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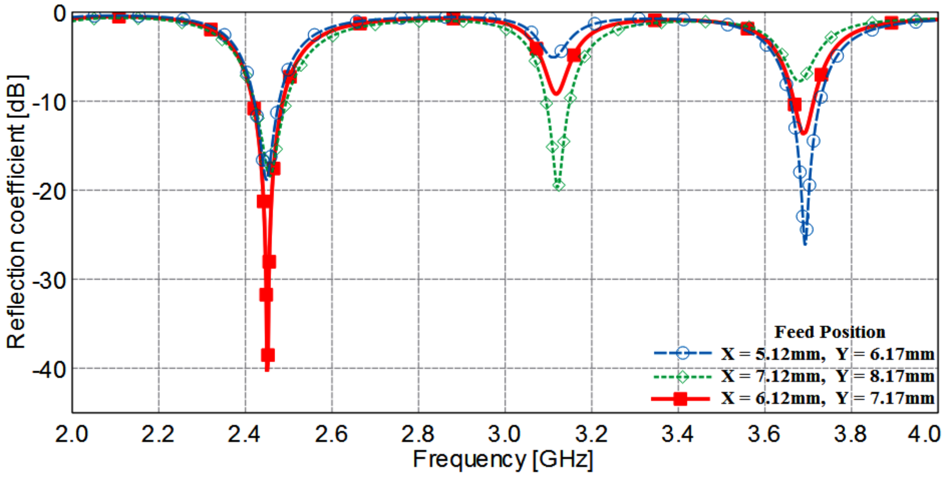

Fig.5 Reflection coefficient versus Frequency graph for the variations of feed position (X and Y).

Then we have done width of the patch parametric analysis. By increasing the width of the patch (W_P), the centre frequency of Bluetooth band goes on decreasing. At W_P = 27mm, we achieved the Bluetooth band with centre frequency 2.44 GHz which is shown in Fig.6.As width of the patch increases, the lower frequency of Bluetooth band shifts left with varying peak.

Then we have done parametric analysis to obtain Dual band antenna (Bluetooth and Wi-Max). The design of antenna is mainly based on the current fact that the current. Fig.9(a) shows that the current is less below the feed point and current directions tell us that the current is leaving from the left bottom corner of the radiating patch. A quarter wavelength rectangular slot is inserted in the below the feed point on the radiating patch to resonate over the Wi-Max band. Due to insertion of rectangular slot, the antenna achieves dual band operation. The length of the rectangular slot is about quarter wavelength of the central Wi-Max band frequency i.e. 3.5 GHz. To find the perfect position for the insertion of this slot, an optimization is done.

For this a parametric study has been done by varying the length and width of the rectangular slot which is shown in Fig.7 and Fig.8 respectively. The rectangular slot inserted below the feed point on the radiating patch is resonating at Wi-Max band (3.44-3.54 GHz). By changing the width of the slot the impedance bandwidth of the

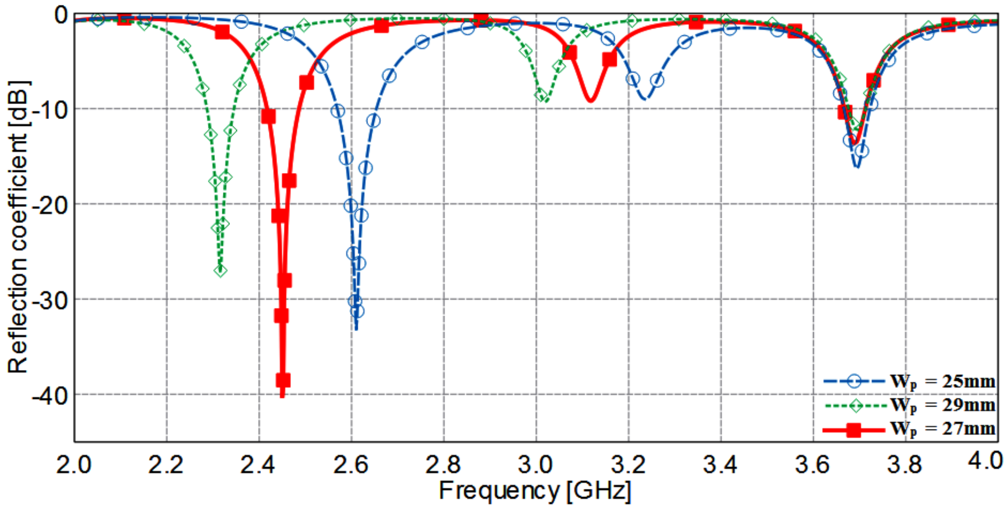

Fig.6. Reflection coefficient versus Frequency graph for the variations of Width of patch (Wp).

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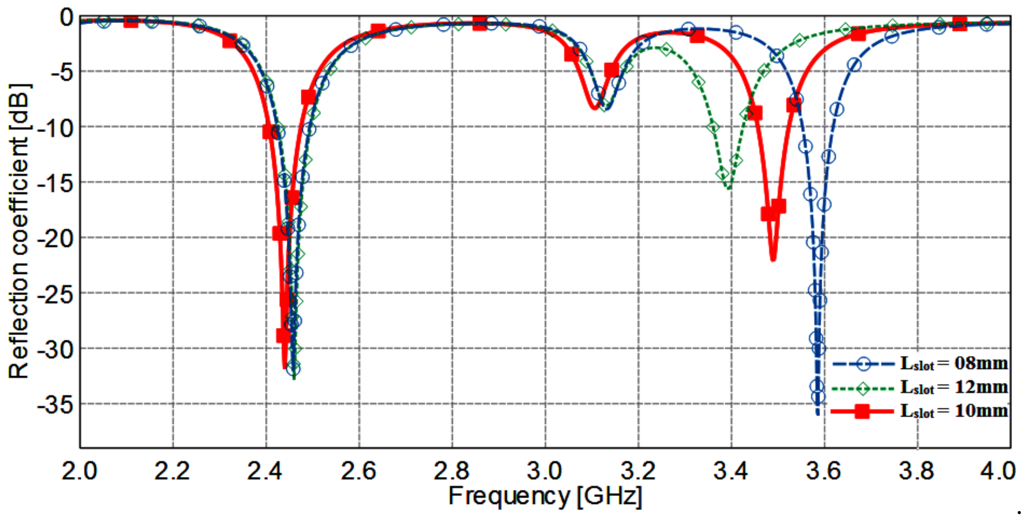

Fig.7 Reflection coefficient versus Frequency graph for the variations of length of rectangular slot (L_{slot}).

Wi-Max band can be controlled, while by increasing the length of the slot, the Wi-Max band shifts to the lower edge frequency with the varying peak. By parametric analysis of length and width the Wi-Max band 3.44-3.54 GHz with a peak -22 dB is obtained. The optimized dimensions of the rectangular slot is L_{slot}=10mm and W_{slot}=2mm.

Fig.9(a) shows current distribution of rectangular single band antenna at 3.5GHz before insertion of rectangular slot and Fig.9(b) shows current distribution of rectangular dual band antenna at 3.5 GHz after insertion of rectangular slot. Due to insertion of rectangular slot, there is a drastic change in current path. Initially there is very less current below the feed point on the radiating patch at 3.5 GHz as shown in fig.9(a) while fig.9(b) shows that the current is mainly revolving around slot and proposed antenna is resonating at Wi-Max band.

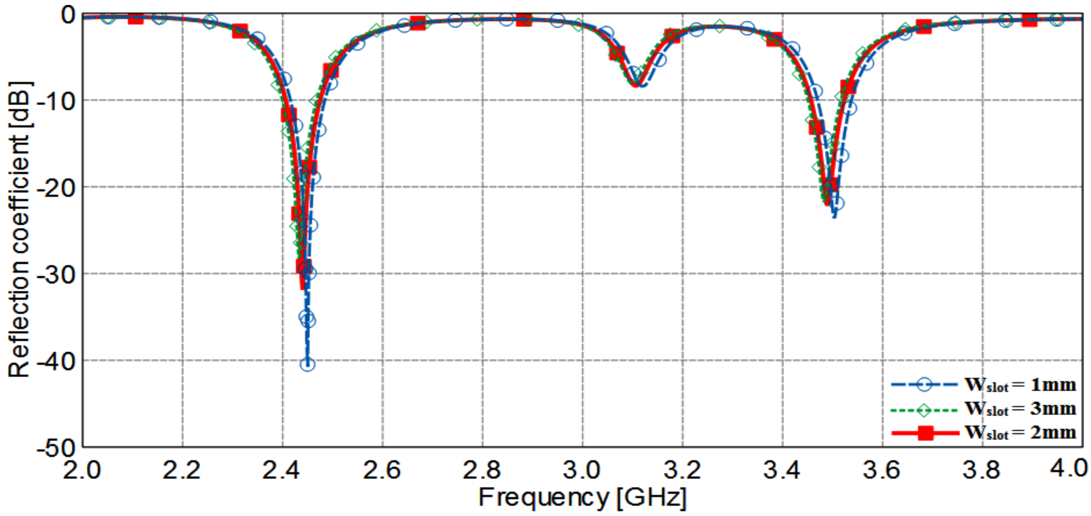

Fig.8 Reflection coefficient versus Frequency graph for the variations of width of rectangular slot (W_{slot}).

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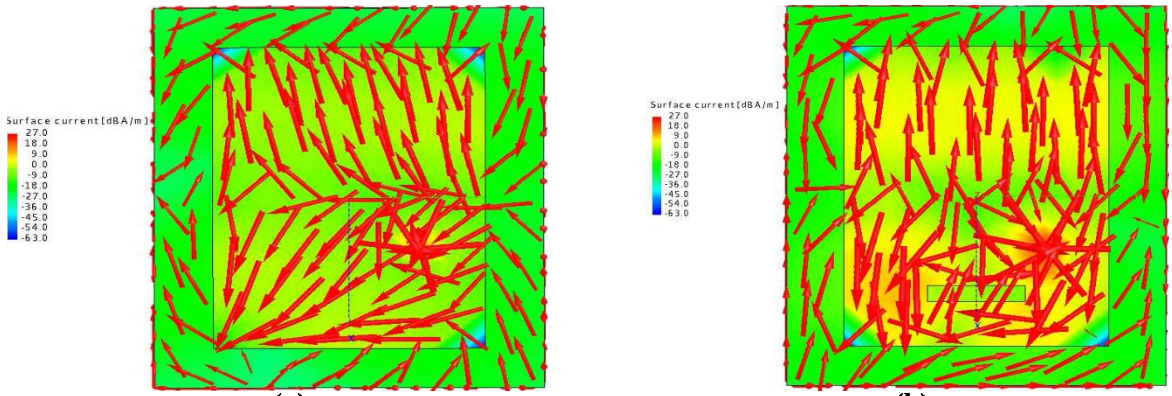

(a) **(b)**

Fig.9 Surface current distribution of the (a) Single band antenna at 3.5 GHz (without slot) (b) Dual band antenna at 3.5 GHz. (with slot)

Then we have got Optimized results of the Dual band antenna. Based on the optimized parameters of the proposed. Dual band rectangular antenna, we obtained the bandwidths of an antenna ranging from 2.405-2.475 GHz (Bluetooth) and 3.44-3.54 GHz (Wi-Max). Fig.10(a) the VSWR ≤ 2 for both bands. This leads to obtain the proper impedance bandwidth within the fore mentioned bands. Fig.10(b) shows the impedance vs. frequency graph of the dual band antenna. Here for Bluetooth and Wi-Max bands, the graph shows impedance of 51.2 and 51.7. Generally it should be approximately 50, but due to substrates dielectric losses some variations has been occurred.

Fig.10(c) shows the gain vs. frequency graph of the dual band antenna. Here for Bluetooth the graph shows gain of 2.42dBi and for Wi-Max band, the gain is decreasing due to substrates dielectric losses. The negative gain (in dBi) at the lower frequency bands indicates the destructive interference of surface currents.Fig.10(d) shows the efficiency vs. frequency graph of the dual band antenna. Here it has been seen that for Bluetooth band, antenna efficiency is approximately 50%. The simulated efficiency of an antenna is decreased after 3 GHz of frequency due to substrates dielectric losses and use of full ground.

Fig.11 shows the radiation pattern for elevation plane (E-plane or Φ=90) and azimuth plane (H-plane or Φ=0) at f=2.44 GHz and at f= 3.5 GHz. It describes how an antenna directs the energy it radiates [4]. It shows an Omni directional radiation pattern along the H-plane and a directional radiation pattern along the E-plane, with low cross polarization.

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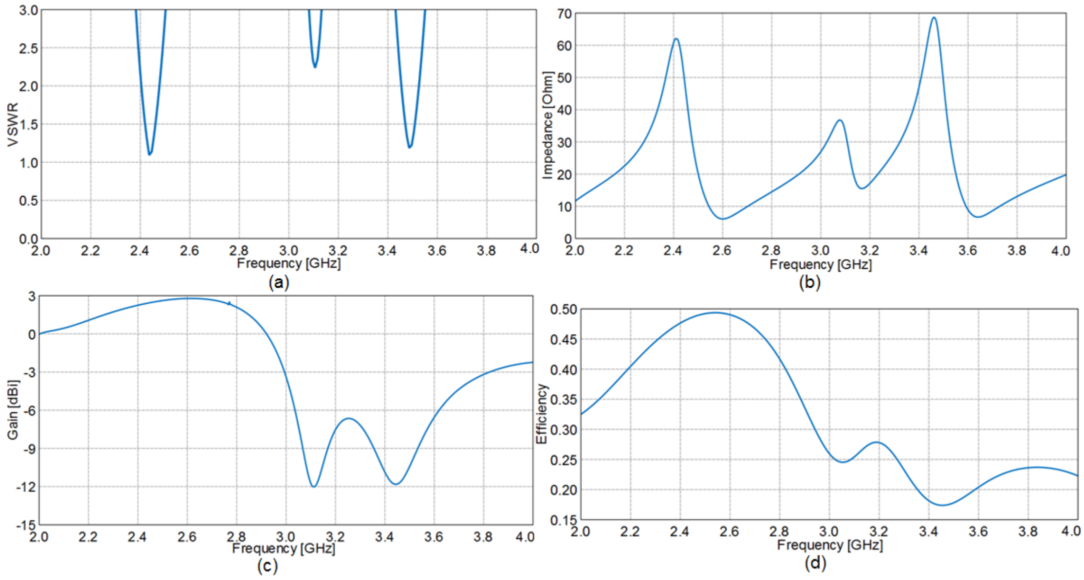

Fig.10 Simulated (a)Graph of VSWR (≤ 2) versus Frequency for Dual Band Antenna, (b)Graph of Impedance versus Frequency for Dual Band Antenna, (c)Graph of Gain versus Frequency for Dual Band Antenna and (d) Graph of Efficiency versus Frequency for Dual Band Antenna.

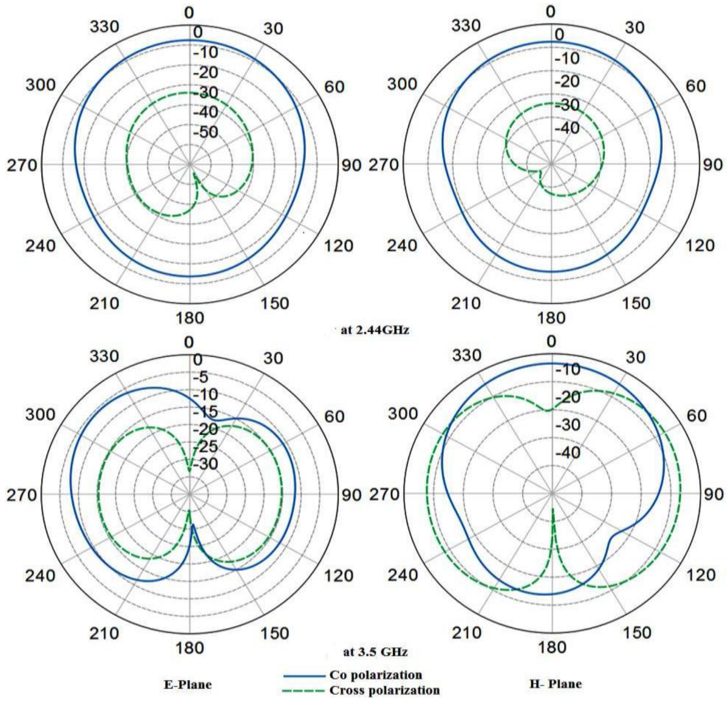

Fig.11: Simulated radiation patterns observed in E-plane and H-plane at (a) 2.44GHz (b) 3.5GHz.

IV. CONCLUSION

To integrate the lower frequency bands into the one antenna, the proposed antenna is a good candidate for such applications. The motivation of integrating two technologies in one antenna is due to the current trend for short range wireless systems of beyond3G to enable wireless connectivity for everybody and everything at any place and at any time. The Bluetooth band is achieved by optimizing the Co-ax feed position and width of the patch, while the dimensions of the quarter wavelength rectangular slot resonate over Wi-Max band (3.44-3.54 GHz). As width of the patch increases, the lower frequency of Bluetooth band shifts left with varying peak. Also By changing the width of the slot the impedance bandwidth of the Wi-Max band can be controlled, while by increasing the length of the slot, the Wi-Max band shifts to the lower edge frequency with the varying peak. The antenna shows more than 50% antenna efficiency at Bluetooth band and higher gain up to 2.42dBi at the Bluetooth band.

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