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COMPACT TRIPLE BAND RECTANGULAR MICROSTRIP ANTENNA FOR WLAN/WIMAX APPLICATIONS

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ABSTRACT

A compact triple band rectangular microstrip antenna (RMSA) for WLAN / WiMAX applications is proposed. The antenna operates at three resonance frequencies 2.4/3.2/3.5GHz Covering the WLAN/ WiMAX operating bands, IEEE WLAN protocol 802.11 b/g employs 2.4 GHz and WiMAX 3.5 GHz. The antenna was studied by means of simulations as well as practical measurements. The Triple band characteristics of antenna are due to the various slots on the radiating structure. The proposed antenna achieves good impedance matching, return loss (greater than -10dB), radiation patterns and consistent gain at all three operating bands. The antenna is simulated using Ansoft's HFSSv11 and measured using network analyzer. The simulated and experimental results of the antenna are in good agreement. The antenna has an overall dimension is 29.44mm x 38.04 mm x1.6mm, when printed on a FR-4 substrate of dielectric constant 4.4.

Keywords: *WLAN, Wimax, Slots, Triple Band, RMSA (Rectangular Microstrip Antenna).*

I.INTRODUCTION

Rarely have technical innovations changed every day life as fast and profoundly as the pervasive use of personal mobile communications. Over last two decades, a mobile wireless service grows rapidly. In fact due to the increase of wireless standards, there is need of multi band and wideband antenna designs have become very important for wireless communication, to fulfill the requirement of modern hand held communication devices like WLAN, WiMAX, Blue tooth UMTS bands etc, and ability to integrate more than one communication standard in a single compact module. Such antenna can work at several frequencies simultaneously.

Recently, there are rapid developments in wireless communications, and in order to satisfy the IEEE 802.11 WLAN standards in the 2.4GHz (2400-2484 MHz) and WiMAX 3.5GHz (3.4GHz-3.66GHz) bands, dual band and triple band operations the printed monopole antennas are required. For available designs, the microstrip antennas [MSAs] are widely used due to their attractive features such as light weight, low profile, ease in fabrication and low cost [1]. A lot of techniques have been proposed to improve the band width and return loss and radiation characteristics. Some interesting designs for printed monopole antenna have been widely studied for different geometric configurations such as inverted F-antenna [2] and a stacked F-radiation strip [3], F-shaped antenna for three resonant frequency [4].The antenna must be integrated in such a way to take up a very small space on printed circuit board systems. A planar printed inverted F-antenna is an attractive candidate due its structure [5-6]. A triple band planar antenna consists of dipoles for three frequencies and the radiating element of the antenna is T-shape slotted is proposed for dual band frequencies [7-8].By considering above facts and to achieve good radiation patterns, impedance matching and better return loss.

In this paper, we present potential configuration for a triple band antenna for the desired wireless LAN and WiMAX applications. Thus a compact triple band RMSA that operates in the2.4/3.2/3.5GHz frequency bands is designed. The proposed antenna exhibits nearly Omni-directional radiation pattern, better return loss and

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maintains moderate gain for the three operating bands. The various antenna parameters are optimized using an Ansoft's high frequency structured simulator [HFSS] and the prototype of the antenna was constructed and tested using Network Analyzer by adjusting the dimensions of the slots in the patch. Details of the antenna designed, stimulated and experimental results are presented and discussed.

II. PROPOSED GEOMETRY OF THE TRIPLE BAND RECTANGULAR MICRO-STRIP PATCH ANTENNA.

Fig 1 shows the proposed geometry of the Triple band rectangular micro-strip patch antenna. It is constructed on a substrate with dielectric constant, ε_r = 4.4 and thickness h = 1.6mm. The proposed antenna consists of a rectangular shape patch, excited by a 50 Ω micro-strip line or inset feeding. The Dimensions of proposed triple -band antenna is as follows. The ground plane is having dimensions of W_g*L_g mm [48*40] mm and Patch is of dimensions W*L mm [38.04*29.44] mm printed on the FR4 epoxy substrate with dielectric constant, ε_r = 4.4. A 50 Ω microstrip line with width WO=3mm, length Y1= 5.56mm with an inset depth of patch Yo =10.2mm is used. Slots with dimensions W1=1.5mm and W3 =1.3mm with W2 =1.4mm and Yo =10.2mm are made as shown in fig1. A square shape with sides Q = wavelength/30 = 4.16mm is cut across all four corners of the patch. Later two identical slots with width Ws = 2mm, length Ls =14mm and S1=1.5mm were embedded in the patch and are equally placed symmetric to the radiating edge of patch as shown.

Here the micro-strip inset feed makes structure suitable for integration with microwave circuitry. The antenna bandwidth shows dependence on both slots length and width and therefore some fine tuning is needed to achieve peak resonance for triple bands at 2.4/ 3.2 /3.5Ghz.

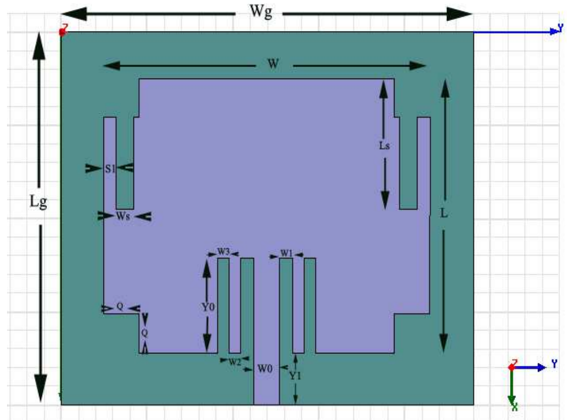

Figure 1. Geometry of triple band microstrip antenna

III. DESIGN SPECIFICATIONS AND MATHEMATICAL FORMULATIONS

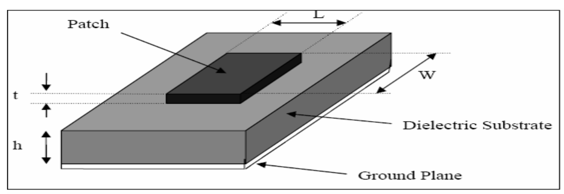

Figure 2.Modle of microstrip antenna

This model represents the micro strip antenna of width 'w' and height 'h' separated by a transmission line 'L'. The microstrip is essentially a non homogeneous of two dielectrics typically a substrate and air as shown in figure 2.

The three essential parameters for the design of a rectangular micros trip Antenna are [1].

• Frequency of operation (*fo*): The resonant frequency of the antenna must be selected appropriately. The Personal Communication System (PCS) uses the frequency range from 1850-1990 MHz, hence the antenna designed must be able to operate in this frequency range. The resonant frequency selected for our design is 2.4 GHz, Dielectric constant of the substrate (ε_r), the dielectric material selected for our design is FR4 epoxy which has a dielectric constant of 4.4. A substrate with a high dielectric constant has been selected since it reduces the dimensions of the antenna.

• Height of dielectric substrate (h*)*: For the microstrip

Patch antenna to be used in wireless applications, it is essential that the antenna is not bulky. Hence, the height of the dielectric substrate is selected as 1.6

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mm. Hence, the essential parameters for the design are:

- $f0$ = 2.4 GHz
- εr = 4.4
- h = 1.6 mm

Step 1: Calculation of the Width (*W*):

The width of the Microstrip patch antenna is given by equation (1)

$$W = \frac{c}{2f_o\sqrt{\frac{(\varepsilon_r+1)}{2}}} \quad \text{--1}$$

Substituting c = 3e8 m/s, ε_r = 4.4 and f o = 2.4GHz, we get: W **= 0.0380363=38.0363mm**

Step 2: Calculation of Effective dielectric constant (ε_r *eff*):

Equation (2) gives the effective dielectric constant as:

$$\varepsilon_{reff} = \frac{\varepsilon_r+1}{2} + \frac{\varepsilon_r-1}{2}\left[1+12\frac{h}{W}\right]^{-\frac{1}{2}} \quad \text{---2}$$

Substituting ε_r = 4.4, W = 38.0363 mm and h = 1.6 mm we get: ε_r ***eff* = 4.0858**

Step 3: Calculation of the Effective length (L_{eff}).

Equation (3) gives the effective length as:

$$L_{eff} = \frac{c}{2f_o\sqrt{\varepsilon_{reff}}} \quad \text{--3}$$

Substituting $\varepsilon_{r\ eff}$ = 4.0858, c = 3e8 m/s and

$f\,o$ = 2.4 GHz we get:

L_{eff} **= .03092=30.920mm**

Step 4: Calculation of the length extension (ΔL):

Equation (4) gives the length extension as:

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

Substituting $\varepsilon_{r\ eff}$ = 4.0858, W = 38.0363 mm and h = 1.6 mm we get: ΔL = **0 .7388mm**

Step 5: Calculation of actual length of patch (*L*):

The actual length is obtained by re-writing equation for L (5) as shown

$$L = L_{eff} - 2\Delta L \quad \text{----5}$$

Substituting L_{eff} = 30.920 mm and ΔL = 0.7388mm we get:

***L* = .0294425=29.4425mm**

Step 6: Calculation of the ground plane dimensions (*Lg* and *Wg*):

The transmission line model is applicable to infinite ground planes only. However, for practical considerations, it is essential to have a finite ground plane and that similar results for finite and infinite ground plane can be obtained if the size of the ground plane is greater than the patch dimensions by approximately six times the substrate thickness all around the periphery. Hence, for this design, the ground plane dimensions would be given as

$L_g = 6h+L=6(1.6mm) + 29.4425mm$
$= 0.03904 = 39.04mm=40mm$
$W_g = 6h+W = 6(1.6mm)+38.0363mm$
$= 0.0476=47.63mm=48mm$

Similarly the calculations can be done for other resonant frequencies.

IV. SIMULATION, EXPERIMENTAL RESULTS AND DISCUSSIONS

IV-1: Return loss

A prototype of the RMSA is simulated, constructed and tested. Figure3.Shows the simulated and measured return loss of the triple band antenna. The radiating element can be excited at three resonance frequencies. The first and second resonance frequency is mainly governed by the dimensions of the slots either side of the micro strip line feed. The third resonance frequency is mainly due to the slots equally placed symmetric to the radiating edges of the patch. Besides these design parameter and the antenna height, the ground plane dimensions influences the good impedance matching can be achieved in the 2.4GHz, 3.2GHz and 3.5GHz. The return loss of the RMSA is greater than the -10dB which clearly shows the ability of the triple band antenna so that three measured bands cover the wireless LAN and WiMAX bands.

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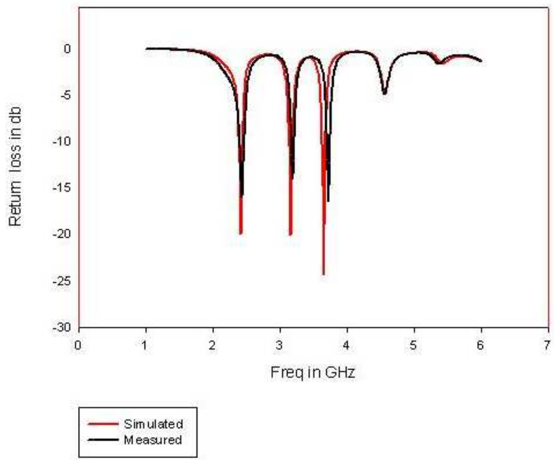


Figure 3. Simulated and Measured return loss characteristic of antenna

IV-2: Radiation patterns:

Figure 4 and 5 shows the simulated and measured radiation patterns of the antenna at 2.4 GHz and 3.5 GHz which is almost identical at all the chosen operating frequencies. The polarization of the antenna is also verified. The low cross polarization level confirms that the antenna is linearly polarized over the entire impedance band. The radiation pattern in the Y-Z plane and X-Z plane are nearly Omni directional patterns. The antenna does offer the same radiation patterns at all the three resonance frequencies with little variations.

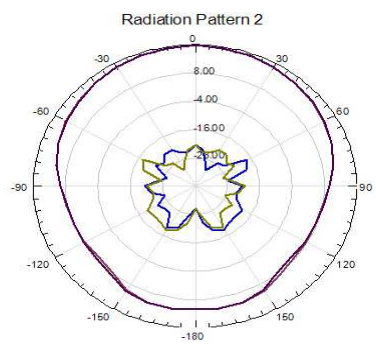


Figure 4(a). Simulated Radiation pattern for phi=0, 90,180,270, 360 deg at 2.4GHz

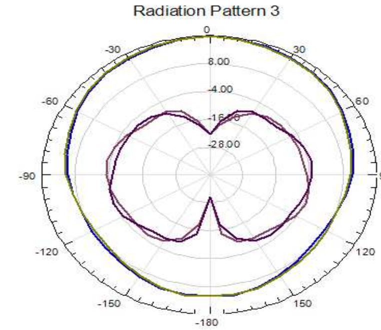
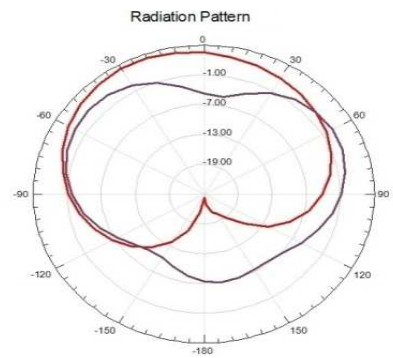


Figure 4(b). Simulated Radiation pattern for phi=0, 90,180,270, 360 deg at 2.4GHz



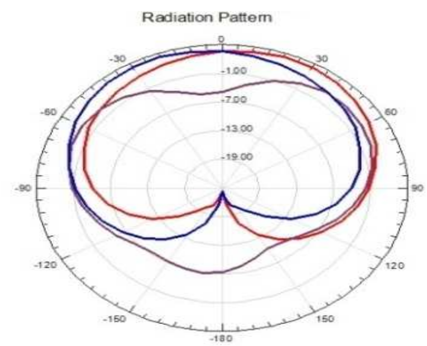


Figure 4. Simulated Radiation pattern for phi=0, 90,180,270, deg at 3.5GHz

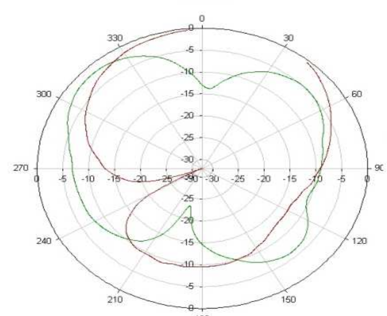


Figure 5(a). Measured Radiation pattern for E-plane pattern at 2.4GHz and H-plane pattern at 2.4GHz

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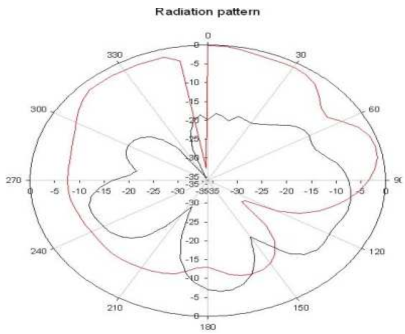


Figure 5(b). Measured Radiation pattern for E-plane pattern at 2.4GHz and H-plane pattern at 2.4GHz

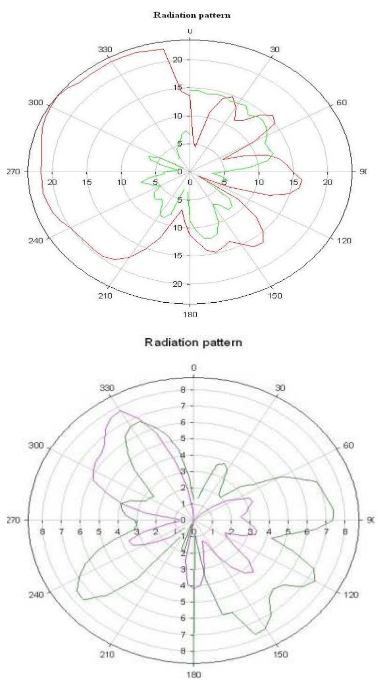
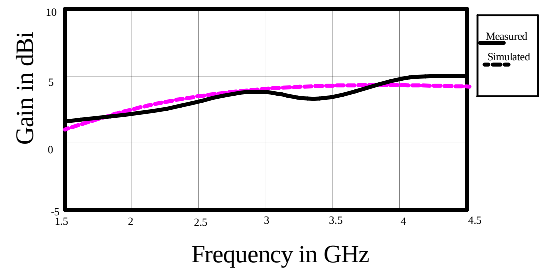


Figure 5. Measured Radiation pattern for E-planepatternat3.5GHz and H-plane pattern at 3.5GHz

IV-3: Gain characteristics

The simulated and the measured gain of the antenna at 2.4/ 3.2/3.5 GHz bands are shown in the figure 4. the peak gain in the 2.4 GHz is about 2.0 dBi , while that in the 3.2 / 3.5 GHz is about 3.2 – 3.9 dBi . The higher the gain at the 3.5GHz band is confirmed.



IV-4: Current distribution, E-field and H –field distribution.

Figure 6, 7 and 8 provides the simulated current distribution, E-field and H-field distribution respectively. It is obvious that in the 2.4 GHz band, current is distributed equally on both lower and upper radiating element. Similar to the conventional current distribution on the arms of λ/2 dipoles. However current is concentrated on the edges of the radiating element. At the resonant frequencies, a half wavelength variation in current is observed along the slot edges. The prototype of final fabricated triple band RMS antenna is shown in figure 9 below.

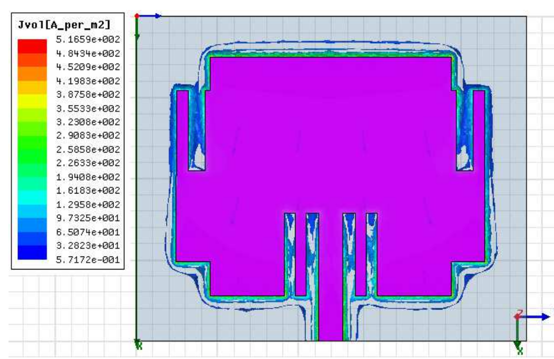


Figure 6. Current distribution in the Triple band RMS Antenna

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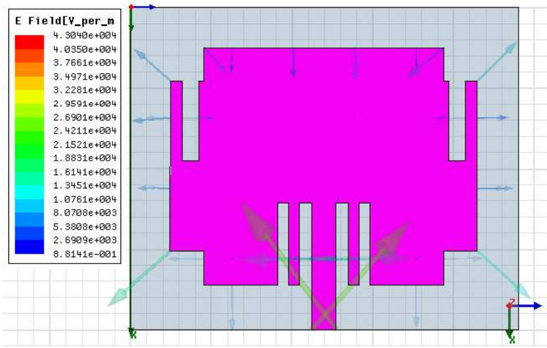

Figure 7. Electric field distribution in the Triple band RMS Antenna

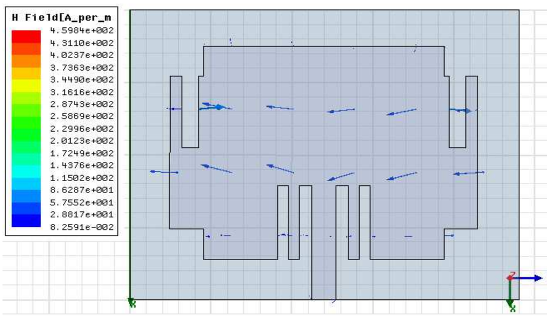

Figure 8. Magnetic field distribution in the Triple band RMS Antenna

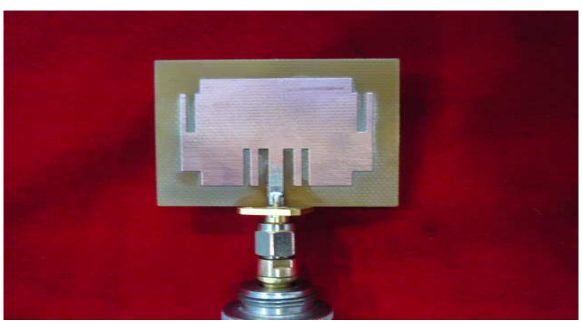

Figure 9. The prototype of final fabricated triple band RMS antenna

V. CONCLUSION

In this paper, a compact triple band inset fed RMSA is proposed. The antenna has been fabricated and tested, which is suitable to completely cover the IEEE 802.11 WLAN standards of 2.4 GHz (2.39-2.48 GHz) and WiMAX band of 3.5 GHz (3.25-3.66 GHz), which are wide enough to cover the required bandwidths of 2.4/3.2/3.5GHz. The good agreement obtained between the experimental and simulated data. The effects of varying the width, height of slots on the radiating element and a gap between them on the resonant frequencies and the impedance band widths are also been studied. Excellent radiation patterns and return loss characteristics, higher gain and low cross-polarization levels. It is clear from those figurers that all the parameters like impedance matching, return loss, Radiation patterns and gain were improved compared to previous radiating structures of antennas. This Triple band antenna was suitable for its use in wireless mobile applications.

VI. ACKNOWLEDGEMENT

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