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Slotted and Miniaturized Patch Antenna for WLAN and WiMAX Applications

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***Abstract*— The properties of Microstrip patch antennas such as low profile, easy fabrication, less cost and conformability well suited and popularly used in wireless devices. A small slotted dual band microstrip patch antenna for wireless applications is presented in this paper. The IEEE operating bands 2.4/5.2 GHz wireless local area network (WLAN)/ worldwide interoperability for microwave access (WiMAX) are covered by this proposed antenna. The antenna can be fed by direct probe feeding using a 50 ohm microstrip line. The parametric analysis such as return loss, directivity, bandwidth, gain and VSWR of micorstrip patch antenna with meandered slots are analyzed using high frequency structure simulator (HFSS). Measured return loss and radiation patterns are observed to be omnidirectional, moderate gain and dual band frequencies suitable for mobile handsets. The overall size of the antenna is 15mm×25mm×1.6mm, fabricated on flame resistant-4 epoxy (FR4) substrate of dielectric constant 4.4. The antenna provides two useful impedance bands with good efficiency. The antenna size reduction is more than 60%. The first band resonates at 2.4 GHz with return loss of -19.79 dB. Hence first band finds application in WLAN. The second band resonance is at 5.2 GHz with return loss of -28.97 dB. WiMAX uses this band. The operation of the antenna is compared along with measured and simulated results. Good validation has been found in measured results and simulated results.**

Index terms -Slot, Patch, Mobile, Return loss, VSWR, HFSS, Dual band, Microstrip.

I. Introduction

Wireless local area network (WLAN) and worldwide interoperability for microwave access (WiMAX) are widely used in modern wireless communication technology for mobile devices [1,3,12,13]. In order to satisfy the various wireless communication protocol systems, mobile phones have wireless data connectivity for various business and personal applications. The most popular standard is WLAN/IEEE 802.11b uses the 2.4 GHz band, which operates in the same frequency range. On the other hand WiMAX/IEEE 802.16 standard that covers 5.2 GHz band, which provides wireless data transfer from single node to multinode links for portable and smaller mobile internet connectivity. This leads to great demand in designing single compact antenna for mobile systems. Microstrip antennas have numerous advantages such as low profile, less cost, light weight, easy fabrication and modeling.

A triple band open L-slot with slit and a strip antenna which provides better impedance, and generates verity patterns of polarizations both linear and circular. Slit and strip mender line antennas has been designed to operate tri bands to meet the requirements for wireless applications [1]. Main issue with a coplanar waveguide (CPW) –fed slot antenna is to provide an easy impedance matching and bandwidth enhancement. So for several impedance matching techniques are proposed based on the change of the slot shapes and also reduced radiation hazard for mobile handset. Monopole antenna have been adopted and studied extensively for wideband communication systems because of their features such as simple structure, small size, wide impedance bandwidth and omnidirectional radiation patterns [2]. Ting WU et al [3] demonstrates a compact triband microstrip monopole antenna composed of a partial ground and Y-shaped radiated patch that consists of two unequal monopole arms and an embedded circle monopole, which gives good polarization characteristics and improves the impedance bandwidths to cover the frequency bands. The proposed paper explains shorted patch elaborated design to get flexibility in the desired frequency for the two operating ranges and tune it for custom applications. More attention has been given to the miniaturization of antenna for mobile systems where physical size of a device is important, which gives better directivity and polarization [4]. A compact inset-fed dual band microstrip antenna has designed to study the effects of varying the slots size of the radiating elements. The impedance bandwidth, Excellent return loss, radiation patterns, high gain and less cross-polarization has been reached [9].

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The printed small dual band microstrip patch antenna with slot structure is presented by the way of simple slot configuration that can be applied as printed antenna. The proposed antenna improves band width, return loss, gain and polarization characteristics having dual band concept with a single metal plane for mobile applications like WLAN/WiMAX. The antenna design has been verified using Ansoft HFSS [8] designer with measured results.

II. DESIGN OF PATCH ANTENNA

Basic structure of microstrip patch antenna is represented in Fig. 1, contains metallic patch, dielectric substrate and a ground plane. The patch is a conducting material like copper and has any possible shapes like circular, rectangular, square etc. The substrate consists of a dielectric material having the dielectric constant ranging between 2.2 to 12. Composite materials such as FR4 (Flame resistant-4), duroid, getek, Rogers RT and matamaterials are widely used as substrates. The antenna may be fed by line feeding, probe feeding etc. The other side of the substrate is ground plane.

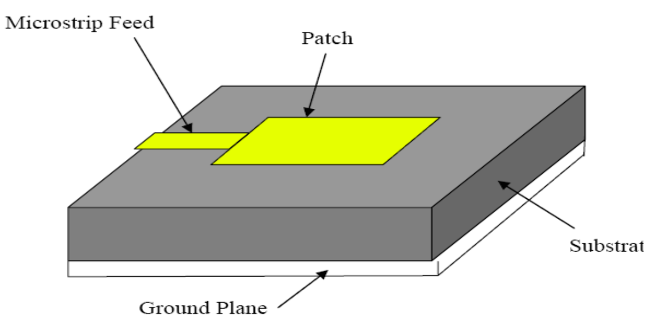

Figure 1. Basic Structure of microstrip patch antenna

Complete dimensions of the proposed dual band small size patch antenna are shown in fig 2. Antenna is build on a dielectric substrate with ϵ_r=4.4, loss tangent δ=0.001 and thickness h=1.6 mm, the patch with dimensions width 13 mm and height 16 mm. Also the ground plane has width 15 mm and height 25 mm. The antenna is excited using a 50 ohms direct microstrip line feeding. Latter two identical slots width of 1 mm, height of 5 mm were combined and placed symmetric to the radiating edge of patch. This type of structures is useful for integration with any microwave circuits. The bandwidth of the antenna depends on both slots length and width and hence sharp tuning is required to obtain peak resonance for dual bands at 2.4/5.2 GHz. By cutting two slots from a patch, gain and band width of microstrip antenna can been enhanced for this antenna.

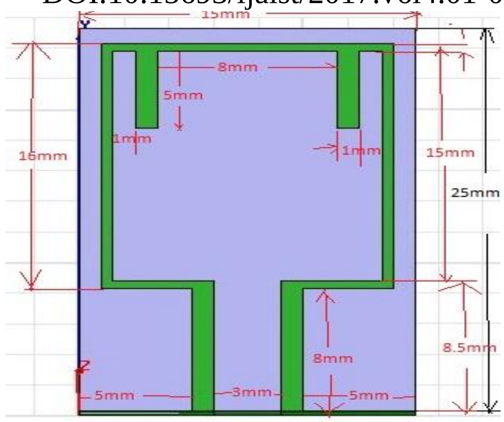

Figure 2. Proposed dual band small size microstrip patch antenna over FR-4 substrate using Ansoft HFSS with dimensions

III. DESIGN EXPRESSIONS FOR PROPOSED PATCH ANTENNA

Design parameters for microstrip patch Antenna are

- **Resonant Frequency:** The resonant frequency of the antenna must be selected appropriately [6,7,9]. The WLAN/WiMAX uses the frequency range from 2400-2484 MHz/5250-5850 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:** 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.

- **Thickness of dielectric substrate:** For the microstrip Patch antenna to be used in wireless applications, it is essential that the antenna is not bulky. Hence, thickness of the dielectric substrate is selected as 1.6 mm. The required parameters for the design are calculated using fundamental equations [5-7,9,13].

i. ***Estimation of patch Width*:**

Microstrip patch antenna width is given by

$$w = \frac{c}{2f0\sqrt{\frac{(\varepsilon r+1)}{2}}} \quad \text{———} (1)$$

ii. ***Effective dielectric constant:***

Effective dielectric constant is given by

$$\varepsilon reff = \frac{(\varepsilon r+1)}{2} + \frac{(\varepsilon r-1)}{2}\left[1+12\frac{h}{w}\right]^{\frac{1}{2}} \_(2)$$

iii. ***Effective length***

Effective length is given by

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$$Leff = \frac{c}{2f0\sqrt{\varepsilon reff}} \_\_\_\_\_\_\_\_\_\_\_\_\_\_(3)$$

iv. ***Extension of Length:***

Length extension is given by

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

v. ***Length of the patch:***

$$L = Leff - 2\Delta \ \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_(5)$$

vi. ***Ground plane length and width:***

The transmission line model is applicable to infinite ground planes only. However, for practical considerations, it is essential to have a finite ground plane. 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

$$Lg = 6h + L \ \_\_\_\_\_\_\_(6)$$
$$wg = 6h + w \ \_\_\_\_\_\_(7)$$

vii. ***Input Impedance:***

The approximate input impedance of a resonant microstrip patch antenna is

$$zin = 90 \frac{\varepsilon r2}{\varepsilon r - 1}\left[\frac{L}{w}\right]^2 \_\_(8)$$

IV. Results and Discussions

Simulated and measured return loss plots for proposed small size dual band microstrip patch antenna are represented in fig 3 and 4. Proposed antenna resonates at 2.33 GHz and 5.24 GHz with return loss of 19.79 dB & 28.97 dB at desired frequencies. Two resonant frequencies are used for the WLAN/WiMAX band. The antenna has two operating bands having band width of 22% (2.16 to 2.38 GHz) in band 1 and 23% (5.13 to 5.36 GHz) in band 2. Simulated radiation patterns of E-plane and H- planes at 2.4 GHz are represented in figures 5 and 6. The radiation patterns are omnidirectional in both E and H planes. The radiation pattern in 3D is shown in figure 7. It shows very good polarization for proposed antenna.

A Close validation has found in measured results and simulated results.

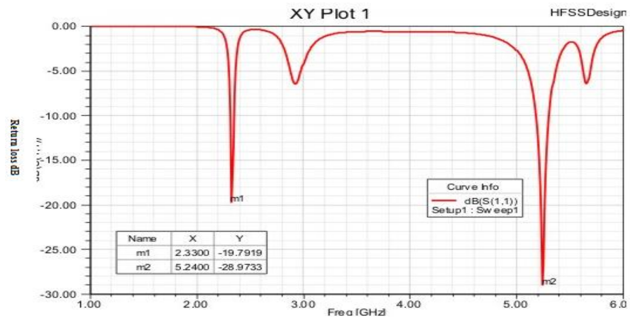

Figure 3. Simulation result of return loss (dB) v/s frequency (GHz)

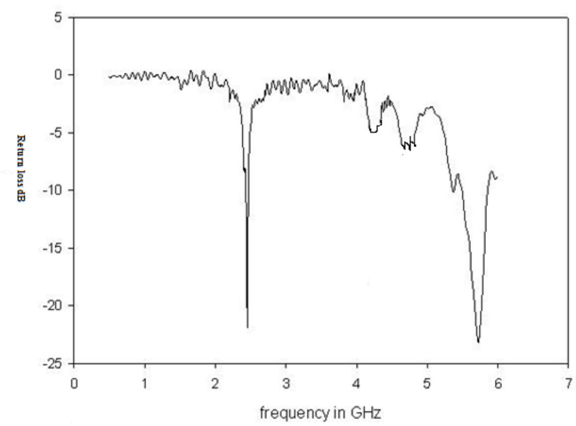

Figure 4. Measured result of return loss(dB) v/s frequency(GHz)

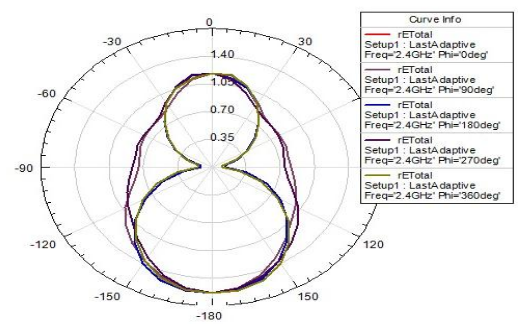

Figure 5. Simulated radiation pattern of E-plane for phi=0, 90,180,270 deg at 2.4 GHz

The simulated results of electric field distribution and current distributions at frequencies 2.4 GHz & 5.25 GHz are shown in the Fig. 8 and 9. It is observed that the current is minimum at the feed and maximum at edges of the patch. The fringing field is responsible for radiation. Fringing fields near the surface of patch antenna are in both directions, hence fields on the edge of the microstrip antenna add up in phase.

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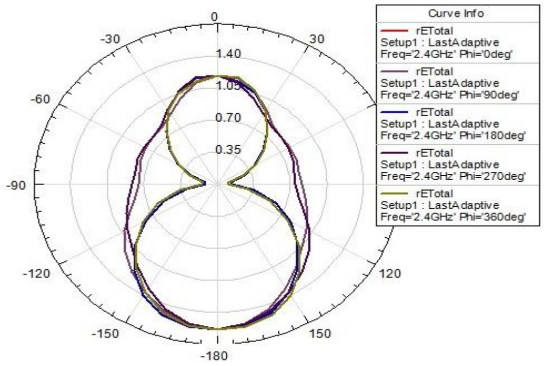

Figure 6. Simulated radiation pattern of H-plane for phi=0, 90,180,270 deg at 2.4 GHz

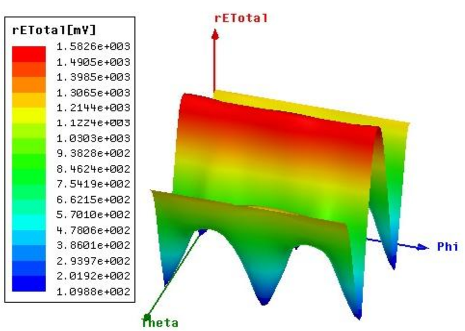

Figure 7. Simulated 3D radiation pattern

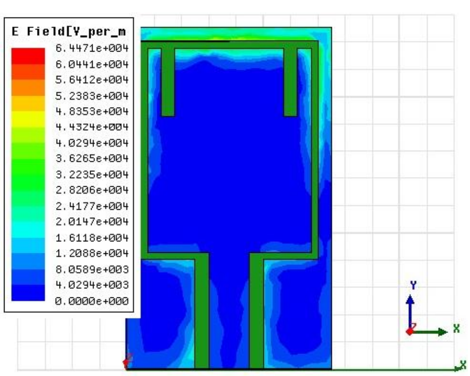

Figure 8. Simulation results of electric field distribution

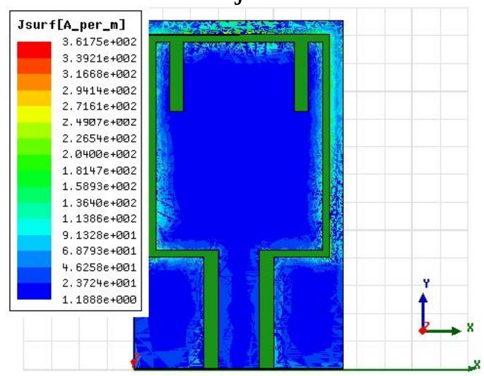

Figure 9. Simulation results of current distribution

The simulated result fig 10 shows VSWR for the designed patch antenna is less than the 2dB, which fulfils the bandwidth requirement for required frequency range. The simulated gain of the proposed antenna at 2.4 GHz is observed as 11.60dB in fig 11, acceptable gain of 1.95 dB at 5.35 GHz.

Fig 12 shows the fabricated dual band microstip patch antenna.

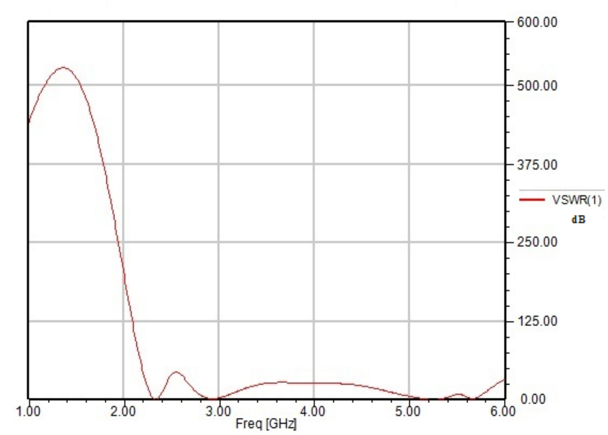

Figure 10. Simulated VSWR v/s frequency

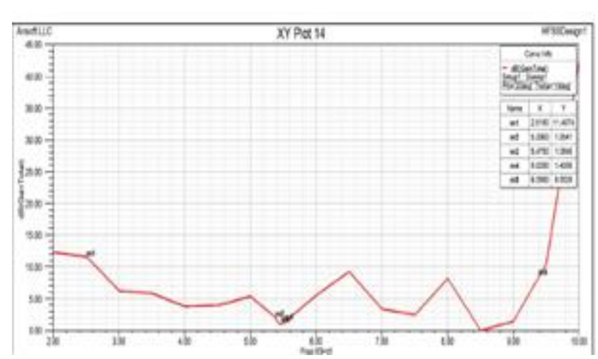

Figure 11. Simulated of Gain v/s frequency

Fig12. The final fabricated dual band microstip patch antenna

Table 1: Results in band-1

Results	Simulated	Measured
Resonant frequency (GHz)	2.4	2.35
Return Loss (dB)	-19.79	-19.51
Band width (Hz)	2.16 - 2.36 (22%)	2.14 - 2.35 (21%)

Table 2: Results in band-2.

Results	Simulated	Measured
Resonant frequency (GHz)	5.2	5.17
Return Loss (dB)	-28.97	-28.72
Band width (Hz)	5.13- 5.36 (23%)	5.10-5.32 (22%)

VI. Conclusion

A slotted miniaturized dual band microstrip patch antenna design has been proposed in this paper for WLAN/WiMAX applications. Employing dual slots with a compact size of 15×25×1.6 $mm^{3,}$ gives dual band with reduction in size. The proposed antenna parameters have been simulated, measured and validated experimentally. The variation of slots controls the frequencies in dual band modes maintaining the same narrowband performance. The simulated and measured results have been successfully validated. Observing the effects of varying the slots size of the radiating elements on the antenna, resonant frequencies and impedance bandwidths have also been studied. Return loss, radiation patterns, gain are appreciable and allow the antenna fit for use in WLAN/WiMAX applications. Proposed design have been fabricated and tested.

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