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Dual band microstrip patch antenna deisgn for wireless communication application

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Abstract—The desired dual –band operation was obtained by proper loading for a rectangular patch antenna .The parametric study of the considered design shows that the radiation pattern, return loss, voltage standing wave ratio (VSWR),impedance matching ,bandwidth and gain are optimized within the band of operation. The results obtained with CST simulations. The results obtained from our simulated antenna of 2.45 GHz (2.4000 to 2.4835GHz) for GPS band and 3.81 GHz (3.4 GHz –5.255) for WIMAX.

Keywords—Microstrip Antenna, dual band, CST Microwave Studio 2014

I. INTRODUCTION

Traditionally each antenna operates at a single frequency but with the rapid development of modern wireless communication system and their applications, wider bandwidth is required, where a different antenna for different applications. On the other hand, there is a great demand for wireless devices that are lightweight, small, attractive and multitasking. Currently, in radar and space satellite communication application, microstrip patch antennas have great demand due to their low profile, mechanical robustness, compatible with MMIC designs, relatively compact and light in weight and double frequency operation. They are easy and low-cost to manufacture and can be conformable in planar and non-planar planes. But, unfortunately they have some limitations and disadvantageous such as relatively low efficiency and low power, spurious feed radiation, narrow frequency bandwidth and relatively high level of cross polarization radiation [1-2]. To overcome these limitations and disadvantageous, researchers have been proposed and investigated many techniques such as slotted patch antennas, microstrip patch antennas on an electrically thick substrate, probe feed stack antenna and the use of various feeding and impedance matching techniques, the use of multiple resonators [3-4]. Presently, wider bandwidth is required for the increasing demand of modern wireless communication system applications. Generally each antenna performs its function at a single frequency, so different antennas require for different applications that will cause a restricted place and space problems.

The microstrip patch antennas have many advantages such as small size, low-cost fabrication, low profile, light weight, conformability, ease of installation and integration with feed networks but it has one serious limitations i.e. these antennas have very narrow bandwidth characteristics as it limits the frequency ranges over which the antenna can perform satisfactorily [6]. These features of patch antennas are major designing considerations of practical patch antenna. In wireless communication systems, the IEEE 802.11 standard was proposed in 1997 for WLANs application. The bands for WLAN application are 2.4 GHz (2.400 GHz to 2.484 GHz), 5.2 GHz (5.150 GHz to 5.350 GHz) and 5.8 GHz (5.725 GHz to 5.825 GHz). The name WiMAX was created by the WiMAX forum which was formed in June 2001 to promote conformity and interoperability of the standard. The WiMAX Forum has published three licensed spectrum profiles: 2.5 GHz (2.52.69 GHZ), 3.5 GHz (3.4-3.69 GHZ) and 5.5 GHz (5.255 GHZ). Worldwide Interoperability for Microwave

Access (Wi-MAX) technology[7] is the most rapidly growing area in the modern wireless communication[5].

II.GEOMETRY OF MICROSTRIP PATCH ANTENNA

As a resonant cavity, there are many possible modes (like waveguides), thus a patch antenna is multimode and may have many resonant frequencies. The fundamental and dominant mode is TM100 (a half wave change along the x-axis and no changes along the other two axes).

1. Radiation Pattern and Directivity

The radiation comes from the fringing fields at the two open ends, as discussed above, which is equivalent to two slot antennas separated by a distance L. It can be proved that the far-field electric field can be expressed as [8]:

$$E = E_0 \operatorname{sinc}\left(\frac{\beta W}{2}\sin\theta\sin\phi\right)\cos\left(\frac{\beta L}{2}\sin\theta\cos\phi\right)(\hat{\theta}\cos\phi - \hat{\phi}\cos\theta\sin\phi) \quad (1)$$

where β is the free space wave number. The first factor is the pattern factor for a uniform line source of width W in the y direction and the second factor is the array factor for the two-element slots separated by L in the x direction. For both components, the peak is at θ=0, which corresponds to the z direction. It has a broadside unidirectional pattern.

The radiation patterns in the two principal planes are

a) E-plane (φ=0°)

$$E = \hat{\theta} E_0 \cos\left(\frac{\beta L}{2}\sin\theta\right) \tag{2}$$

a) H-plane (φ=90°)

$$E = -\hat{\phi} E_0 \,\mathrm{sinc}\left(\frac{\beta W}{2}\sin\theta\right)\cos\theta \tag{3}$$

The directivity of the microstrip antenna can be expressed as

$$D = \begin{cases} 6.6 = 8.2\,\mathrm{dBi}, & W \ll \lambda_0 \\ 8W/\lambda_{0,} & W \gg \lambda_0 \end{cases} \tag{4}$$

The larger the width, the larger the directivity.

2) Input Impedance and Bandwidth

The typical impedance at the edge of a resonant rectangular patch ranges from 100 to 400, and the radiation impedance of a patch at the edge can be approximated as

$$Z_a \approx 90\frac{\varepsilon_r^2}{\varepsilon_r - 1}\left(\frac{L}{W}\right)^2 (\Omega) \tag{5}$$

An empirical formula can be used to estimate the fractional bandwidth for VSWR < 2:

$$\frac{\Delta f}{f_0} = \frac{16}{3\sqrt{2}}\frac{\varepsilon_r - 1}{\varepsilon_r^2}\frac{Ld}{\lambda W} \approx 3.77\frac{\varepsilon_r - 1}{\varepsilon_r^2}\frac{Ld}{\lambda W} \tag{6}$$

Thus, the bandwidth is proportional to the thickness of the substrate. This also indicates that the higher the permittivity, the smaller the bandwidth.

3) Design Equations and Procedures

Because of the fringing effects, electrically the patch of the antenna looks larger than its physical dimensions; then arrangement on L is given by

$$\Delta L = 0.412d(\varepsilon_{reff} + 0.3)(W/d + 0.264)/[(\varepsilon_{reff} - 0.258)(W/d + 0.8)] \tag{7}$$

Where the effective (relative) permittivity is

$$\varepsilon_{reff} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2\sqrt{1 + 12d/W}} \tag{8}$$

This is related to the ratio of d/W. The larger the d/W, the smaller the effective permittivity. The effective length of the patch is now

$$L_{eff} = L + 2\Delta L \tag{9}$$

The resonant frequency for the TM100 mode is

$$f_r = \frac{1}{2L_{eff}\sqrt{\varepsilon_{reff}}\sqrt{\varepsilon_0\mu_0}} = \frac{1}{2(L+2\Delta L)\sqrt{\varepsilon_{reff}}\sqrt{\varepsilon_0\mu_0}} \quad (10)$$

An optimized width for an efficient radiator is

$$W = \frac{1}{2f_r\sqrt{\varepsilon_0\mu_0}}\sqrt{2/(\varepsilon_r+1)} \quad (11)$$

if the substrate parameters (εr and d) and the operational frequency are known, how can we obtain the dimensions of the patch antenna (W and L)? Based on these simplified formulas, we can adopt the following design procedure to design the antenna: Step 1: Use Equation (11) to find the width W. Step 2: Calculate the effective permittivity εreff using Equation (8). Step 3: Compute the extension of the length ΔL using Equation (7). Step 4: Determine the length L by solving Equation (10) for L, giving the solution

$$L = \frac{1}{2f_r\sqrt{\varepsilon_{reff}}\sqrt{\varepsilon_0\mu_0}} - 2\Delta L \quad (12)$$

III. DESIGN PARAMETERS

Figure 1(a) shows the front view geometry and the structure designed on CST Microwave Studio software of proposed microstrip line feed patch antenna with dual band operation for GPS and WiMax. The dimensions and feed point location for proposed antenna have been optimized to get the best possible impedance match to the antenna[5]. The following parameters are used for design of proposed antenna.

Designing Parameters	***Value***
f_o	***2.45 GHz***
E_r	***4.3***
H	***1.6 mm***
W	***37.6 mm***
E_{reff}	***3.589***
L_{eff}	***28.8 mm***
L_g	***38.8 mm***
w_g	***47.2 mm***

In this paper several parameters have been investigated using CST Microwave Studio software.

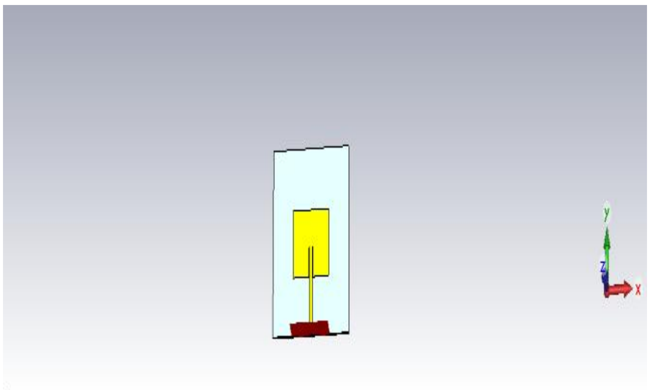

Figure 1: Front view geometry of proposed antenna

IV. SIMULATED RESULTS

The parameters for the designed antenna were calculated and the simulated return loss results are shown in Figure 2. The bandwidth of 57 MHz (2.42GHz – 2.4775GHz) for GPS and WLAN has been achieved as shown in Figure 3(a) and the bandwidth of 85 MHz (3.75 GHz –3.84 GHz)for WiMax has been achieved as shown in Figure 3(b) resonating at 3.81 GHz GHz band for WiMax standard .

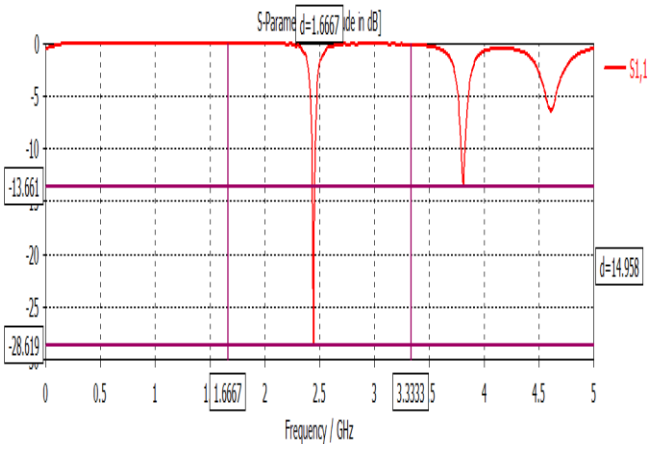

Figure 2: Simulated Return Loss Curve

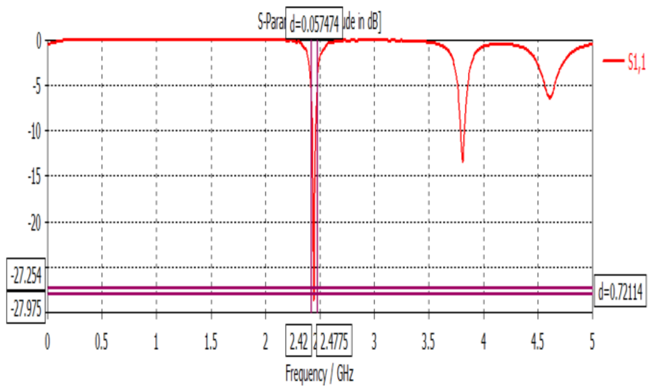

Figure 3(a): Bandwidth plot for GPS

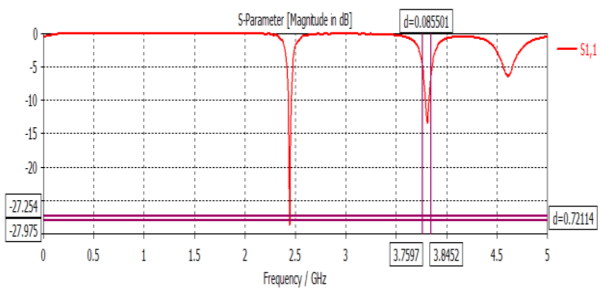

Figure 3(b): Bandwidth plot for Wimax

The achieved value of return loss is good enough and frequency is closed enough to the specified frequency band 2.45 GHz for GPS, and 3.81GHz for Wimax Application. The return loss value for 2.45 GHz is – 28.619dB, and for 3.81 GHz is -13.66 dB suggests that there is good matching at the frequency points below the -10 dB region clearly shown in figure 2.. The maximum achievable gain over the entire frequency band of and for 2.45 GHz is 6.13 dB has been achieved as shown in figure 7.

The achieved antenna impedance is 48.3 ohm as shown in Figure 5(a), which is very closed to the required impedance of 50 ohm. The VSWR ratio at 2.45 GHz frequency is 1.357 is shown in Figure 5(a), the VSWR ratio at 3.81 GHz frequency is 1.54 is shown in Figure 5(b), it should lie in between 1 and 2. The optimum feed positions have been determined for good impedance matching shown in the figure 4, because the input impedance is controlled by the position of the feed to patch connection point. The used microstrip feed line is designed of microstrip patch antenna made of impedance closed to 50 ohm.

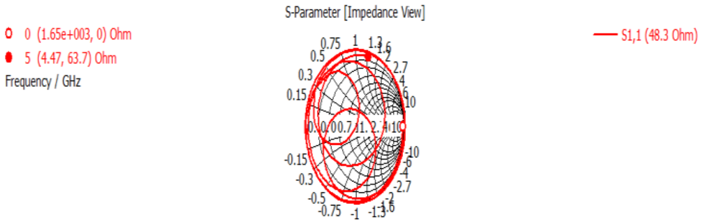

Figure 4: Antenna Characteristic Impedance

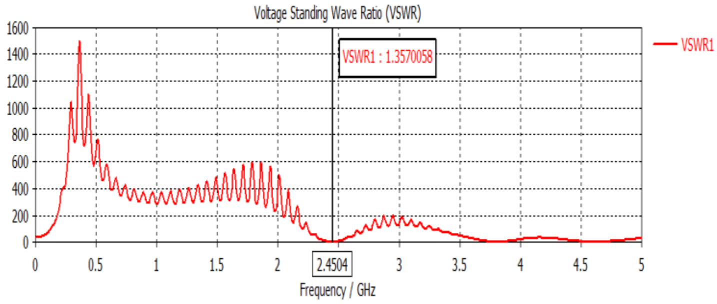

Figure 5(a): VSWR curve at 2.45 GHz frequency

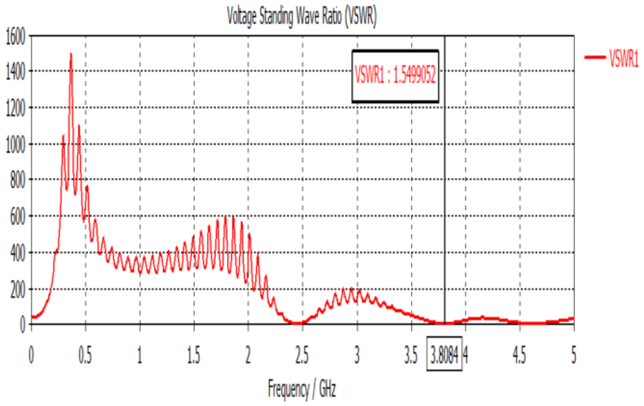

Figure 5(b): VSWR curve at 3.81 GHz frequency

The dual band characteristics of the proposed antenna are achieved.

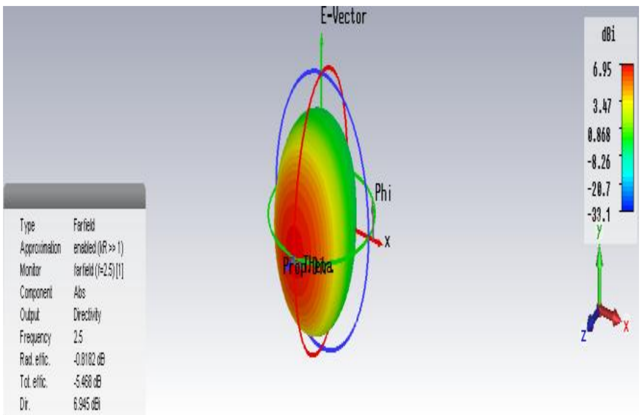

Figure 6: 3-D Radiation Pattern of Patch antenna directivity

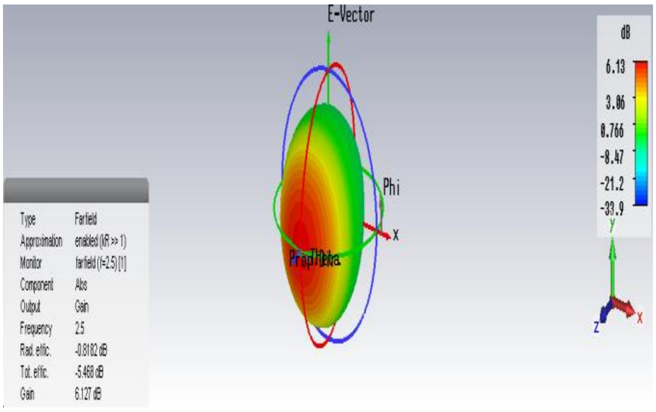

Figure 7: 3-D Radiation Pattern of Patch antenna gain

IV. CONCLUTION

A new dual band microstrip line feed patch antenna has been designed and evaluated in this work. The feeding technique, the adjusted patch shape and the dimensions of the antenna made it possible to modify the acceptable reflection coefficient and characteristics of the radiation pattern in the expected frequency. The different parametric study, gain and radiation efficiency of the proposed antenna were analyzed and discussed. However, the size of the microstrip antenna is not very small .In this the gain of this antenna is small but it can be increased using gain enhancement techniques. Work is going on to achieve even better results with good axial ratio over a wide bandwidth

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