A circular microstrip patch antenna to operate in dual band for wireless communications

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Abstract. A dual band circular microstrip patch antenna is designed and simulated to obtain electronic circuit miniaturization of an antenna in high speed wireless local area networks (IEEE 802.11a standard). The proposed antenna contains a substrate layer (FR-4 lossy) with a dielectric constant of 4.9 and there is a circular patch on the upper layer of the substrate. The coaxial probe feed is used to excite the desired antenna which reduces the spurious radiation and hence obtained good efficiency. Also the cavity model is used for larger bandwidth while maintaining the lower size of the antenna. An ‘E’ shaped slot is introduced in the radiating patch to obtain dual band resonance frequency with maximum current distribution on the surface. Finally the simulated results using Computer Simulation Technology (CST) microwave studio 2009 in this design are compared with manual computation results and are found to be suitable for WLAN applications.

Keywords: Micro-strip antenna; Cavity model; Dual band antenna; Coaxial probe feed

1. Introduction

An antenna is an electrical device which is used to convert an electromagnetic signal to an electrical signal at a receiver and vice-versa at a transmitter. Basically a radiating patch is placed on one side of a dielectric substrate and there is a ground plane on the other side of a microstrip patch antenna [1]. Due to the high demand of electronic circuit miniaturization in wireless communication systems the design and implementation of novel microstrip structures of antenna was the burning question until 1970 the revolution of microstrip antenna [2].

The importance of microstrip antenna has increased due to light weight, low cost, planar or conformal layout, and ability of integration with electronic or signal processing circuitry [3-4]. Also there is a versatility in terms of operating frequency, polarization pattern and impedance in application of microstrip antenna such as from transportation, communication to biomedical can be seen in aircraft and ship antennas (Communication and navigation, altimeters, blind landing systems), Missiles (Radar, proximity fuses and telemetry), Satellite communications (Domestic direct broadcast TV, vehicle-based antennas, Communication), Mobile (radio Pagers and hand phones, man pack systems, mobile vehicle), Remote sensing (Large, lightweight apertures)

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Biomedical Applicators [5]. In addition in microwave and millimeter-wave integrated circuits the use of this patch antenna has some advantages feature along with the ability to conform to planar and non-planar surfaces [6].

But there are some operational disadvantages of microstrip patch antenna which are narrow frequency bandwidth, larger value of $Q$, poor polarization purity and low efficiency [7]. But in some applications the microstrip patch antenna are first choice where narrow frequency bandwidth with the lower antenna size are desirable. Besides the use of thick dielectric substrate allow the good efficiency and large frequency band in a microstrip patch antenna [8-12]. Although surface wave increase due to thick dielectric substrate and hence the power losses occur yet there are some method such as cavity and stacking etc are used to reduce the value of surface wave while maintaining the lower size and larger bandwidth of the desired antenna [13-17].

2. Literature review

In the present day due to the need of small size of antenna in electronic circuit miniaturization, the researchers around the world have focused on the development of microstrip patch antenna with efficient radiation characteristics while maintaining their small profile. In this section we have tried to see the survey about the development of microstrip patch antenna in large-scale integration technology.

For the purpose of microwave access and WLAN applications there has been proposed a double L-slot microstrip patch antenna array with CPW feed technology by Chitra et al. [18]. This paper showed that there is a peak gain higher than 3dBi at 3.5 GHz which is a good omnidirectional radiation characteristic for proposed operating frequencies. Tong et al. [19] investigates a U-slot microstrip patch on the substrate layer. In this paper to obtain the larger frequency band antenna the thickness of substrate layer and hence the antenna size has increased than there use of foam material as a substrate. The relative permittivity of the substrate that is used in place of previous foam material is 2.33. But the causes of replacement it is easy to fabrication and also there have suitable resonant frequencies and far-field patterns. The gain of the desired antenna is about 6.5 dB. Guo et al. [20] investigates a U-slot circular patch antenna. The authors use the foam material as a substrate and also there has been used L-probe feeding. Hence there has obtained a larger bandwidth i.e. about 15% than that using the U-slot alone and about 14% than that of using the L-probe feed alone. The bandwidth of the desired antenna in this paper is applicable for WLAN and satellite. From the necessity of high-speed technology as like WiMAX a broadband microstrip patch antenna has been developed by Matin et al. [21]. The designed antenna of this paper exhibits 36.2% impedance bandwidth with more than 90% antenna efficiency which is applicable for 2.3/2.5 GHz WiMAX and of 2.4 GHz WLAN. To increase the bandwidth of microstrip patch antenna here the microstrip feeding excitation and a trapezoidal conductor- backed plane has been studied by Chien et al [22]. At the resonant frequencies of 2.01 to 4.27 GHz and 5.06 to 6.79 GHz the return loss are found -10dB which covering all the 2.4/5.2/5.8 GHz WLAN bands and 2.5/3.5/5.5 GHz WiMAX bands. Dang et al. [23] to reduce the size of the desired microstrip antenna also with cost effective and simple structure presents a rectangular patch antenna which is suitable for all frequency bands of WiMAX and WLAN applications. The better efficiency of a microstrip patch antenna has achieved by Mittra et al. using Double Negative Slab (DNS), dielectric Slab and frequency selective surface (FSS) [24]. In this paper it is achieved about 3.3% bandwidth and of 4.2 dB gain.

In my research work it is desired to obtain the larger bandwidth through the use of thick dielectric substrate and at the same time through the use of cavity model it is also desired to obtain good efficiency of the antenna. Also to obtain desirable featured antenna we have studied about different shape of the patch generally square, rectangular, circular, triangular, and elliptical [25], properties of dielectric constant of different materials [26], resistive loading [27] and short circuited element [28]-[29]. Also we have studied the different feeding technique
and the pattern of the slots on the patch of the antenna [30]-[35].

3. Analytical model
Here we have designed a dual band circular microstrip patch antenna at the resonant frequency of 2.76 GHz and 5.9 GHz. Due to the easy of fabrication and input impedance matching here we have used coaxial feeding technique. The thickness of substrate are taken between $0.003\lambda_0 < h < 0.05\lambda_0$ in order to achieve maximum bandwidth [36]. Design Procedure starts with a first-order approximation to the solution of effective radius can be written as [37]

$$a_{eff} = \frac{x_{11} \times c}{2\pi f_r \sqrt{\varepsilon_r}}$$  \hspace{1cm} (1)

Here, the lowest order mode $TM_{11}$, uses $x_{11} (1.84118) c = velocity of light=300 \times 10^9 mm/sec\newline f_r=Resonant frequency \varepsilon_r=Dielectric constant of the substrate\newline Then the actual radius will be [32]

$$a = \frac{a_{eff}}{\sqrt{1 + \frac{2h}{\pi \varepsilon_r a_{eff}}} \left[\ln \left(\frac{\pi a_{eff}}{2h}\right)\right]}}$$  \hspace{1cm} (2)

Where, h must be in mm unit. The geometry of the desired dual band circular micro-strip patch antenna using CST 2009 is as follows

![Figure 1. Geometry of dual band microstrip antenna.](image)

4. Antenna designed specification
In this section the value of various dimensions of the patch antenna is shown in Table 1.

5. Simulation results
The different simulated results (using the CST microwave stdio2009) like return loss, voltage standing wave ratio (VSWR), Smith chart, directivity and gain are discussed below
Table 1. Dimensions of the dual band circular patch antenna.

| Variable                        | Value |
|---------------------------------|-------|
| Radius of the patch(a)          | 26 mm |
| Dielectric constant of the substrate(\(\varepsilon\)) | 4.9   |
| Width of small slots(w)         | 1 mm  |
| Length of small slots(l)        | 2 mm  |
| Width of large slot(W)          | 1 mm  |
| Length of large slot(L)         | 7 mm  |

5.1. Return Loss, Smith chart, VSWR

In antenna the return loss (RL) is a parameter which indicates how the impedance matching has occurred in between transmitter an antenna. For the case of good impedance matching the power losses become minimum and the antenna becomes more efficient. The proper impedance matching is obtained through the proper selection of the input feed point. The return loss of the designed dual band microstrip patch antenna is shown in fig. 5(a). It is seen that the return loss, -27.665 dB is found at a resonant frequency of 2.76 GHz and that of -34.141 dB is found at a resonant frequency of 5.96 GHz, where -10 dB is acceptable for practical applications. The bandwidths are found 120 MHz at the resonant frequency of 2.76 GHz and 200 MHz at the resonant frequency of 5.96 GHz, in which 84 MHz is acceptable bandwidth [38]. Fig. 5(b) shows the smith chart which calculates the impedance of our designed antenna. It is about 45 ohm which is close to acceptable value of 50 ohms and also the fig. 5(c) shows the VSWR which is below 2 for the whole bandwidth and these parameters indicates that the designed antenna is operable in required frequency band [38].

5.2. Directivity and Gain

The directivity and gain in both 2D and 3D pattern of the designed dual band circular microstrip antenna are shown in figs. 5(d) and 5(e). From the figure of directivity of the designed microstrip antenna it is seen that the directivity is 9.037 dBi at the resonant frequency of 2.76 GHz and that of 5.96 GHz is 7.992 dBi which agree well with the previous results [38-42]. Also the designed dual band antenna gives the gain 7.819 dB and 7.878 dB at 2.76 Hz and 5.96 GHz frequencies, respectively. From 2D pattern it is also clear that the main lobe magnitudes are 7.8 dB and 5.6 dB, directions of the main lobe are 3.0 deg. and 25 deg. with angular widths 64.5 deg. and 35.2 deg. at 2.76 GHz and 5.96 GHz frequencies, respectively which agrees well with the previous results [38-42].

6. Summary of the results

The results of the dual band antenna operating at 2.76 GHz and 5.96 GHz are summarized in Table 2.

Table 2. Antenna parameters of the dual band antenna, resonating at 2.76 GHz and 5.96 GHz frequencies.

| Resonating frequency, \(f_r\) (GHz) | Return Loss (dB) | Bandwidth, (MHz) | VSWR | Directivity, (dBi) | Gain, (dB) |
|-------------------------------------|------------------|------------------|------|-------------------|-----------|
| 2.76                                | -27.665          | 120              | 1.08 | 9.037             | 7.819     |
| 5.96                                | -34.141          | 200              | 1.05 | 7.992             | 7.878     |
Figure 2. Variation of $S$ parameter with respect to the radius of the patch resonating at 2.76 and 5.96 GHz frequencies.

7. Physical parametric study of dual band antenna
The effect of radius of the circular patch on the performance of the designed microstrip antenna is shown in fig. 6. From figure it is seen that with the decreasing value of radius of the radiating patch the resonating frequency increases. At the same time there is changing the return loss with the changing value of the radius of patch. Thus the actual radius calculation is a vital part in designing circular microstrip patch antennas.

8. Conclusions
The work in this research is primarily focused on the design and simulation of simple, small and high efficiency dual band circular microstrip patch antennas using coaxial feeding technique. Then from the simulation results the multiband microstrip antenna has designed. The designed rectangular antenna covers two frequencies of 2.76 GHz and 5.96 GHz which produces the bandwidth of approximately 3% while maintaining their lower size and good efficiency. And also it has shown that the designed antenna provides good impedance matching of approximately 50 ohm’s at resonant frequencies. Due to easy of fabrication with coaxial feeding line it can be used for various applications such as in military purposes, radio altimeters and various wireless devices.

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