Optimization of Dual-Band Microstrip Patch Antenna with Quarter Wave Transformer Feed and Two Narrow Slots

Abdul Sayeed¹ Awij Aalam Shaikh² Khan Tabish³ Mohd Anis⁴ Ansari Adee⁵
¹,²,³,⁴,⁵M.H. Saboo Siddik College of Engineering, Mumbai University,

I. INTRODUCTION

Microstrip antennas are widely used in many applications due to their low profile, low cost and ease of fabrication. In some applications it is desired to have a dual band or multiband characteristics. These characteristics can be obtained by coupling multiple radiating elements or by using tuning devices such as varactor diodes. A micro strip slot antenna is that type of antenna which is having slots on the geometry plane of micro strip patch [1, 2, 3]. However, these methods make antenna more complicated. A simple method to achieve the dual band characteristic in a microstrip antenna is embedding two vertical slots in the patch as the structure proposed in our paper in which the radiating patch includes a pair of vertical slots. In microstrip antennas, embedded slots can also be used to enhance the impedance bandwidth of a single band antenna. To realize a broadband characteristic in feeding a microstrip antenna, a quarter wave transformers can be used. In this paper, dual band characteristics are achieved by embedding two vertical slots in a rectangular patch near quarter wave feed line equidistant from center. Also, quarter wave transformer is used to realize matching between the feed systems and radiating system in a wide frequency range. This vertical shaped slot of microstrip patch operates at 2.792GHz and 3.216GHz for the solution of dual band for wireless local area network (WLAN) frequencies bands. In applications in which the increased bandwidth is needed for operating at two separate sub-bands, a valid alternative to the broadening of total bandwidth is represented by dual-frequency patch antennas. Indeed, the optimal antenna for a specific application is one that ensures the matching of the bandwidth of the transmitted and/or the received signal. Dual-frequency antennas exhibit a dual-resonant behaviour in a single radiating structure. Despite the convenience that they may provide in terms of space and cost, little attention has been given to dual-frequency patch antennas.

II. DUALBAND ANTENNA DESIGN

A micro strip Patch antenna is a narrowband, wide—beam antenna fabricated by etching the antenna element pattern in metal trace bounded to an insulating dielectric substrate. Such as on a printed circuit board for hardware implementation, with a continuous metal layer bonded to the other side of the substrate forms a ground plane as shown fig 1. Low dielectric constant substrates are generally referred for maximum radiations. The conducting patch can take any shape but its shape are the most commonly used configuration. As other configurations are complex to analyze and difficult to design. A micro strip antenna is characterized by its Length, Width, input impedance, Polarization, Gain and Radiation pattern.

Fig.1(a): Micro strip patch antenna

The configuration of the proposed antenna is shown in Fig. 1(b). The substrate used for this design is FR4 with relative permittivity of 4.2, loss tangent of 0.025 and thickness of h = 1.6 mm. Dimensions of the ground plane are also 46.8mm £ 42.2 mm. As shown in Fig. 1, the radiating element is a square patch with a two narrow vertical slots near the centre. The radiating patch is fed by a quarter wave transform. By using these slots, the dual band operation of the antenna can be achieved. The basic geometry is a slotted rectangular-patch antenna, in which two narrow slots, with dimensions L, and d, are etched on the patch close to and parallel to the radiating edges. The location of the slots with respect to the patch is defined by the quantities w and l, which are very small with respect to the dimensions L and W of the patch. The dual-
frequency operation in the slotted structure can be interpreted as that associated with two modes that arise from the perturbation of the TM₁₀₀ and of the TM₀₁₀ mode. In particular, since the narrow slots are etched close to the centre of the patch, they are located close to the current minima, so that minor perturbations of the TM₀₁₀ mode are expected. Many dual banding techniques are discussed in [6],[7],[8]. The frequency ratio f₂/f₁ for the two frequency bands of 2.79GHz and 3.21GHz works out to be 1.15. For such small frequency ratio the most simple design of achieving dual band is to make the Width and Length of the MS patch correspond to half wavelength at above two resonances[8].

Calculation of Width:
The width is critical in terms of power efficiency, antenna impedance and bandwidth. It is largely dependent on the antenna operating frequency and the dielectric constant[10].

\[ W = \frac{c}{2f_o \sqrt{\varepsilon_{reff} + 1}} \]  

Where c is the free-space velocity of light = 3×10⁸ m/s and \( \varepsilon \) is the dielectric constant of material.

Calculation of Effective Dielectric Constant:
The Micro strip separates two dielectrics, i.e. air and Substrate. Hence most of the electric field lines remain inside the substrate and some extend to air. The value of this effective dielectric constant is given by

\[ \varepsilon_{eff} = \frac{\varepsilon_{eff} + 1}{2} + \frac{\varepsilon_{eff} - 1}{2} \left[ \frac{1 + 12h}{W} \right]^{-1/2} \]  

Where \( h \) and \( W \) are the height and width of substrate material for an antenna respectively.

Calculation of Length (L):
The length of the patch determines the resonance frequency is a critical factor for patch

\[ L_{eff} = \frac{c}{2f_o \sqrt{\varepsilon_{eff}}} \]  

\[ L_{eff} = L - 2\Delta L \]  

The \( \Delta L \) is the length due to the fringing field and can be calculated using the equation

\[ \Delta L = \frac{0.412h(\varepsilon_{eff} + 0.3)w}{(\varepsilon_{eff} + 0.258)h + 0.8} \]  

Calculation of Ground Dimensions:
The ground dimension for the antenna can be calculated as below:

Width of ground is given as: \( W_g = W + 6h \)  

Length of ground is given as: \( L_g = L + 6h \)

III. DUALBAND ANTENNA CALCULATIONS:
The Resonant Frequency is set to \( f_r = 2.8 \)GHz and the specified relative permittivity of FR4 epoxy substrate is \( \varepsilon_r = 4.4 \) and assuming height of substrate as \( h = 1.6 \)mm. Considering these specifications, the calculated values of the prototype microstrip patch antenna with resonant frequency \( fr = 2.8 \)GHz.

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The Figure 3 shows the return loss of the microstrip dualband patch antenna with 2 slots having return loss of S11 parameter of -27.51dB at 2.792GHz and -27.24dB at 3.216GHz. Figure 4 shows Z parameter of 48.31Ω at 2.792GHz and 51.14Ω at 3.216GHz. Figure 5 shows VSWR of 1.0879 at 2.792GHz and 1.0908 at 3.216GHz. Figure 6 shows radiation pattern at 2.79GHz.
Figure 7 shows radiation pattern at 3.21GHz. Figure 8 shows gain of 3.172dB at 2.79GHz. Figure 9 shows gain of 2.67dB at 2.79GHz. Figure 10 shows directivity of 6.1dB at 2.79GHz. Figure 11 shows directivity of 3.54dB at 3.21GHz.

<table>
<thead>
<tr>
<th>PARAMETER</th>
<th>2.79GHz</th>
<th>3.21GHz</th>
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<tr>
<td>Return loss</td>
<td>-27.51dB</td>
<td>-27.24dB</td>
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<tr>
<td>Gain</td>
<td>3.172dBi</td>
<td>2.67dBi</td>
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<tr>
<td>Directivity</td>
<td>6.1dBi</td>
<td>3.54dBi</td>
</tr>
<tr>
<td>Bandwidth</td>
<td>77MHz</td>
<td>49MHz</td>
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Table 2: Performance characteristics of Dual band antenna on FR4 Substrate

V. CONCLUSION

Thus, we have successfully simulated and designed a dualband microstrip antenna using HFSS software and microstrip technology. The Return Loss and VSWR on both the operating frequency are improved to a better and high value with an increased bandwidth and gain. This prototype can be integrated into the design of microwave or millimetre-wave integrated circuit where the compactness is crucial.

REFERENCES