

DUAL BAND RECTANGULAR MICROSTRIP PATCH ANTENNA FOR VARIETY OF WIRELESS APPLICATIONS

Mudit Gupta

Asst. Professor, Amrapali Institute of Technology & Sciences, Haldwani (India)

Abstract:

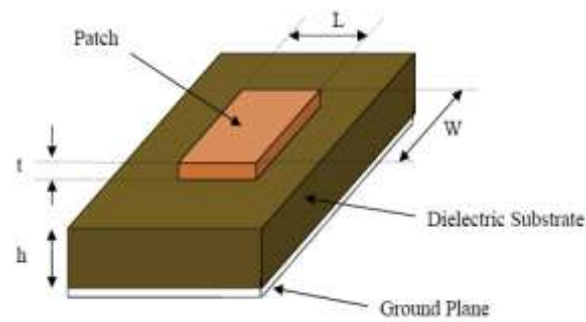
In this paper, a HFSS is used to design an Rectangular Microstrip Patch Antenna. The aim of this thesis is to design and fabricate an Rectangular Microstrip Antenna and study the effect of antenna dimensions Length (L) , Width (W) and substrate parameters relative dielectric constant (ϵ_r) , substrate thickness on power, vswr, return loss, impedance, admittance parameters . Low dielectric constant substrates are generally preferred for maximum radiation. Conducting patch can take any of the shape but rectangular and circular configurations are the most commonly used configuration. The other configurations are more complex to analyze and require heavy numerical computations.

The length of the antenna is nearly half wavelength in the dielectric; it is a very critical parameter, which governs or control the resonant frequency of patch antenna. In the view of design, selection of patch width and length are the major parameters along with feed line depth. The desired microstrip patch antenna design is initially simulated by using HFSS simulator and patch antenna is realized as per design requirements.

Keywords: *Compact, Rectangular, WLAN, HFSS, Coaxial Feed.*

I. INTRODUCTION

Because of the booming demand in wireless communication system and UHF applications, microstrip patch antennas have attracted much interest due to their low profile, light weight, ease of fabrication and compatibility with printed circuits. However, they also have some drawbacks, such as narrow bandwidth, low gain spurious feed radiation limited power handling capacity . To overcome their inherent limitation of narrow impedance, bandwidth and low gain, many techniques have been proposed and investigated. When we change the shape of a microstrip antenna and it is covered with a dielectric layer , its properties like resonance frequency, gain are changed which may seriously degrade or upgrade the system performance. Therefore, in order to introduce appropriate correctness in the design of the antenna, it is important to determine the effect of dielectric layer and shapes on the antenna parameter.



Structure of a Microstrip Patch Antenna

II. DESIGN OF MICROSTRIP PATCH ANTENNA

In this paper, the procedure for designing the rectangular micro strip patch antenna were explained. Next, a compact rectangular micro strip patch antenna is designed for WLAN, Bluetooth & Wi-MAX. Finally, the results obtained from the simulations will be demonstrated. Results show that the proposed antenna has promising characteristics for Bluetooth and Wi-Max at 2.42 GHz frequency for Bluetooth & WLAN and 3.2 GHz for Wi-MAX application respectively.

The resonant frequency selected for my design is 2.44 GHz.

1. ϵ_{reff} is calculated as follows :

$$\epsilon_{reff} = \frac{\epsilon_r + 1}{2} + \frac{\epsilon_r - 1}{2} \left[1 + 12 \frac{h}{W} \right]^{-1/2}$$

2. ΔL is calculated as below:

$$\Delta L = 0.412h \frac{[\epsilon_{reff} + 0.3] \left[\frac{w}{h} + 0.264 \right]}{[\epsilon_{reff} - 0.258] \left[\frac{w}{h} + 0.8 \right]}$$

3. For the particular resonate frequency the effective length of the patch is calculated by:

$$L_{eff} = \frac{c}{2f_r \sqrt{\epsilon_{reff}}}$$

4. Considering the rectangular patch Microstrip antenna the resonating frequency for the mode TM_{mn} is given by :

$$f_0 = \frac{c}{2\sqrt{\epsilon_{reff}}} \left[\left(\frac{m}{L} \right)^2 + \left(\frac{n}{W} \right)^2 \right]$$

Where, m, n are the operating modes of the Microstrip patch antenna, along with L – length W - width.

5. For the effective radiation the design of the structure is the utmost important aspect and for this the width is calculated as :

$$Width = \frac{c}{2f_r} \sqrt{\frac{2}{\epsilon_r + 1}}$$

III. DESIGN CALCULATION

3.1 Dielectric Constant of the Substrate (ϵ_r)

The dielectric material of the Microstrip Patch Antenna is FR-4 with $\epsilon_r = 4.4$, as this one of the maximum values of the dielectric substrate has been taken in order to reduce the size of the antenna.

3.2 The Frequency of the Operation (f_0)

The frequency of operation for the Patch antenna design has been selected as 2.44GHz.

3.3 Height of the Dielectric Substrate (h)

Microstrip Patch antenna has been designed in order to rule out the conventional antenna as the patch antennas are used in most of the compact devices. Therefore the height of the antenna has been decided as 1.6mm.

3.3.1 Calculation of Width

By the formula

$$Width = \frac{c}{2f_r} \sqrt{\frac{2}{\epsilon_r + 1}}$$

With the substituting the values of $c=3 \times 10^8$ m/s $f_r = 2.44$ GHz and $h = 1.6$ mm $Width w = 0.03742$ m = 37.42mm.

3.3.2 Calculation of Effective Dielectric Constant

$$\epsilon_{reff} = \frac{\epsilon_r + 1}{2} + \frac{\epsilon_r - 1}{2} \left[1 + 12 \frac{h}{W} \right]^{-\frac{1}{2}}$$

From the equation With the substituting the values $\epsilon_r = 4.4$, $h = 1.6$ mm, $w=37.42$ mm Effective Dielectric Constant $\epsilon_{reff} = 4.0819$

3.3.3 Calculation of Effective Length

From the equation

$$L_{eff} = \frac{c}{2f_r \sqrt{\epsilon_{reff}}}$$

With the values $\epsilon_{reff} = 4.0819$, $c= 3 \times 10^8$ m/s

$f_r = 2.44$ GHz.

3.3.4 Calculation of the Length Extension (ΔL)

From the equation

$$\Delta L = 0.412h \frac{[\epsilon_{reff} + 0.3] \left[\frac{w}{h} + 0.264 \right]}{[\epsilon_{reff} - 0.258] \left[\frac{w}{h} + 0.8 \right]}$$

With the values from h , w and ϵ_{reff} the ΔL is being calculated as 0.7387mm $\Delta L = 0.7387$ mm.

3.3.5 Calculation of Length of the Patch

By the equation

$$L = L_{eff} - 2\Delta L$$

Where $\Delta L = 0.7387$ mm, $L_{eff} = 30.4277$ mm $L = 28.9503$ mm.

3.3.6 Calculation of Bandwidth

$$B \propto (\epsilon_r - 1)wh/\epsilon_r^2 L$$

$$B \propto 0.4397$$

3.3.7 Calculation of Voltage Signal Wave Ratio

From the equation given below:

$$VSWR = (1 + |\Gamma|) / (1 - |\Gamma|)$$

Γ = reflection coefficient

Where, $\Gamma = 0.4$

$$VSWR = 2.333$$

3.3.8 Calculation of the Return Loss for the Patch Antenna

From the equation given below:

$$RL = -20 \log |\Gamma| \text{ (dB)}$$

Where, $\Gamma = 0.4$

$$RL = 7.96 \text{ dB}$$

3.3.9 Calculation of the Ground Plane Dimensions (L and W) of the Antenna

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

Therefore, for that design, the ground plane dimensions would be given from the equation is:

$$L_g = 6h + L$$

$$W_g = 6h + W$$

Where $h = 1.6$, $L = 28.95 \text{ mm}$, $W = 37.42 \text{ mm}$

$$L_g = 38.55 \text{ mm}$$

$$W_g = 47.02 \text{ mm}$$

3.3.10 Coordinates of the Feed Point of Antenna is Given As

(3.2, -1.6, 5) with center of the antenna at the origin.

IV. DETAILS OF THE SLOTS ON THE PATCH OF PROPOSED ANTENNA WILL BE GIVEN AS

There are two rectangular slots of 12mm * 4mm at the coordinates on (-14.475, -15, 1.6) and (14.475, 15, 1.6) respectively.

The centre of the patch will be taken as the origin and the feed point location is given by the co-ordinates (X_f & Y_f) from the origin whose value which is given as (3.2 & 5) respectively. The feed point must be located at that point on the patch, where the input impedance is 50 ohms for the specified resonant frequency. Therefore, a hit and trial error method which is used to find the location of the feed point. For different locations of the feed point coordinate X_f & Y_f , the return loss (RL) is recorded and that feed point is selected as the optimum one where the RL will be most negative i.e. less than or equal to -10 dB. Hence in this example, X_f & Y_f are varied in the specified range i.e. $1 \text{ mm} \leq X_f \leq 5 \text{ mm}$, $0 \text{ mm} \leq Y_f \leq 10 \text{ mm}$. So here the feed point coordinates must be (3.2, -1.6, 5) shown in Figure1.



Fig.1 Double Slotted Patch Antenna

V. RETURN LOSS

The center frequency is selected as the one at which the return loss is minimum. As described in chapter 4, the bandwidth can be calculated from the return loss (RL) plot. The bandwidth of the antenna can be said to be those range of frequencies over which the RL is greater than -9.5 dB (-9.5 dB corresponds to a VSWR of 2 which is an acceptable figure). Figure 2& Figure 3 shows the S11 parameters (return loss) for the proposed antenna without slot and with slot respectively. From the Figure 2 it is to be clear that the designed antenna will not resonates at the 2.42 GHz and 3.24 GHz frequencies. But after making the two rectangular slots in the patch antenna of dimensions 12mm * 4mm the designed antenna resonates at the 2.42 GHz and 3.24 GHz frequencies respectively. Figure 3 shows that the return loss for the 2.42 GHz is -18.7037 dB and the return loss for the 3.24 GHz is -39.1369 dB which covers the minimum required value of return loss of -10 dB.

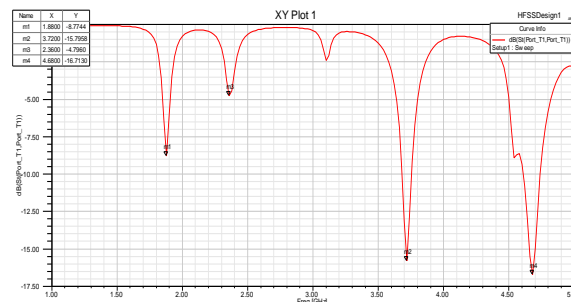


Fig.2 Return Loss of Microstrip Patch Antenna without slot

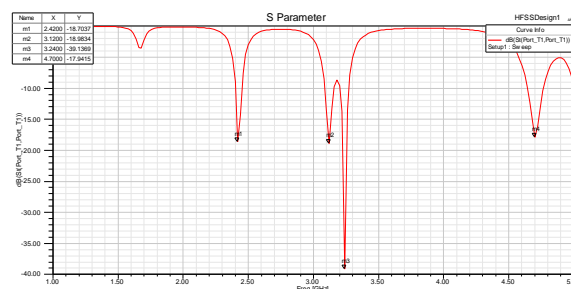


Fig.3 Return Loss of Microstrip Patch Antenna with two rectangular slots

VI. VOLTAGE STANDING WAVE RATIO (VSWR) OF MICROSTRIP PATCH ANTENNA

Figure 4 and Figure 5 shows the plot of VSWR vs frequency of the simulated antenna without slot & with slots respectively. In Figure 5 VSWR must lie in the range of 1-2 which has been achieved for 2.42 GHz and 3.24

GHz frequency, near the operating frequency value. The VSWR ratio at 2.42 GHz frequency is 1:1.2627 and the VSWR ratio at 3.24 GHz frequency is 1:1.0223 is shown in Figure 5.

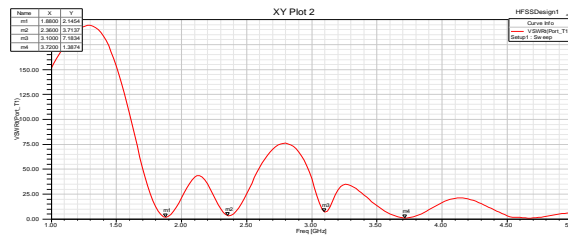


Fig.4 VSWR v/s Frequency Plot of without slot antenna

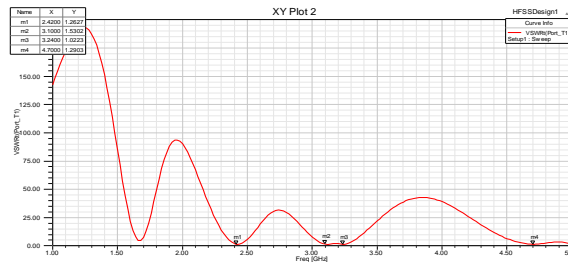


Fig.5 VSWR v/s Frequency Plot of slotted antenna

6.1 Radiation Pattern plots

Since a Microstrip patch antenna radiates normal to its patch surface, the elevation pattern for $\theta = 0$ and $\theta = 90$ degrees would be important. The radiation pattern showing the gain for the desired slotted antenna has been shown in Figure 6 & Figure 7.

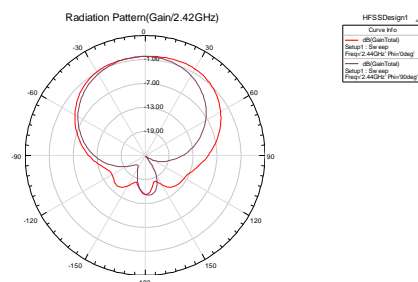


Fig.6 Gain at the 2.42 GHz Frequency

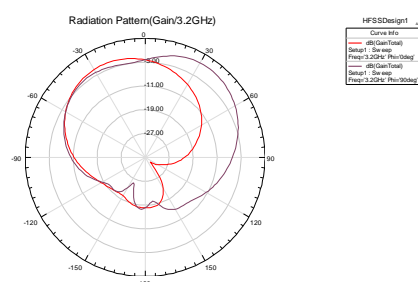


Fig.7 Gain at the 3.24 GHz Frequency

The radiation pattern showing the directivity for the designed slotted antenna has been shown in the Figure 8 & Figure 9.

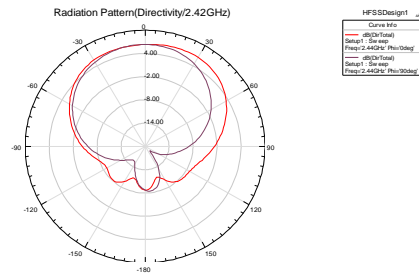


Fig.8 Directivity at the 2.42 GHz Frequency

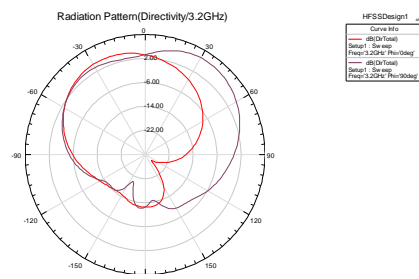


Fig.9 Directivity at the 3.24 GHz Frequency

VII. CONCLUSION

Microstrip antenna has numerous inherent advantages such as low profile, light weight, easy fabrication and suitability of mass production compatibility with planar solid state devices. A Microstrip patch antenna is that type of antenna which offers a low profile, that is thin and easy manufacturability, which provides the great advantage over the traditional antennas.

In this paper ,we are designing the rectangular microstrip patch antenna using the following parameter $f_0 = 2.44$ GHz, $\epsilon_r = 4.4$, $h = 1.6$ mm.

Figure 2& Figure 3 shows the S11 parameters (return loss) for the proposed antenna without slot and with slot respectively. From Figure 2 it is clear that the designed antenna does not resonates at 2.42 GHz and 3.24 GHz. But after making the two rectangular slots of the dimensions 12mm * 4mm the designed antenna resonates at 2.42 GHz and 3.24 GHz frequencies respectively. Figure 3 shows the return loss for the 2.42 GHz is -18.7037 dB and the return loss for 3.24 GHz is -39.1369 dB which covers the minimum required value of return loss of -10 dB.

Figure 4 and Figure 5 shows the plot of VSWR vs frequency of the simulated antenna without slot & with slots respectively. In Figure 5 VSWR must lie in the range of 1-2 which has been achieved for 2.42 GHz and 3.2 GHz frequency, near the operating frequency value. The value of VSWR is 1.2627 at resonant frequency of 2.42 GHz & VSWR is 1.0223 at resonant frequency of 3.24 GHz.

The bandwidth of the antenna can be said to be those range of frequencies over which the return loss is greater than -10 dB (corresponds to a VSWR of 2). Thus, the bandwidth of antenna can be calculated from return loss versus frequency plot. The bandwidth of the proposed patch antenna is 129 MHz for 2.42 GHz frequency and 374 MHz for 3.24 GHz frequency.

The radiation pattern showing the gain for the desired antenna has been shown in Figure 6& Figure 7. The gain for 2.42 GHz frequency is 5.927 dB and for 3.24 GHz frequency is 6.749 dB. In general, the value of gain should be greater than 5 dB but in some cases it is acceptable to 3 dB.

The radiation pattern showing the directivity for the designed antenna has been shown in Figure 8 & Figure 9. The directivity for 2.42 GHz frequency is 6.424 dBi and for 3.24 GHz frequency is 7.131 dBi. In general, the value of directivity should be greater than 5 dBi.

Results show that the proposed antenna has promising characteristics for Wi-Max and WLAN at 3.24 GHz frequency for WiMax and 2.42 GHz for WLAN application respectively.

The results obtained using simulation of HFSS suggests that the patch antenna could be designed for any resonant frequency and bandwidth. The optimization of the microstrip patch antenna is partially realized in this thesis. Realization of results by the HFSS would be concluded with the fabrication of the patch of the Microstrip Patch Antenna. The investigation has been limited mostly to the theoretical study.

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