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Design & Fabrication of Rectangular Microstrip Patch Antenna for WLAN using Symmetrical slots

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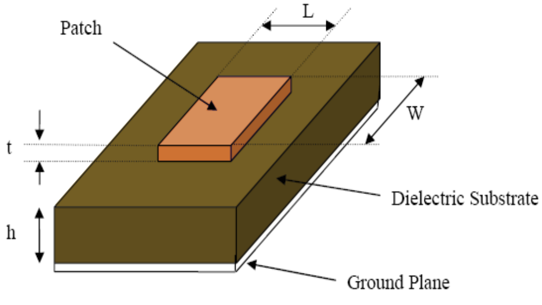
ABSTRACT: This paper presents the symmetrical rectangular slotted microstrip patch antenna. The proposed antenna is simulated with the help of HFSS. The aim of this paper is to design and fabricate the Rectangular Microstrip Antenna and study the effect of antenna dimensions Length (L) , Width (W) and substrate parameters relative dielectric constant (εr), 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, micro strip 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.



Structure of a Microstrip Patch Antenna.

When we change the shape of a micro strip 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.

II. STRUCTURE & DESIGN

A. Design of Micro strip 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. Finally, the results obtained from the simulations will be demonstrated. Results show that the proposed antenna has promising characteristics for WLAN at 2.42 GHz.

The resonant frequency selected form y design is 2.44 GHz.

1. $\varepsilon reff$ is calculated as follows :

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

2. ΔL is calculated as below:

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

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

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

4. Considering the rectangular patch Microstrip antenna the resonating frequency for the mode TM*mn*is given by :

$$f0 = \frac{c}{2\sqrt{\varepsilon reff}}[(\frac{m}{L})^2 + (\frac{n}{W})^2]$$

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:

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

B. Design Parameters

1. Dielectric Constant of the Substrate (εr):

The dielectric material of the Microstrip Patch Antenna is FR-4 with *εr*= 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.

2. The frequency of the operation (f0):

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

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.

C. Calculations

Calculation of width:

By the formula

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

With the substituting the values of *c*=3x10^8m/s *fr*= 2.44GHz and *h* = 1.6mm *Width w* = 0.03742m = 37.42mm.

Calculation of effective dielectric constant:

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

From the equation With the substituting the values ε_r= 4.4, *h* = 1.6mm, *w*=37.42mm Effective Dielectric Constantε_{reff}= 4.0819

Calculation of effective length:

From the equation

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

With the values ε_{reff}= 4.0819, *c*= 3x10^8m/s
fr= 2.44GHz.

Calculation of the length extension(ΔL):

From the equation

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

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

Calculation of length of the patch:

By the equation

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

Where *ΔL*= 0.7387mm, *Leff*= 30.4277mm L =28.9503mm.

Calculation of Bandwidth:

B □ (εr-1)wh/εr^2L
B □□□□□

Calculation of Voltage Signal Wave Ratio:

From the equation given below:
VSWR = (1+|Γ|)/(1-|Γ|)
Γ = reflection coefficient
Where, Γ =0.4
VSWR = 2.333

Calculation of the return loss for the patch antenna:

From the equation given below:
RL = -20log |Γ| (dB)
Where, Γ =0.4
RL= 7.96 dB

Calculation of the ground plane dimensions (*Lg*and *Wg*) 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:

$Lg = 6h + L$

$Wg = 6h + W$

Where h= 1.6 , L=28.95mm ,W=37.42mm

$Lg = 38.55mm$

$Wg = 47.02mm$

Coordinates of the feed point of antenna is given as: (3.2,-1.6,5) with center of the antenna at the origin.

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 center 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. $1mm \le X_f \le 5mm$, $0mm \le Yf \le 10mm$. So here the feed point coordinates must be (3.2,-1.6,5) shown in Figure1.

Fig.1. Structure of Double Slotted Patch Antenna.

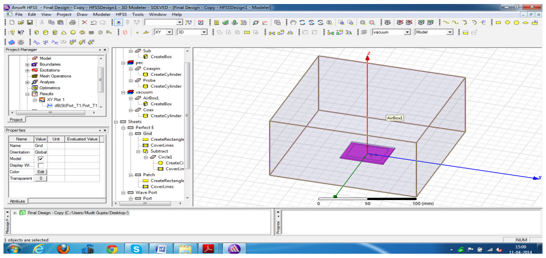


Fig.2. Conventional Micro strip patch antenna without slot.

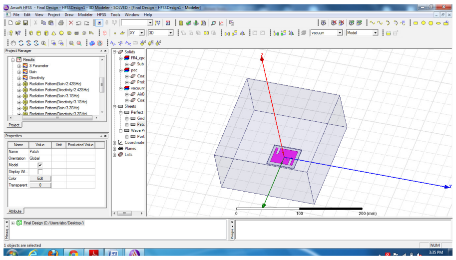


Fig. 3. Micro strip patch antenna with slots designed using HFSS.

III. DESIGN METHODOLOGY

1. With the help of simulation software An soft HFSS following design variation were followed:

- By varying the slit circumference along one of thediagonal axes with respect to the other diagonal axison a patch radiator, circularly polarized radiation canbe achieved with compact size.
- The performance of the antennas is compared, basedon fixed overall antenna size and patch radiator size.Circularly polarized microstrip antennas based on larger-perimeter types of slits are more compact.
- Following are Different slit shapes embedded inmicrostrip square patch radiators:

  i) Truncated corners ii) Truncated corners and slitsiii) V-shaped slits iv) Rectangular slitsv) V-shaped slits and square slitsvi) Combined V-shaped and circular slits
- Slits along the diagonal directions of the patch can excite two resonant modes with equal magnitudes, and orthogonal to each other. By slightly changing the circumference of the slits in the diagonal directions, the resonance frequencies of the two orthogonal resonant modes can be slightly changed for the circularly polarized radiation requirements.

2. Using HFSS simulation we can observe followingParameters: Return Loss, Gain, Bandwidth, VSWR,Directivity, and Radiation Pattern.

3. Fabrication of circularly polarized micro strip patch antenna using symmetric slit on FR4 substrate and verify all above mention parameters.

4. Compare simulation results and hardware implementation results.

IV. SIMULATION AND RESULTS

A. 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 4& Figure 5 shows the S11 parameters (return loss) for the proposed antenna without slot and with slot respectively. From the Figure 4 it is to be clear that the designed antenna will not resonates at the 2.42 GHz. But after making the two rectangular symmetrical slots in the patch antenna of dimensions 12mm * 4mm the designed antenna resonates at the 2.42 GHz frequency. Figure 5 shows that the return loss for the 2.42 GHz is -18.7037 dB which covers the minimum required value of return loss of -10 dB.

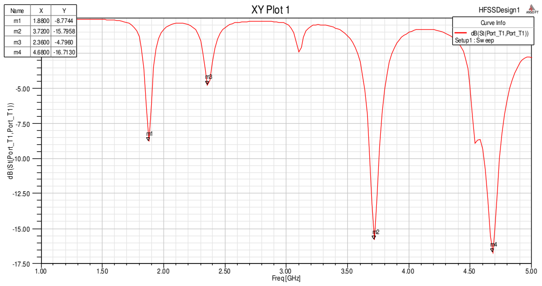


Fig. 4. Return Loss of Microstrip Patch Antenna without Slot.

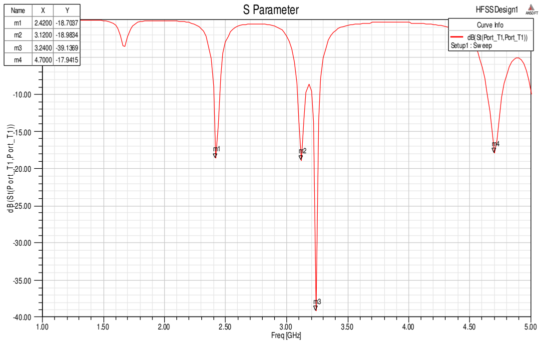


Fig. 5. Return Loss of Microstrip Patch Antenna with two rectangular slots.

B. Voltage Standing Wave Ratio (VSWR) of Micro strip patch Antenna

Figure 6 and Figure 7 shows the plot of VSWR vs frequency of the simulated antenna without slot & with slots respectively. In Figure 7 VSWR must lie in the range of 1-2 which has been achieved for 2.42 GHz frequency, near the operating frequency value. The VSWR ratio at 2.42 GHz frequency is 1:1.2627 is shown in Figure 7.

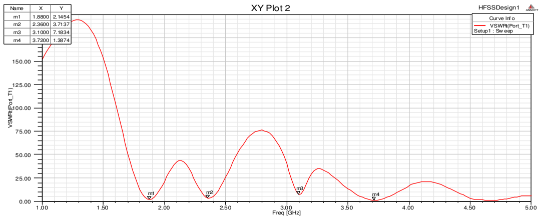


Fig. 6. VSWR v/s Frequency Plot of without slot antenna.

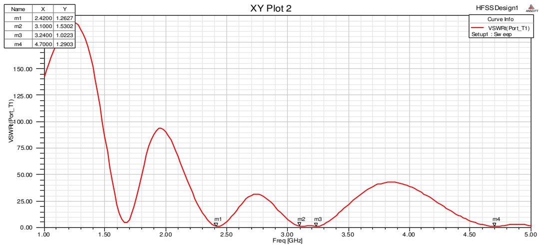


Fig.7. VSWR v/s Frequency Plot of slotted antenna.

C. Radiation Pattern plots

Since a Microstrip patch antenna radiates normal to its patch surface, the elevation pattern for θ = 0 and θ = 90 degrees would be important. The radiation pattern showing the gain for the desired slotted antenna has been shown in Figure 8.

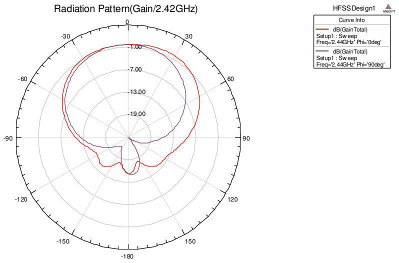


Fig. 8. Gain at the 2.42 GHz Frequency.

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

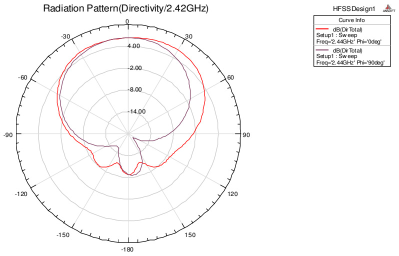


Fig. 9. Directivity at the 2.42 GHz Frequency.

V. CONCLUSION

Micro strip 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 Micro strip 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, ε_r=4.4, h =1.6 mm.

Figure 4& Figure 5 shows the S11 parameters (return loss) for the proposed antenna without slot and with slot respectively. From Figure 4 it is clear that the designed antenna does not resonates at 2.42 GHz. But after making the two rectangular symmetrical slots of the dimensions 12mm * 4mm the designed antenna resonates at 2.42 GHz frequency. Figure 5 shows the return loss for the 2.42 GHz is -18.7037 dB which covers the minimum required value of return loss of -10 dB.

Figure 6 and Figure 7 shows the plot of VSWR vs frequency of the simulated antenna without slot & with slots respectively. In Figure 7 VSWR must lie in the range of 1-2 which has been achieved for 2.42 GHz frequency, near the operating frequency value. The value of VSWR is 1.2627 at resonant frequency of 2.42 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.

The radiation pattern showing the gain for the desired antenna has been shown in Figure 8. The gain for 2.42 GHz frequency is 5.927 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 9. The directivity for 2.42 GHz frequency is 6.424 dBi. In general, the value of directivity should be greater than 5 dBi.

Results show that the proposed antenna has promising characteristics at 2.42 GHz for WLAN application.

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 paper. 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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