Enhancing the Bandwidth of a Microstrip Patch Antenna using Slots Shaped Patch

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Abstract— In this work, three different geometry shapes, the U, E and H and rectangular are developed from a rectangular patch of the width (W) = 38.01 mm and length (L) 28.75 mm. The proposed antennas are simulated using HFSS software and the results compared with the conventional rectangular patch antenna. The results obtained clearly show that, bandwidth of conventional rectangular micro strip antenna can be enhanced from 56.8MHz to 82.1 MHz for rectangular slot, 71MHz for U- shape slot, 89.7MHz for E– shape slot and 70.1MHz for H-Shape slot. The E-shaped patch antenna has the highest bandwidth followed by rectangular shape slot then U-shaped patch antenna and H- shaped patch antenna. The substrate material used for the proposed antennas is copper with the dielectric constant of 4.4 and loss tangent of .002. The proposed antennas may find applications in Wireless Local Area Network (WLAN).

Keywords: Patch Antenna, Slot Shaped, Micro strip, WLAN

I. INTRODUCTION

Microstrip patch antennas are very vital because of their benefits such as low profile, less manufacture cost, minimum power requirements etc. A patch antenna hence now is required to be used in different fields of science & technology for various uses. Many traditional antenna applications cover different frequencies spectrum and there is a need to design an antenna which will perform perfectly for many frequency bands without changing the configuration or structure of the antenna.

Microstrip patch antenna consists of a radiating patch which is generally made of conducting material such as gold or copper and can take any possible shape. The radiating patch and the feed lines are usually photo etched on the dielectric substrate which has a ground plate as shown in Fig. 1.

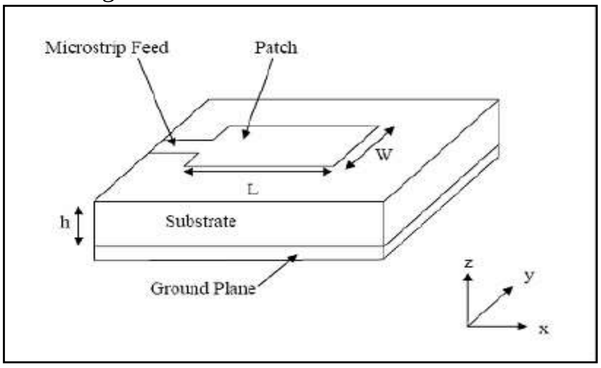

Fig. 1: Structure of a microstrip patch antenna

In order to simplify analysis and performance prediction, the patch is generally square, rectangular, circular, triangular, and elliptical in shape.

For a rectangular patch, the length *L* of the patch is usually 0.333λo < L< 0.5λo, where λo is the free space wavelength. The patch is selected to be very thin such that the patch thickness t<<λo. The height *h* of the dielectric constant of the substrate (ε_r) is typically in the range 2.2 ≤ εr ≤ 12. The microstrip patch antennas radiate primarily because of the fringing fields between the patch edge and the ground plane. For good antenna performance, the choice of substrate used is an important factor. There are numerous substrates that can be used for the design of microstrip antennas within the dielectric constants range of 2.2 ≤ Ɛ≤ 12. The low dielectric constant Ɛ is about 2.2 to 3, the medium around 6.15 and the high approximately above 10.5.

A thick dielectric substrate having a low dielectric constant is desirable since this provides better efficiency, larger bandwidth and better radiation. However, such a configuration leads to a larger antenna size. In order to design a compact microstrip patch antenna, substrate with higher dielectric constants must be used which are less efficient and result in narrower bandwidth.

II. DESIGN METHODOLOGY

A. *Design Equations*

– Width of the patch (W)

$$W = \frac{c}{2f_0\sqrt{\frac{(\varepsilon_r+1)}{2}}} \tag{1}$$

– Effective Dielectric Constant

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

– Effective Length

$$L_{eff} = \frac{c}{2f_0\sqrt{\varepsilon_{eff}}} \tag{3}$$

– Length extension ΔL

$$\Delta L = 0.412h\frac{(\varepsilon_{eff}+0.3)\left(\frac{W}{h}+0.264\right)}{(\varepsilon_{eff}-0.258)\left(\frac{W}{h}+0.8\right)} \tag{4}$$

– Actual length of the patch (L)

$$L = L_{eff} - 2\Delta L \tag{5}$$

B. *Feeding Techniques*

Microstrip patch antennas can be fed by a variety of methods. These methods can be classified into two categories-contacting and non-contacting methods. The RF power is fed directly to the radiating patch using a connecting element such as a microstrip line. In the non-contacting scheme, electromagnetic field coupling is done to transfer power between the microstrip line and the radiating patch. The four most popular feed techniques used are the

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microstrip line, coaxial probe (both contacting schemes), aperture coupling and proximity coupling (both non-contacting schemes).

C. Method of Analysis

There are many methods of analysis for microstrip antenna. The most popular models are the transmission-line, cavity and full-wave. The transmission-line model is the easiest of all, it gives good insight and it is adequate for most engineering purposes and requires less computation. However, it is less accurate. The cavity model is more accurate and gives good physical insight but is complex. The full-wave models are very accurate, very versatile, and can treat single elements, finite and infinite arrays, stacked elements, arbitrary shaped elements and coupling. However, they are the most complex models and usually give less physical insight.

D. Bandwidth

The most serious limitation of the microstrip antenna is its narrow *BW*. The bandwidth could be defined in terms of its *VSWR* or input impedance variation with frequency or in terms of radiation parameters. For the circularly polarized antenna, bandwidth is defined in terms of the Axial Ratio. *VSWR* is a very popular parameter for determining the bandwidth of a particular antenna configuration (1≤ *VSWR* ≤ 2) as an acceptable interval for determining the bandwidth of the antenna. Bandwidth is presented more concisely as a percent where

$$\%BW = \frac{\Delta f}{f_0} \times 100 \qquad (6)$$

Where Δf is the width of the range of acceptable frequencies, and is the resonant frequency of the Antenna. The expressions for approximately calculating the percentage BW of the (RMSA) antenna in terms of patch dimensions and substrate parameters is given by.

$$\%BW = \frac{A \times h}{\lambda_0 \sqrt{\varepsilon r}} \sqrt{\frac{W}{L}} \qquad (7)$$

Where A is constant, and can take the values 180, 200 and 220

For A = 180, $\frac{h}{\lambda_0 \sqrt{\varepsilon r}} \leq 0.045$

For A = 200, $0.045 \leq \frac{h}{\lambda_0 \sqrt{\varepsilon r}} \leq 0.075$

For A = 220, $\frac{h}{\lambda_0 \sqrt{\varepsilon r}} \leq 0.075$

With an increase in W, bandwidth increases. However, W should be taken less than λ to avoid excitation of higher order modes. The BW of the MSA can also inversely proportional to its quality factor (Q).

$$BW = \frac{VSWR - 1}{Q\sqrt{VSWR}} \qquad (8)$$

The BW is usually specified as frequency range over which VSWR ≤ 2. However, in recent years considerable effort has been spent to improve the bandwidth of the microstrip antenna, in part by using alternative feeding schemes.

E. Return Loss

The return loss is another way of expressing mismatch. It is a logarithmic ratio measured in *dB* that compares the power reflected by the antenna to the power that is fed into the antenna from the transmission line. The relationship between *VSWR* and return loss is as follows

$$Return\ loss\ in\ dB = 20 log_{10}\left(\frac{VSWR}{VSWR-1}\right) \qquad (9)$$

III. Antenna Design and Analysis

The designed parameters for the proposed patch antenna were calculated Table 1.

Frequency of operation fo	2.4GHz
Height of Substrate (h)	1.6 mm
Dielectric constant (ε_r)	4.4
Width of the Patch (W)	38.01mm
Length of the Patch (L)	28.75mm
Loss Tangent	.002

Table. 1: Antenna Parameters

The proposed antenna is to be used for the wireless local area network (WLAN). The antenna is to operate in the frequency range from 2GHz to 3GHz. The dielectric material selected is Copper and FR4 dielectric constant of 4.4. The dielectric constant is kept high in order to get a reduced antenna size. The objective is to get an improve bandwidth from the conventional rectangular patch since the higher dielectric substrate results in size reduction at the expense of bandwidth reduction.

In this design, we have proposed different geometry shapes from a patch of width (W) = 38.01mm and length (L) =28.75mm. The three proposed antennas are simulated using HFSS software, under the same conditions and results compared with the conventional rectangular patch antenna, and the shape with improve bandwidth is adopted, and implemented. The bandwidth was obtained where return loss is less than - 10dB which is an acceptable level to describe the loss of the power which reflects back from the antenna without being radiated.

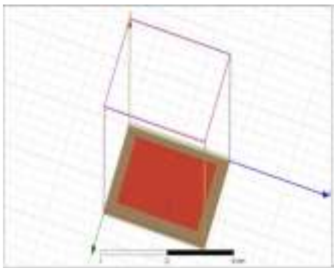

Fig. 2: Without any slot

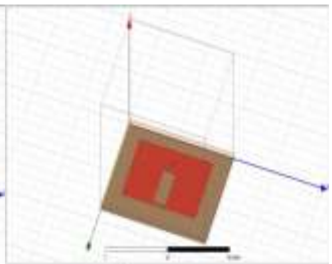

Fig. 3: with Rectangular Slot

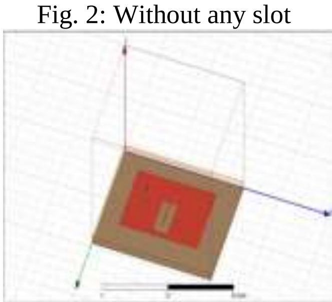

Fig. 4: With U slot

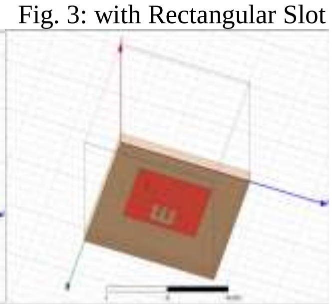

Fig. 5: with E Slot

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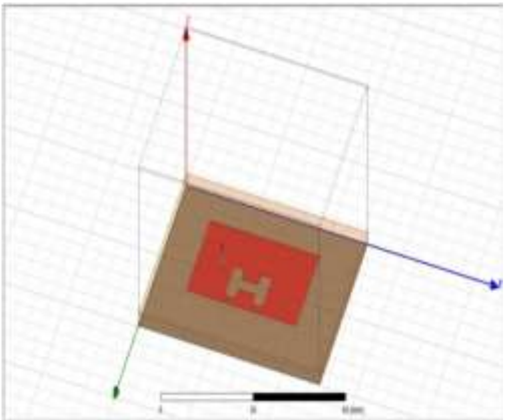

Fig. 6: with H slot

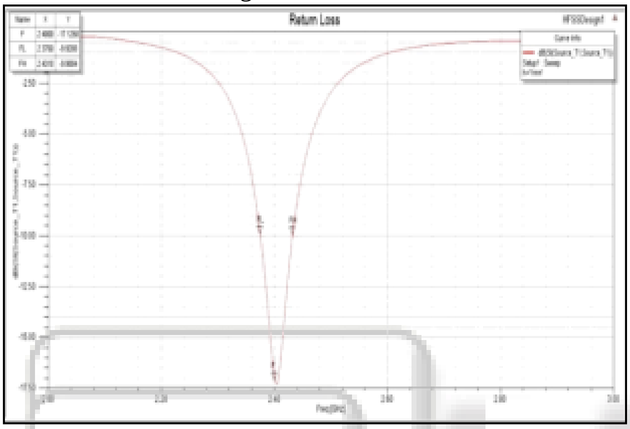

Fig. 7: Return Loss without slot

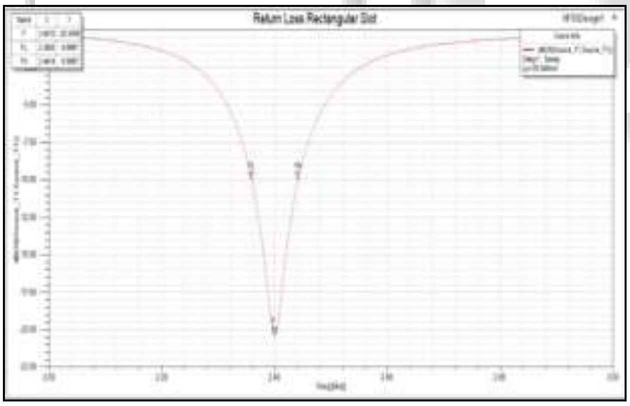

Fig. 8: Return loss for Rectangular Slot

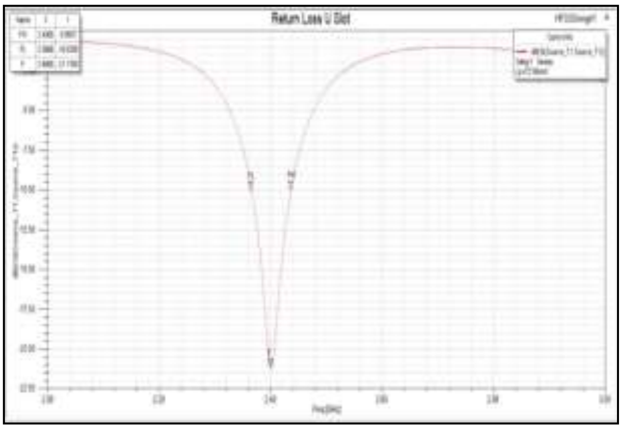

Fig. 9: Return loss for U Slot

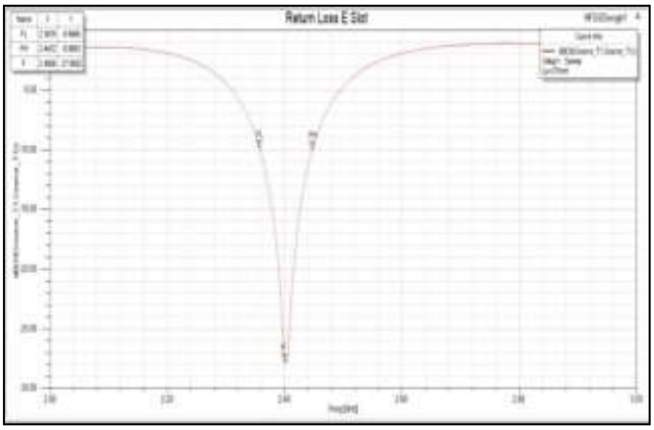

Fig. 10: Return loss for E Slot

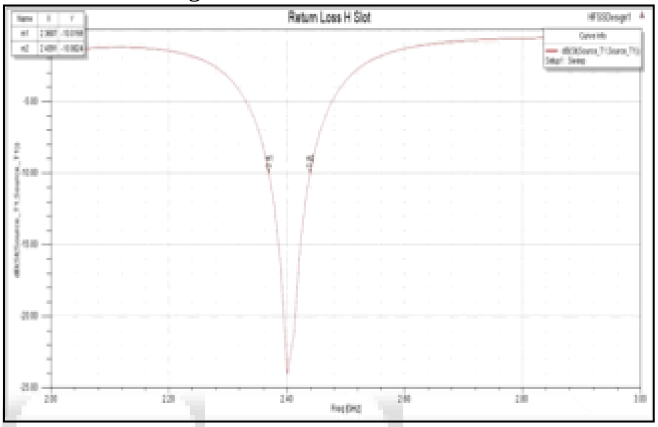

Fig. 11: Return loss for H Slot

The bandwidth of the conventional RMSA is found to be 56.8MHz.The expressions for approximately calculating the percentage bandwidth of the RMSA in terms of patch dimensions and substrate parameters is given by,

$$\%BW = \frac{A \times h}{\lambda_0 \sqrt{\varepsilon r}} \sqrt{\frac{W}{L}} \qquad (10)$$

Figure 10, shows the variation of return loss versus frequency of E- shape patch antenna. The antenna resonates at 2.49GHz. This development is as a result of the slots. The bandwidth is 89.7MHz.

Figure 9, shows the variation of return loss versus frequency of U-shaped patch antenna. The antenna resonates 2.4GHz, due to the U-slots. The overall bandwidth is 71MHz.

Figure 7, shows the variation of return loss versus frequency of H- shape patch antenna. The bandwidth is 70.1MHz.

This clearly shows that slot can be either resonant or non-resonant. If it is resonant, the current along the edges of the slot introduces additional resonances near the patch resonance, adding them together causes enhancement in the bandwidth.

Figure 10 and figure 9 give the highest bandwidth more than bandwidth of conventional RMSA. This further enhancement in bandwidth, when compare to RMSA is as a result of insertion of slots used for the construction of E and U-shaped patches. The current along the edges of the slot induces an additional resonance, which adds to the fundamental resonance of the radiating element that helps to increase bandwidth.

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The Bandwidth Obtained in a microstrip antenna at 2.4 GHz operating Frequency is 56.8 MHz.

The Bandwidth Obtained in a Microstrip Antenna with Rectangular-Shaped Slot resonating at 2.4 GHz is 82.1MHz.

The Bandwidth Obtained in a Microstrip Antenna with U-Shaped Slot resonating at 2.4 GHz is 71 MHz.

The Bandwidth Obtained in a Microstrip Antenna with E-Shaped Slot resonating at 2.4 GHz is 89.7MHz.

The Bandwidth Obtained in a Microstrip Antenna with H-Shaped Slot resonating at 2.4 GHz is 70.4 MHz.

Thus, with the introduction of the slot the bandwidth of the antenna increased for the same parameters. antenna increased for the same parameters.

IV. Conclusion

In this work, the aim was targeted at improving the bandwidth of microstrip antennas constructed with dielectric material with higher dielectric constant. We have selected four different patch antennas and the simulated results compare with the conventional microstrip patch antenna. The results obtained clearly show that bandwidth of conventional RMSA made with dielectric substrates having higher dielectric constants can be improved using U and E-shaped patch antenna. We have observed that E-shaped patch antenna has the highest bandwidth follow by U-shaped patch antenna and H-shaped antenna.

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