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Different Structural Modification Methods of the Patch for Reducing the Size of An Microstrip Patch Antenna

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Abstract

The aim of this paper is to present a simulation and analysis of a rectangular microstrip patch antenna with three different structural modifications to reduce the size of the antenna. We have tried to decrease the size of the antenna by inducing three different shaped slits inside the patch of the antenna. All these models have been designed and analyzed using CST Microwave Studio software. For designing the antennas, Flame Retardant 4 (FR-4 lossy) has been used as the substrate material with a dielectric constant of Ɛr=4.3. The antenna works at the frequency of 2.4 GHz. Performance characteristics such as return loss S11 parameter<-10 dB, directivity, side lobe level, gain and bandwidth of each of the modified designs are obtained and compared with the original design. We were able to reduce the size by maximum 18% and minimum 7% by only inducing the slits, while maintain the performance.

Keywords: *2.4 GHz band; Antenna patches; Microstrip patch antenna; Miniaturization; Structural modification.*

1. Introduction

Recent advancement in wireless communication technology demands more and more compact devices. So, it has become very crucial to miniaturize the individual building block of the wireless communication system. Antenna is a key component of the wireless communication systems. It is believed that antenna is an individual block which takes most of the real estate in a modern wireless communication system [1]. So, miniaturization of the antenna can really help to reduce the size of the wireless communication device. But it is a very challenging task to reduce the size of the antenna as doing so can also affect the performance of the antenna. This is very important to focus on the parameters of the antenna like return loss, radiation pattern, gain and efficiency while reducing the size of the antenna because that also hampers these parameters.
Microstrip patch antennas are currently receiving considerable amount of attention for using in wireless communication devices. These antennas are highly flexible in design, shape and conformability thus allowing for relatively easy miniaturization and integration inside the compact wireless communication devices [2]
But a major limitation of microstrip patch antenna is low efficiency and narrow impedance bandwidth, which makes the miniaturization more challenging without compromising the basic parameters.
At lower frequencies the size of the microstrip antennas becomes large. In modern communication systems the compact microstrip patch antennas are desirable. There are various techniques to reduce the size of the microstrip antennas. One of which is to structurally modify the antenna to decrease the size of the antenna by increasing the electrical length of the antenna.

2. Basic structure of microstrip patch antenna

A simple microstrip patch antenna has a radiating patch on one side of the substrate material and ground plane on the other side.
Microstrip antennas has the basic structures as below [3]:
Patch: This is the radiating conductive element of the antenna and it can be of different shapes and sizes.
Substrate: This isolates the radiating patch from the ground plane & characterized by its permittivity.
Ground plane: This is a conductor which works as ground for the circuit.
Feedline: This is used to excite the circuit by guiding the current to it by direct or indirect contact.
The basic structure of a microstrip patch antenna is shown in Figure 1.

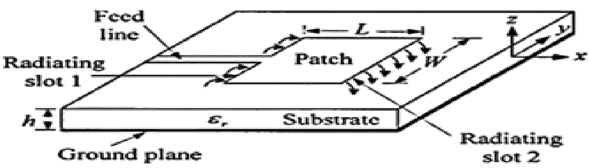

Fig. 1: Basic structure of microstrip patch antenna

3. Miniaturization techniques

The use of patch designs for wireless communication antennas allows for several additional miniaturization techniques. The main focus of miniaturization is to decrease the size of the antenna at a certain frequency, but to conserve the sufficient electromagnetic performance. Miniaturization techniques for patch antennas include:

1. Using high-permittivity dielectric (substrate/ superstrate) materials [4]: high-permittivity dielectrics can be used as substrate material to reduce the size of the antenna because they shorten the effective wavelength and result in lower resonance frequencies, thus assisting in antenna miniaturization.
2. Insertion of shorting pins [5]: Adding a shorting pin between the ground and conducting plane increases the electrical length of the antenna, and, in turn, decreases the required visible dimensions for a specific operating-frequency scenario.
3. Patch-stacking [6]: Piling two or more radiating patches vertically reduces antenna size by increasing (nearly doubling) the length of the current-flow path.
4. Structural modification [1]: Another way to reduce the size of microstrip antenna is by modifying its shape, by inserting slot to meander currents.

In our case we have chosen to reduce the size of the antenna by three different structural modifications.

4. Antenna design and simulation:

We have intended to design an antenna which works at 2.4 GHz resonant frequency. We have used copper as the radiating material and FR-4 (Ɛr =4.3, tanδ =0.015). At first we have designed an elementary edge fed rectangular patch antenna and observed its performance. Then we have tried to reduce the size of the antenna by inducing different slits inside the patch while maintaining the performance. CST microwave studio has been used to design and simulate the antenna. The performance of the antenna has been observed accurately and then they have been compared.

4.1. Fundamental design

Firstly, the antenna has been designed theoretically for the allocated frequency band. For designing the antenna equation has been used. In (1) is for calculating the Length of the patch of the antenna for a selected frequency.

$$L_T = \frac{c}{4 f_r \sqrt{\xi}} \qquad (1)$$

Where, c=speed of light
fr =resonance frequency of the antenna
ξ= dielectric constant of the substrate material
The parameters used to design the antenna is given in Table 1. The design of the antenna is shown in Figure 2. The simulation results of the designed antenna are as shown in Figure 3. & Figure 4.

Table 1: Design Parameters

Parameter	Measurements (mm)
Patch Length	28.4
Patch Width	45
Substrate Length	58.4
Substrate Width	50
Heigth of Substrate	1.6
Matching line Length	10
Matching line Width	0.8
Feeding line Length	15
Feeding line Width	2.9

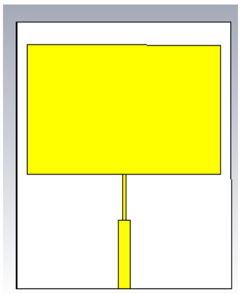

Fig.2: Basic design of the patch antenna

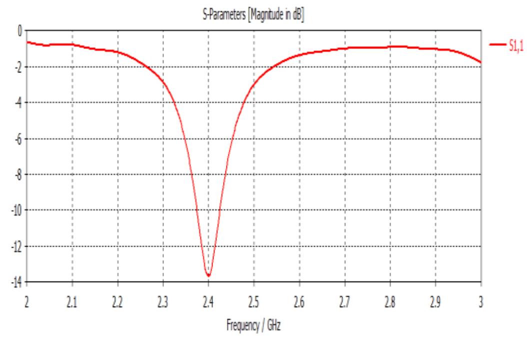

Fig. 3: Return loss or S11 parameter of the basic antenna

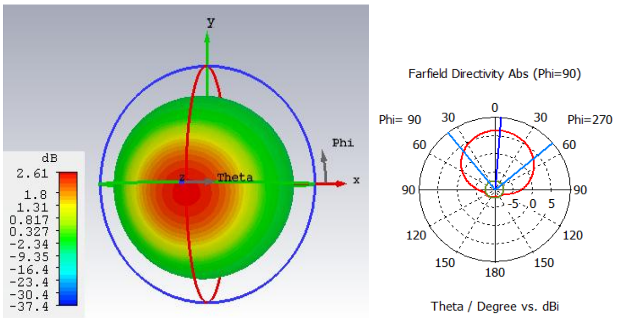

Fig. 4: (a)Farfield radiation pattern in 3D form (b) Farfield directiviy in polar form

4.2. Antenna design with structural modifications

This section discusses the simulation design and results of different structurally modified models to increase the electrical length of the antenna hence decrease the physical size of the antenna

4.2.1. Antenna with cross slit

The parameters used to design the antenna is given in Table 2. The design of the antenna is shown in Figure 5. The simulation results of the designed antenna are as shown in Figure 6 & Figure 7.

Table 2: Design Parameter of first modification

Parameter	Measurements (mm)
Patch Length	26.35
Patch Width	45
Substrate Length	56.35
Substrate Width	50
Heigth of Substrate	1.6
Matching line Length	10
Matching line Width	0.8
Feeding line Length	15
Feeding line Width	2.9

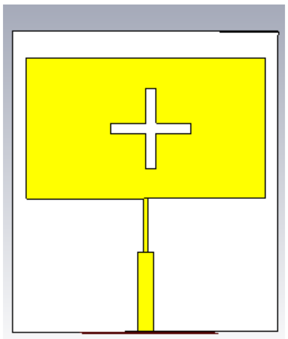

Fig. 5: Structural modification of the patch with cross slit

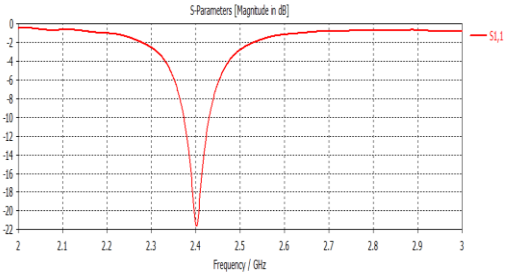

Fig. 6: Return loss or S11 parameter

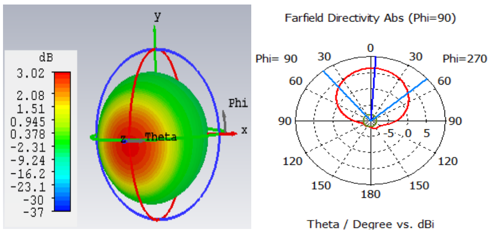

Fig. 7: (a) Farfield radiation pattern in 3D (b) Farfield directivty in polar form

4.2.2. Antenna with rectangular slit

The parameters used to design the antenna is given in Table 3. The design of the antenna is shown in Figure 8. The simulation results of the designed antenna are as shown in Figure 9 & Figure 10.

Table 3: Design parameter of second modification

Parameter	Measurements (mm)
Patch Length	26
Patch Width	45
Substrate Length	56
Substrate Width	50
Heigth of Substrate	1.6
Matching line Length	10
Matching line Width	0.8
Feeding line Length	15
Feeding line Width	2.9

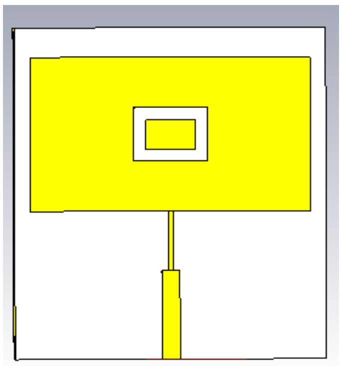

Fig. 8: Structural modification of the patch with rectangular slit

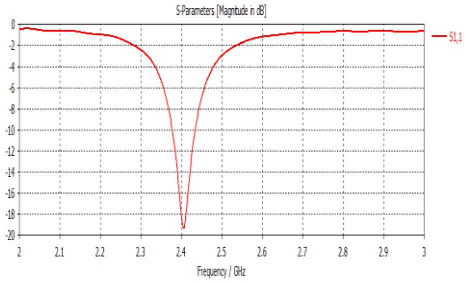

Fig. 9: Return Loss or S11 parameter

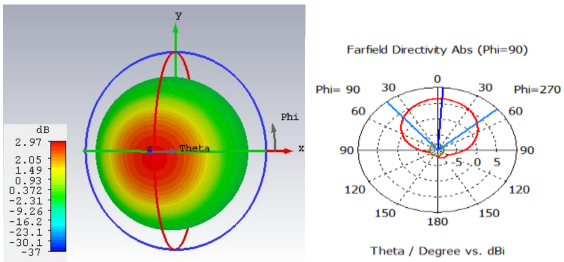

Fig 10: (a)Farfield radiation pattern in 3D (b) Farfield directivty in polar form

4.2.3. Antenna with S shaped slit

The parameters used to design the antenna is given in Table 4. The design of the antenna is shown in Figure 11. The simulation results of the designed antenna are as shown in Figure 12 & Figure 13.

Table 4: Design parameters for third modification

Parameter	Measurements (mm)
Patch Length	23.25
Patch Width	45
Substrate Length	53.25
Substrate Width	50
Heigth of Substrate	1.6
Matching line Length	10
Matching line Width	0.8
Feeding line Length	15
Feeding line Width	2.9

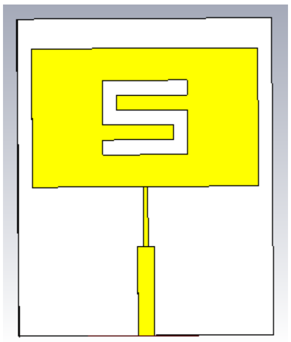

Fig 11: Structural modification with s shaped slit

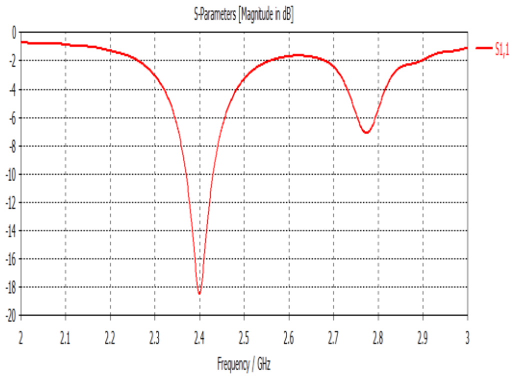

Fig 12: Return Loss or S11 parameter

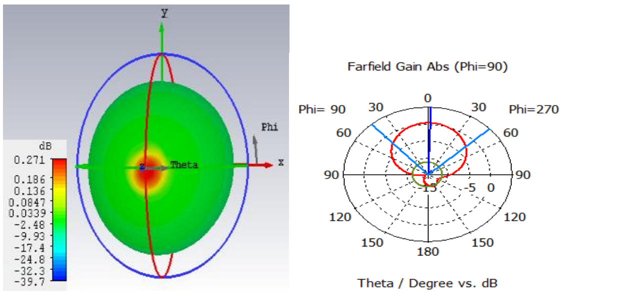

Fig 13: (a) Farfield radiation pattern in 3D (b) Farfield directivty in polar form

5. Results and analysis

The results from all the designed antenna has been discussed in this section. The comparison of the result has been presented in Table 5.

Table 5: Comparison of all performance of the antennas

Parameter	Rectangular Antenna Patch Type			
	Basic	**With cross slit**	**With rectangular slit**	**with s shaped slit**
Return Loss S_{11} (dB)	-13.65	-21.63	-19.34	-21.36
Directivity (dBi)	6.3	6.3	6.3	6.13
Gain (dB)	2.615	3.03	2.98	0.5
Band Width (MHz)	50.8	75.2	56.1	60.7
Side Lobe Level (dB)	-13.8	-14.3	-14.4	-11.8
Patch Size (LengthXWidth) (mmXmm)	28.4X45	26.35X45	26X45	23.25X42
Size Reduced (%)	------	7.21	8.5	18.12

The basic antenna has a return loss of -13.65 dB, the antenna gain is 2.615 dB and the the main lobe magnitude of the directivity of the antenna is 6.3 dBi, the side lobe level is -13.8 dB and bandwidth is 50.8 MHz

Then we have induced a cross shaped slit, a rectangular slit and a meandered slit inside the rectangular patch of the antenna.

The dimension of the antenna with cross slit is 26.35mmX45mm. It is 7.21% less than the actual design. We can see from Table 5, the antenna with cross slit has return loss of -22.3 dB. The antenna gain is 3.03 dB.and the main lobe magnitude of the directivity of the antenna is 6.3 dBi, the side lobe level is -14.3 dB and bandwidth is 75.2 MHz. This indicates that all the basic parameters are improved by this modification.

The dimension of the antenna with rectangle slit is 26mmX45mm. It is 8% less than the actual design. We can see from Table 5 the antenna with cross slit has return loss of -19.34 dB. The antenna gain is 2.98 dB.and the main lobe magnitude of the directivity of the antenna is 6.3 dBi, the side lobe level is -14.4 dB and bandwidth is 56.9 MHz. This indicates that all the basic parameters are improved by this modification.

The dimension of the antenna with s shaped slit is 23.25mmX42mm. It is 18% less than the actual design. We can see from Table 5, the antenna has a return loss of -21.36 dB at 2.4 GHz, the antenna gain is 0.5 dB, the main lobe magnitude of the directivity of the antenna is 6.13dBi, side lobe level is –11.8 dB and bandwidth is 60.7. The return loss, the directivity, bandwidth has improved from the original design, but the gain has reduced by this modification the antenna is 2.615 dB and the main lobe magnitude of the directivity of the antenna is 6.3 dBi, the side lobe level is -13.8 dB and bandwidth is 50.8 MHz.

6. Conclusion

Here in this paper some structural modifications are presented to reduce size of antenna; each modification has its own merits and demerits. One can use any one or combination of these modifications to reduce size of antenna nearly approximate to requirement. Here structural modified antennas for 2.4 GHz has been designed, without much affecting main parameter for size reduction. The results show a reduction in size as well as return loss.

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