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Design and Study the Characteristics of E-shaped Micro Strip Patch Antenna with Different Dielectric Substrates

M. Lakshmi Raviteja [1], K. Nehru [2], T.S. Arulananth [3], V.Damodhar Rao [4] and G N S Bhagya Sri [5]

[1]*Department of Electronics and Communication Engineering, Institute of Aeronautical Engineering, Dundigal, Hyderabad, India.*
[2]*Department of Electronics and Communication Engineering, Institute of Aeronautical Engineering, India.*
[2]*Orcid ID: 0000-0002-5673-0593*
[3]*Department of Electronics and Communication Engineering, MLR Institute of Technology, India.*
[4]*Department of Electronics and Communication Engineering, Hyderabad, India.*
[5]*Department of Electronics and Communication Engineering, Hyderabad, India.*

Abstract

E shaped micro strip patch antenna is being designed using FR4-Epoxy, RT Duroid, Rogers_RO_3006, Rogers_RO_3010 materials. The dielectric constant of FR4-epoxy, epoxy-kevlar, Rogers_ro_3006, Rogers_ro_3010 are 4.4, 3.6, 6.15 and 10.2 respectively. The return loss, radiation pattern & gain of the proposed antenna show that it has promising characteristics for various wireless communication applications. In this design the effects of changing the dielectric constant of the substrate is also studied. It is analysed that how antenna performance varies while changing the value of dielectric constant. The proposed antenna is coaxially fed. The design is being simulated using HFSS (High Frequency Structural Simulator) software.

Keywords: E shaped micro strip patch antenna, FR4-Epoxy, RTDuroid, Roggers_RO_3006, Roggers_RO_3010, HFSS.

INTRODUCTION

The study of microstrip patch antennas has made great progress in recent years. Compared with conventional antennas, microstrip patch antennas have more advantages and better prospects. Different researchers have used different dielectric substrates to fabricate microstrip patch antenna. So a question arises that which dielectric substrate among the common substrates available gives better performance and what are the properties of the dielectric substrates which affects antenna performance. So a comparative study has been performed to know the dielectric properties of four different substrates which affect antenna performance. The aim of the study to design E-shaped microstrip patch antenna on four different substrates and analyze their radiation characteristics [1-4].

A microstrip patch antenna consists of a radiating patch on one side of dielectric substrate, while has a ground plane on the other side. The radiating patch may be of any shape i.e., rectangular, square, circular, elliptical, triangular etc. The substrate has the dielectric constant in the range of $2.2 \leq \varepsilon_r \leq 12$ can be used. The merits of microstrip patch antenna are low profile, light weight, low volume, low cost and can easily be integrated with the microwave integrated circuits [5-8].

As the communication technology improves higher frequency range available for the longer bandwidth. Analysis of transmission line is done by microwave and milli meter wave frequencies. Thus micro strip patch antenna structures characterization is very important. It depends on geometrical shape of the micro strip patch antenna and property of the medium [9-11].

The HFSS is a software package analysis modeling and analysis of 3-dimensional structures. HFSS utilizes a 3D full wave finite element method to compute the electrical behaviors of high frequency and high speed components. The HFSS is more accurately characterizes the electrical performance of components and effectively evaluates various parameters. It helps the user to observe and analyze various performance of electromagnetic properties of structures such as propagation constant, characteristic port impedance, generalized S-parameters and Y-parameters etc., are normalized to specific port impedances. The HFSS software is designed for extracting modal parameters by simulating passive devices. It is necessary for designing high frequency and high speed components used in modern electronic devices. The HFSS simulated results are more accurate and helpful before design and fabricating of real world components [12-14].

The effective dielectric constant ε_{reff} can be calculated from the formula

$$\varepsilon_{reff} = \frac{\varepsilon_r+1}{2} + \frac{\varepsilon_r-1}{2\sqrt{1+\frac{12h}{W}}} \qquad (2)$$

METHODS

The subsection heading should also use The procedure for designing a rectangular micro strip patch antenna is explained. In this procedure there are three essential parameters for the design: the frequency of operation f, the dielectric constant of the substrate ε_r and the height of the dielectric substrate h.

For a given ε_r and h, we design a rectangular micro strip antenna for the resonant frequency f_r (finding the width and length of the patch).The E-Shaped Microstrip Patch Antenna is as shown in figure 1.

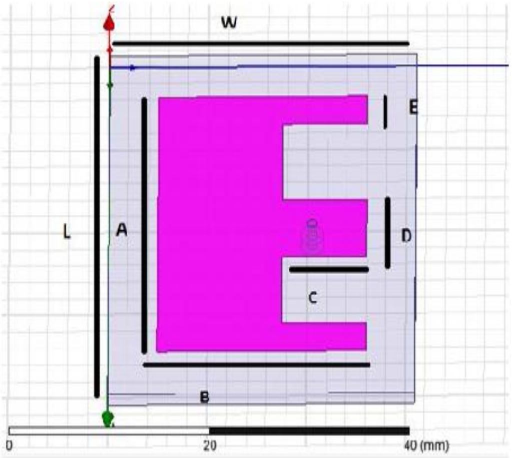

Figure 1: E-Shaped MicroStrip Patch Antenna

B .Antenna Dimensions

The width of the micro strip antenna is given by:

$$W = \frac{1}{2f_r\sqrt{\mu_0\varepsilon_0}}\sqrt{\frac{2}{\varepsilon_r+1}} = \frac{v_0}{2f_r}\sqrt{\frac{2}{\varepsilon_r+1}} \qquad (1)$$

The microstrip patch antenna looks longer than its physical dimensions because of the effect of fringing. The effective length therefore is differing from the physical length by ΔL . A very popular approximation to calculate the extension of the length of the patch is given by:

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

We want to match antenna to $50\ \Omega$; $R_{in} = 50\ \Omega$.The mutual effects of the parallel equivalent admittance is given as

$$R_{in} = \frac{1}{2(G_1+G_{12})}$$

$$R_{in} = \frac{1}{2(G_1+G_{12})}\cos^2\left(\frac{\pi}{L}y_0\right)$$

$$G_1 = \frac{I_1}{120\pi^2}$$

$$I_1 = \int\left[\sin\left(\frac{k_0W}{2}\cos\theta\right)\right]^2 \sin^3\theta\, d\theta$$

$$G_{12} = \frac{1}{120\pi^2}\int\left[\sin\left(\frac{k_0W}{2}\cos\theta\right)\right]^2 J_o(k_0L\sin\theta)\sin^3\theta\, d\theta$$

Calculating the dimensions of Ground plane.

$$\lambda_{eff} = \frac{v_0}{f_r}\sqrt{\varepsilon_{reff}} \qquad (5)$$

$$\text{Length of ground plane} \geq \left(\frac{\lambda_{eff}}{4}\right)\times 2 + L \qquad (6)$$

$$\text{Width of ground plane} \geq \left(\frac{\lambda_{eff}}{4}\right)\times 2 + W \qquad (7)$$

The design of E-shaped patch antenna is shown in figure 2. The dimensions of the substrate is taken as $40\ mm \times 31\ mm$. The thickness(H) of the substrate is taken as 1.5 mm. The patch is being formed by cutting the slots so that required design and its characteristics can be obtained. The two arms of the of patch are of the size $8.5\ mm \times 3.5\ mm$. The middle arm is of the size of $8.5\ mm \times 3.5\ mm$. The antenna proposed is of co-axially fed. The dimensions of antenna are (A:31mm),(B:21mm),(C:7.5mm) (D:7.5mm) and (E::3.5mm).

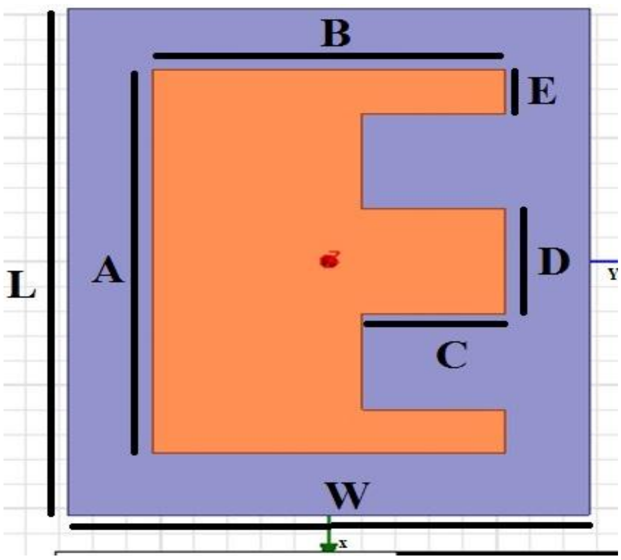

Figure 2: E shaped Patch antenna Geometry

FABRICATION

Proposed design of E-slot microstrip patch antenna fabricated using the photolithographic technique. In this method unwanted metal areas of the metallic layer are removed through chemical etching process by which desired design is obtained. Before this process, select a proper substrate material for the proposed antenna design. A female SMA connector (brass metal) is connected in antenna to join feed and ground. SMA abbreviated as sub miniature version A, which provides electrical performance to antenna. This connector offers low reflections and constant 50 ohm impedance. After fabrication process, all the parameters of proposed antenna are measured using Spectrum Analyzer. The fabrication of E-shaped micro strip patch antenna of FR4_Epoxy subsrate is shown in figure 3 and the fabrication of E-shaped Micro strip Patch antenna of RT Duroid Substrate is shown in figure 4.

Figure 3: E-shaped Microstrip Patch Antenna of FR4_Epoxy Substrate

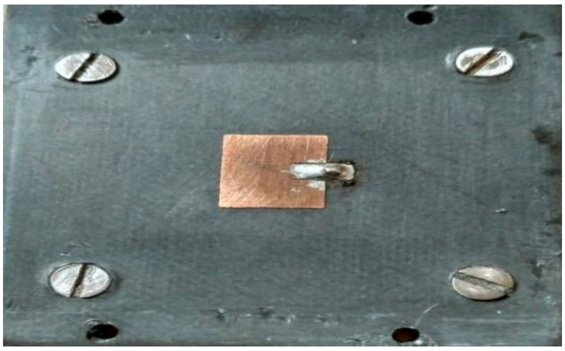

Figure 4: E-shaped Microstrip Patch Antenna of RT Duroid Substrate

RESULTS

A.Simulation Results Using FR4_Epoxy as substrate

The simulation of the design is being done using HFSS software. The substrate used is FR4_Epoxy having dielectric constant 4.4. The above given dimensions are used to simulate the structure. The operating frequency is 9.2 GHz and obtained return loss is -20.6985 dB. The gain obtained at this frequency is 3.04 dB which is better than conventional antennas. The simulation results are shown with the help of figure 5 and figure6. The proposed antenna is radiating very efficiently as can be seen in the figure7.

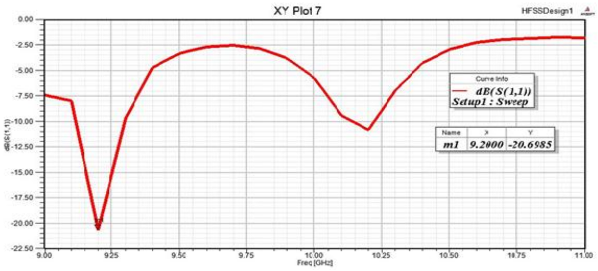

Figure 5: Return loss Vs Frequency graph of Microstrip Patch antenna using FR4_Epoxy as Dielectric Substrate

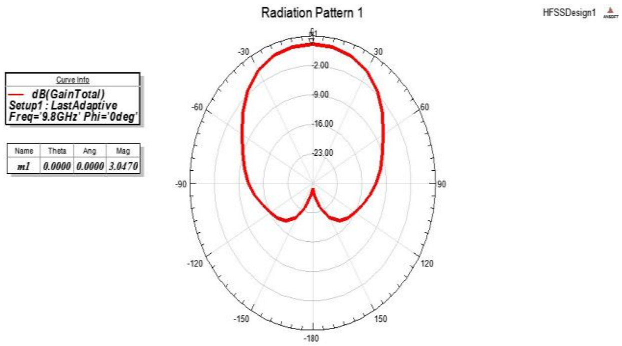

Figure 6: Radiation Pattern for FR4 Epoxy Substrate

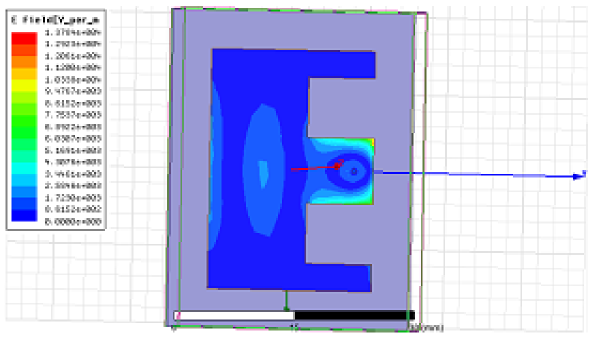

Figure 7: Simulation of Radiation pattern for FR4 Epoxy Substrate

B.Simulation Results Using Rogers_3006 as substrate

The substrate used is Rogers_3006 having dielectric constant 6.15. The above given dimensions are used to simulate the structure. The operating frequency is $10.8\ GHz$ and obtained return loss is $-5.5760\ dB$. The gain obtained at this frequency is $3.7083\ dB$ which is better than conventional antennas. The simulation results are shown with the help of figure 8 and figure 9. The proposed antenna is radiating very efficiently as can be seen in the figure 10.

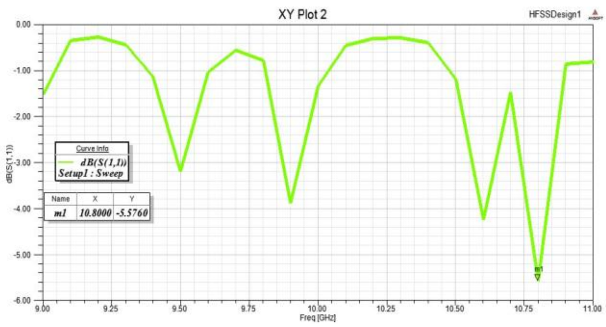

Figure 8: Return loss Vs Frequency graph of Microstrip Patch antenna using Rogers_3006 as Dielectric Substrate

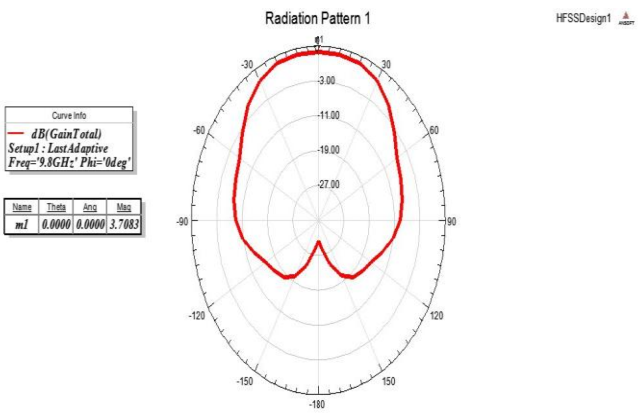

Figure 9: Radiation Pattern for Roggers_3006Substrate

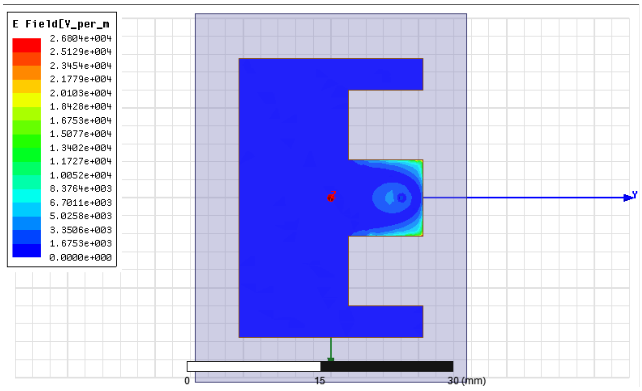

Figure 10: Simulation of Radiation Pattern for Roggers_3006Substrate

C.Simulation Results Using Rogers_3010 as substrate

The simulation of the design is being done using HFSS software. The substrate used is FR4_Epoxy having dielectric constant 10.2. The above given dimensions are used to simulate the structure. The operating frequency is $11.10\ GHz$ and obtained return loss is $-13.7094\ dB$. The gain obtained at this frequency is $-9.5\ dB$ which is better than conventional antennas. The simulation results are shown with the help of figure 11 and figure 12. The proposed antenna is radiating very efficiently as can be seen in the figure 13

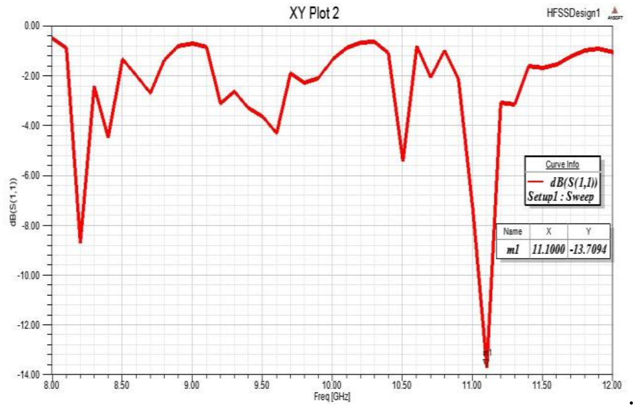

Figure 11: Return loss Vs Frequency graph of Microstrip Patch antenna using Rogers_3006 as Dielectric Substrate

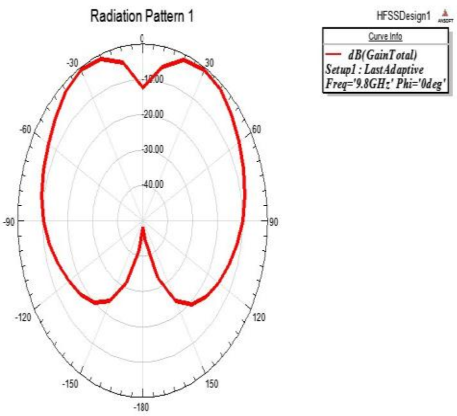

Figure 12: Radiation Pattern for Roggers_3010 Substrate

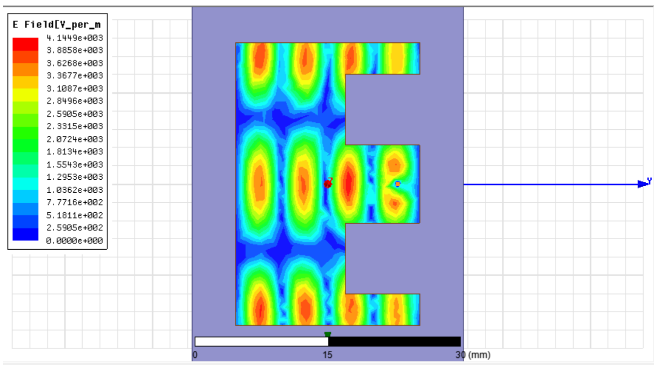

Figure 13: Simulation of Radiation Pattern for Roggers_3010 Substrate

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D. Simulation Results Using RT Duroid as Substrate

The simulation of the design is being done using HFSS software. The substrate used is RT Duroid having dielectric constant 10.2. The above given dimensions are used to simulate the structure. The operating frequency is $10.9\ GHz$ and obtained return loss is -8.3901 dB. The gain obtained at this frequency is -12.5762 dB which is better than conventional antennas. The simulation results are shown with the help of figure 14 and figure 15. The proposed antenna is radiating very efficiently as can be seen in the figure 16

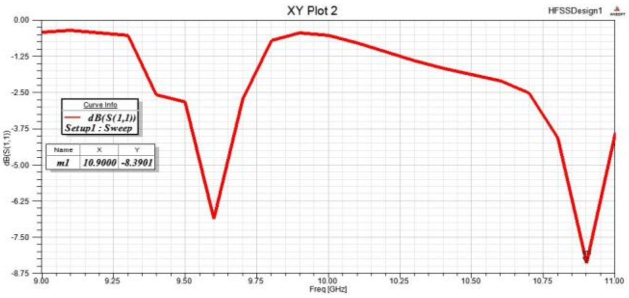

Figure 14: Return loss Vs Frequency graph of Microstrip Patch antenna using RT Duroid as Dielectric Substrate

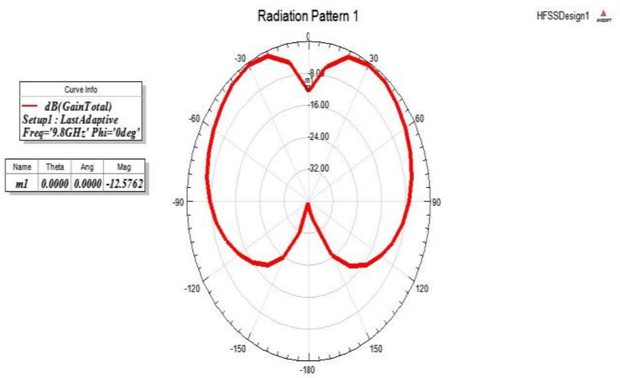

Figure 15: Radiation Pattern for RT Duroid Substrate

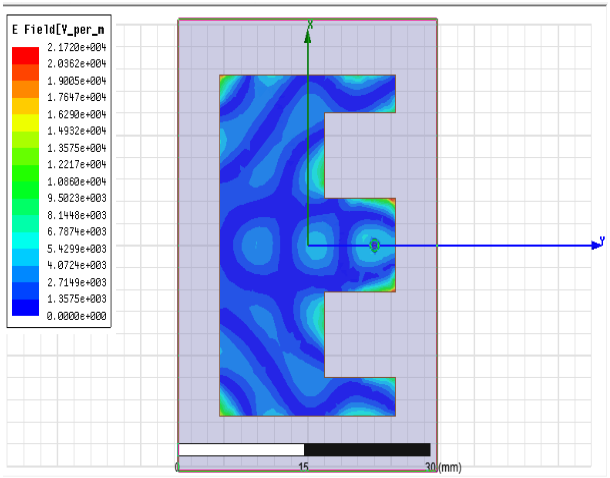

Figure 16: Simulation of Radiation Pattern for RT Duroid Substrate

In simulation when FR4_Epoxy is being used as substrate the return loss & gain is obtained as $-20.6985\ dB$&$3.04\ dB$ at operating frequency of $9.2GHz$ is shown in Network Analyser while testing. When RT Duroid is used with dielectric constant 10.5 return loss and gain are -8.3901&-12.5762 dB at operating frequency $10.9\ GHz$ is the result in testing. Similarly in simulation the return loss and gain are given as follows in table 1.

Table 1: Comparison of different substrates for Dielectric constant, Return Loss, Gain and Operating Frequency

Substrate	Dielectric Constant ε_r	Return loss in dB (Simulation)	Gain in dB	Operating Frequency GHz
FR4_Epoxy	4.4	−20.6985	3.04	9.2
RT_Duroid	10.2	−8.3901	−12.5762	10.9
Rogers_3006	6.15	−5.5760	3.7083	10.8
Rogers_3010	10.2	−13.7094	−9.5	11.10

CONCLUSION

E shaped microstrip antenna is being proposed & design is being simulated, fabricated and tested with Vector Network Analyzer using four different substrates i.e. FR4_Epoxy, RT Duroid, Rogers_3006, Rogers_3010 of dielectric constant 4.4, 10.2, 6.15, 10.2 respectively. The dielectric constant should be low for designing an antenna. FR4_Epoxy is low when compared to different substrates. Return loss should be low for designing the antenna. When compared to different substrates, when the dielectric constant is increasing the return loss is increasing of the various substrates .The return loss can be decreased by 34 % by using the FR4_Epoxy substrate when compared to Rogers_3010.We can conclude that when dielectric constant increases ,gain decreases .Roggers_3006 which is having high gain when compared to different substrates .The gain is increased by 18.022% by using the Rogers_3006 when compared to FR4_Epoxy substrate .The Dielectric Constant ε_r is increasing ,the operating frequency increases .Rogers_3010 operating frequency is high when compared to different substrates. When compared to RT_ Duroid with Rogers_3010,it is increased by 1.81%.frequency .

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