Design and Comparative Analysis of Micro strip Patch Antenna at 2.4GHz for wireless Applications

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***Abstract* - Here we discussed different dielectric substrate frequently used in microstrip patch antenna to achieve overall efficiency of antenna. Different substrates like FR4 epoxy, Roger 4350 and Benzocyclobuten are in use to achieve better gain and bandwidth. The rectangular microstrip patch antenna was analysed using Ansys HFSS and also made a comparison among the different substrates which shows different results based on same parameter. Design frequency is 2.4GHz. Microstrip patch antenna are integral components in modern wireless communication system and their performance is greatly influenced by the choice of substrate material [2].This research contributes to the understanding and practical implementation of microstrip patch antenna in various RF and wireless communication system.**

Key words - Micro strip, rectangular patch, FR4 epoxy, Rogers 4350, Benzocyclobuten.

1. INTRODUCTION

Micro strip patch antenna have various application in the field of radio frequency, wireless and satellite communication, GPS receivers and Radar system [1]. Use a rectangle as the main radiator. There are several advantages of broadband antenna, such as

1. Planar
2. Small in size
3. Simple in structure
4. Low in cost
5. Compact integration
6. Polarization
7. Easy to be fabricated [1,2,6]

Whereas the disadvantages of rectangular patch antenna are as follows

1. Narrow bandwidth
2. Surface wave excitation
3. Complex feed network
4. Sensitivity to substrate changes
5. Limited gain[2]

The choice of substrate material place in critical role in the design and performance of this antennas. In this context, the selection of substrates such as FR4 epoxy, Roger 4350 and Benzocyclobuten is of significance importance. Each of these substrate material possesses unique electrical and mechanical properties, making them suitable for different antenna design requirements.FR4 epoxy is a cost-effective dielectric material with moderate performance characteristics [4], while Roger 4350 offers excellent electrical properties and low dielectric loss [5]. Benzocyclobuten, on the other hand, is known for its high thermal stability and low dielectric constant. Whereas the limitations of FR4 epoxy is limited frequency performance, mechanical brittleness and limited heat resistance. While Roger 4350 is limited availability and environmental concerns [5]. Benzocyclobuten is of cost-effective and processing complexity.

2. ANTENNA DESIGN

We have taken FR4 epoxy as the substrate material with relative permittivity of 4.4[1] and thickness is 1.6mm [7].And with resonant frequency of 2.4 GHz.

TABLE 1 FORMULAS THE FOR SIZE OF THE PATCH

Width of the patch:	**Length of the patch:**
$W = \frac{c}{2f\sqrt{\frac{\varepsilon_r+1}{2}}}$	$L = \frac{c}{2f\sqrt{\varepsilon_{reff}}} - 2\Delta L$
$\Delta L = 0.412h\frac{(\varepsilon_{reff}+0.3)(\frac{w}{h}+0.264)}{(\varepsilon_{reff}-0.258)(\frac{w}{h}+0.8)}$ $\varepsilon_{reff} = \frac{\varepsilon_{r+1}}{2}+\frac{\varepsilon_{r-1}}{2}(\frac{1}{\sqrt{1+12h/w}})$	

TABLE 2. DESIGN VALUES FOR PATCH ANTENNA

Ground	w_1 x L_1	60 x 60
Substrate	w_3 x L_3x H	60 x 60 x 1.6
Patch	w_2 xL_2	29.4 x 38
Feed length	FL	30
Feed width	Fw	3

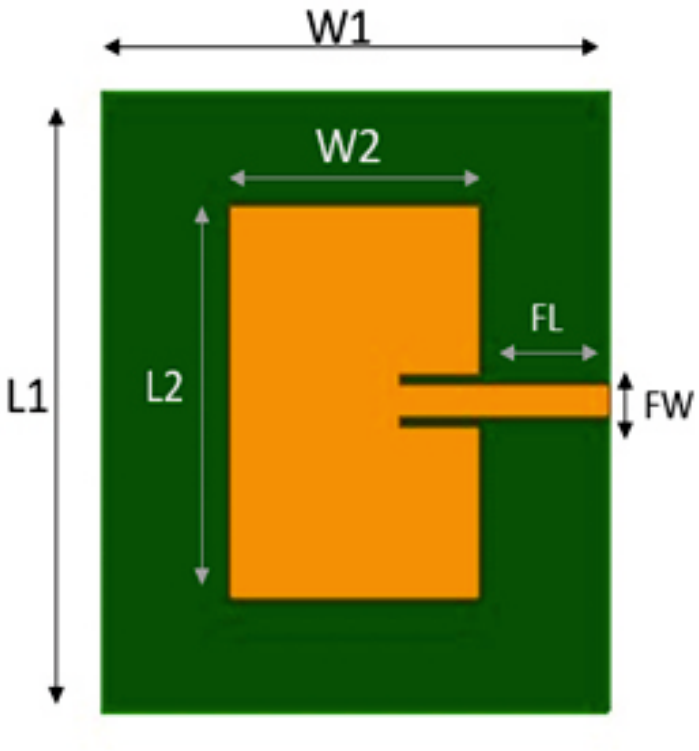

Fig1. Top view of rectangular patch antenna

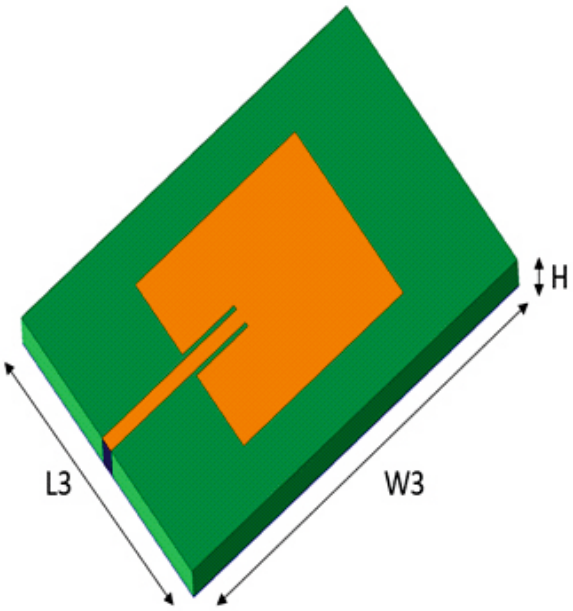

Fig2. Side view of rectangular patch antenna

PATCH ANTENNA WITH FR4 EPOXY

For the design with FR4 epoxy we have observed that it got five frequency bands ranging from 2 GHz to 7 GHz for all the five bands the VSWR < 2 which is good for the antenna.

When the designed antenna is stimulated by using HFSS the return loss and the VSWR are shown below. From the results obtained, we could observed that the designed antenna is having a band frequency operation of 2.4GHz with -29.9 dB return loss [4].

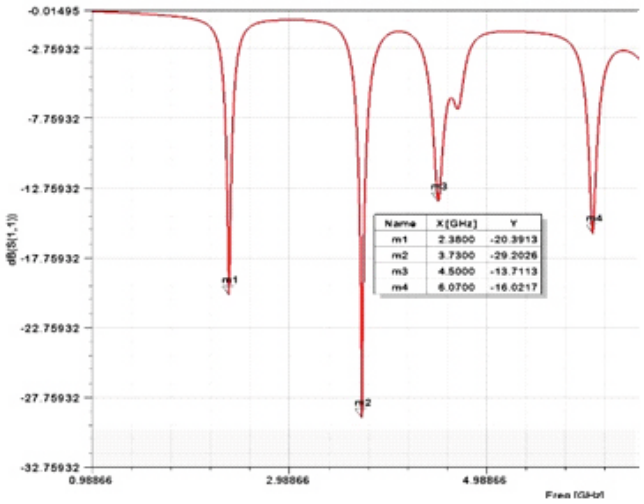

Fig 3.S11 parameter of rectangular shape microstrip antenna with FR4 epoxy material

S11 represents how much power is reflected from the antenna, and hence is known as the reflection coefficient also referred as return loss. S11 parameter is a critical measure of an antenna's performance and its value from 2GHz to 7GHz indicates the frequency range in which the antenna operates efficiency. Antennas operating in the 2GHz to 7GHz frequency range find applications in various wireless communication systems such as

1. Radar systems
2. 5G Networks
3. Aerospace and Defense
4. Satellite communication[3,8]

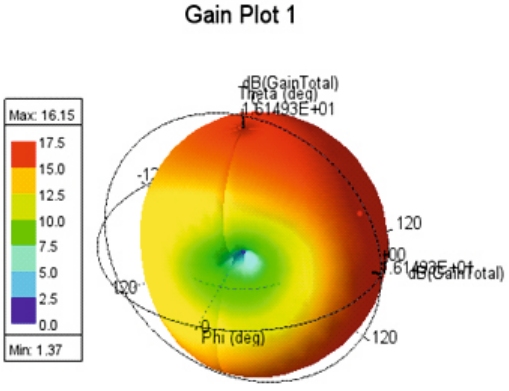

Fig4a.Gain plot of rectangular shape microstrip patch antenna with frequency 2.38GHz

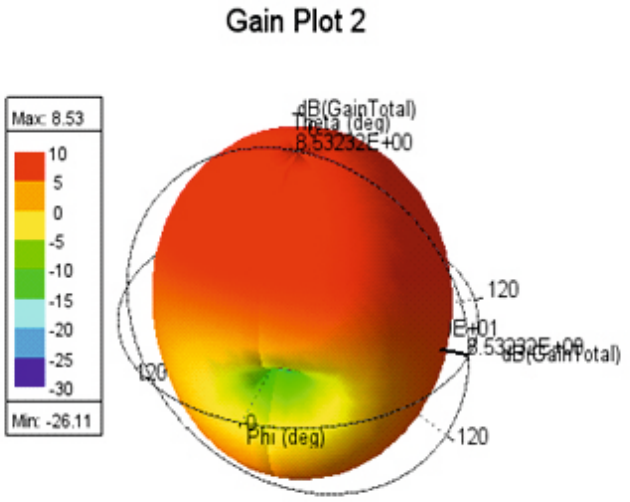

Fig4b.Gain plot of rectangular shape microstrip patch antenna with frequency 3.73GHz

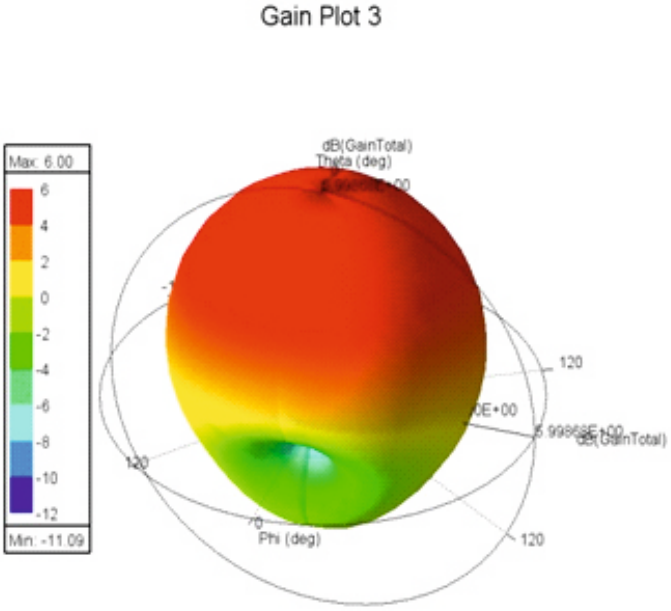

Fig4c.Gain plot of rectangular shape microstrip patch antenna with frequency 4.5GHz

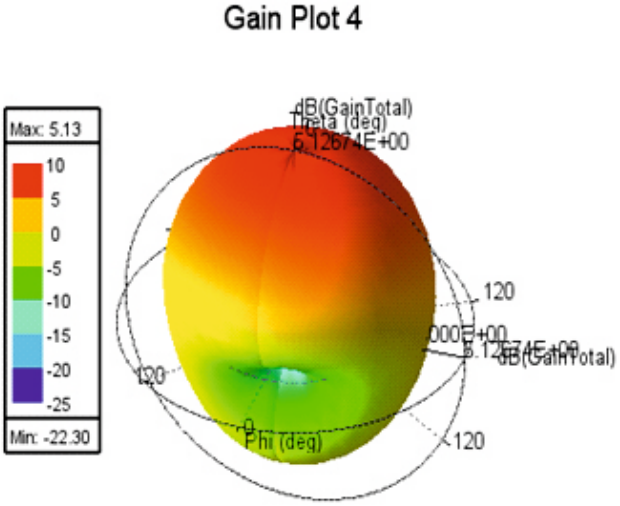

Fig4d.Gain plot of rectangular shape microstrip patch antenna with frequency 6GHz

In antenna gain is important as it represents the ability of an antenna to direct or attention its radiated power in a particular route. Higher advantage shows elevated performance in transmitting or receiving signals in a specific course, enhancing the antenna's overall performance. The antenna with gains in the range of 5dB to 20dB are good.

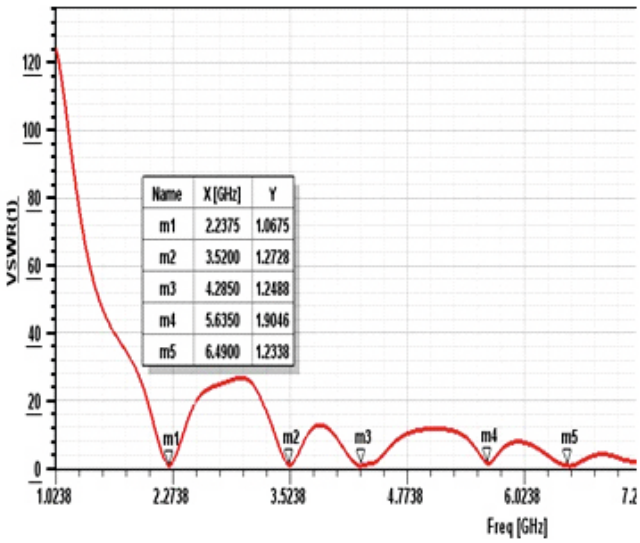

Fig5. VSWR of rectangular shape microstrip patch antenna with FR4 epoxy material.

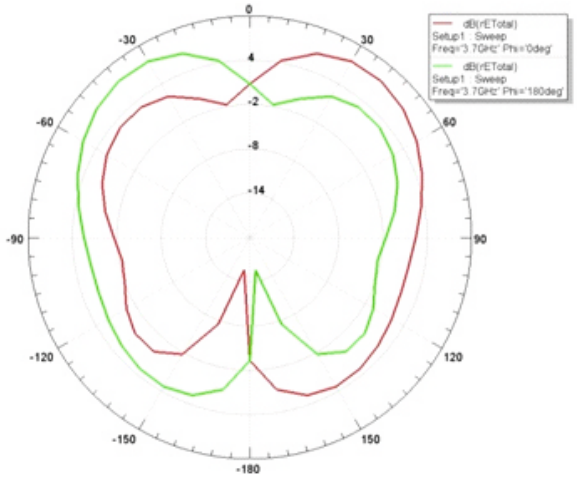

Fig6a. RE plot of rectangular shape microstrip patch antenna with frequency 2.38GHz.

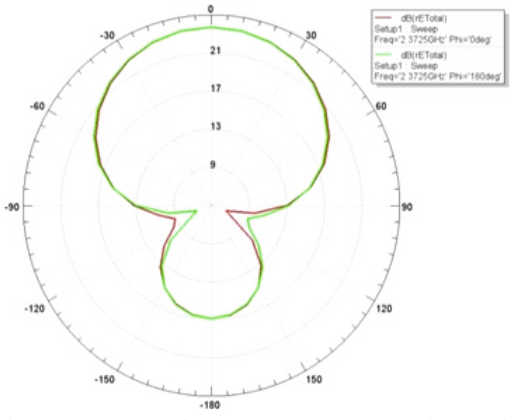

Fig6b. RE plot of rectangular shape microstrip patch antenna with frequency 3.7GHz.

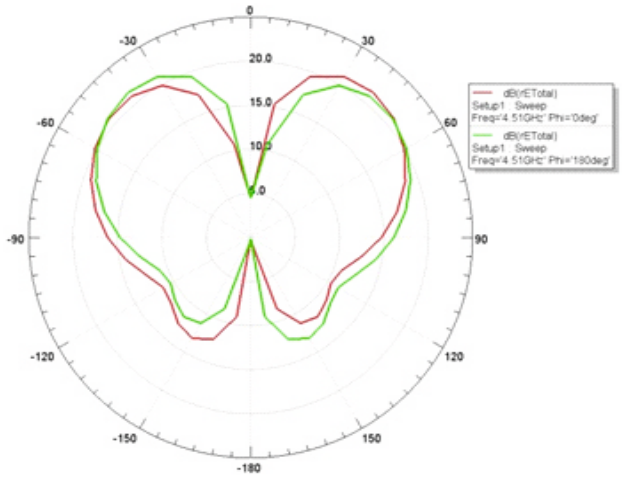

Fig6c. RE plot of rectangular shape microstrip patch antenna with frequency 4.51GHz.

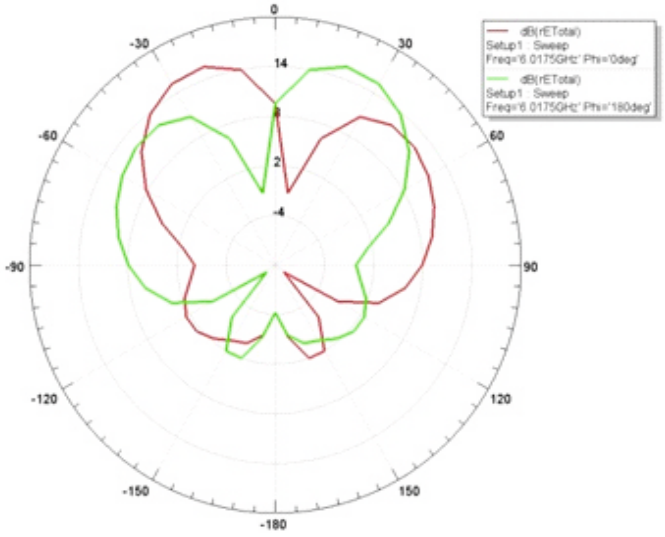

Fig6d. RE plot of rectangular shape microstrip patch antenna with frequency 6GHz.

The electromagnetic model is defined as a mathematical or graphical representation of the properties of electromagnetic radiation emitted from an antenna operating in the direction of electromagnetic wave emission . A radiation pattern can represent several quantities, such as gain ,directivity and electric field.

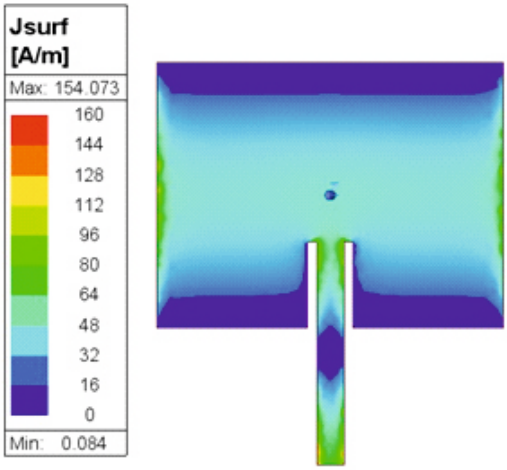

Fig7a.Current efficiency of rectangular shape microstrip patch antenna with frequency 2.38GHz.

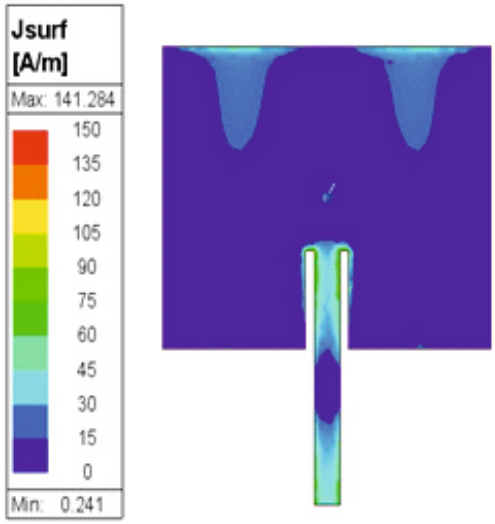

Fig7b.Current efficiency of rectangular shape microstrip patch antenna with frequency 3.73GHz

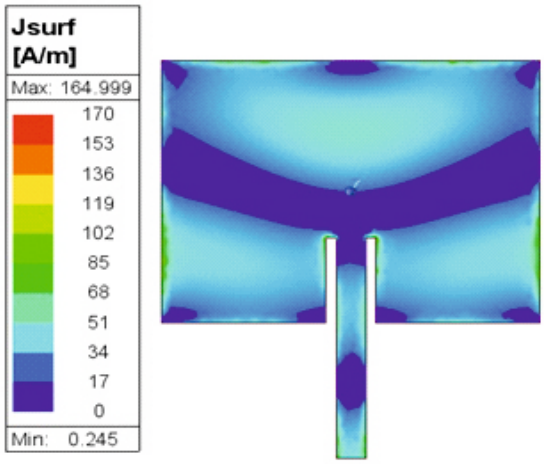

Fig7c.Current efficiency of rectangular shape microstrip patch antenna with frequency 4.5GHz.

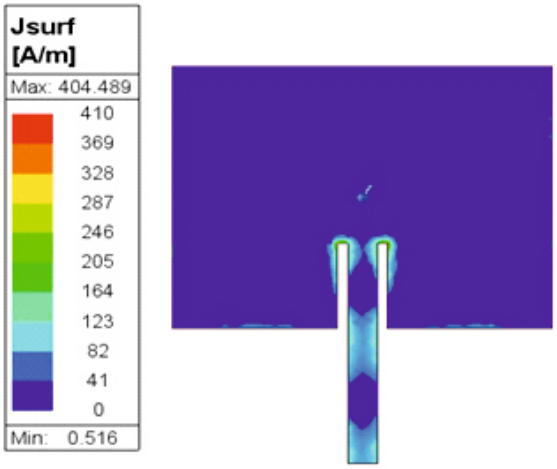

Fig7d. Current efficiency of rectangular shape microstrip patch antenna with frequency 6GHz.

Antenna efficiency is the ratio of power radiated by the antenna to the power supplied to the antenna. Antenna efficiency is usually expressed as a percentage ranging from 0%to 100%.

Table 3. Antenna Parameters

Frequency	S11	VSWR	Gain	.	Bandwidth
f_1	2.38GHz	1.0675	16.15dB	92%	57.8MHz
f_2	3.73GHz	1.2728	8.53dB	40%	87.2MHz
f_3	4.5GHz	1.2488	6.0dB	42%	83.4MHz
f_4	6.0GHz	1.9046	5.13dB	43%	107.9MHz

PATCH ANTENNA WITH ROGER 4350

The Roger 4350 has permittivity of 3.66 [6] for the same patch antenna which is used with FR4 in that substrate has been replaced with Roger 4350, in the simulation of antenna with Roger 4350 as substrate has given the 4-frequency band ranging from 2GHz to 8GHz.

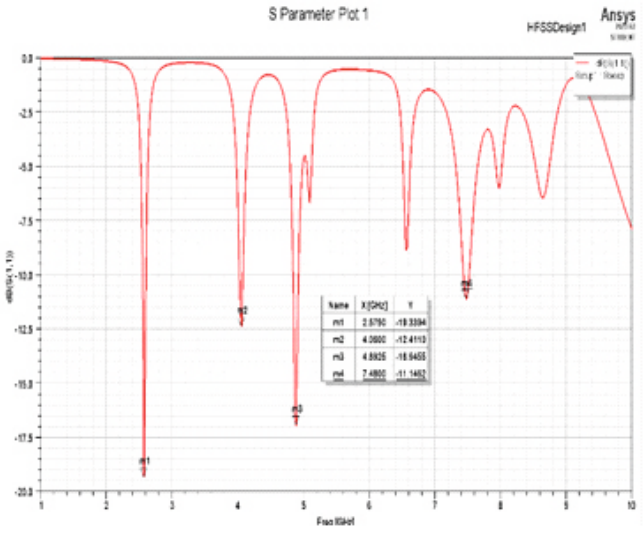

Fig8. S11 parameter of rectangular shape microstrip patch antenna with Roger 4350 material.

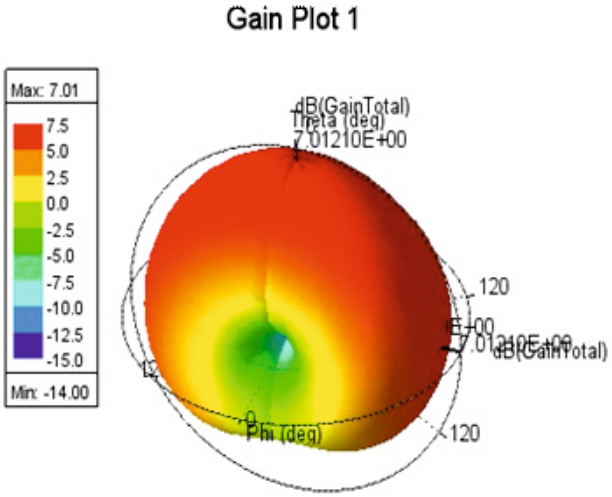

Fig9a. Gain plot of rectangular shape microstrip patch antenna with frequency 2.5GHz.

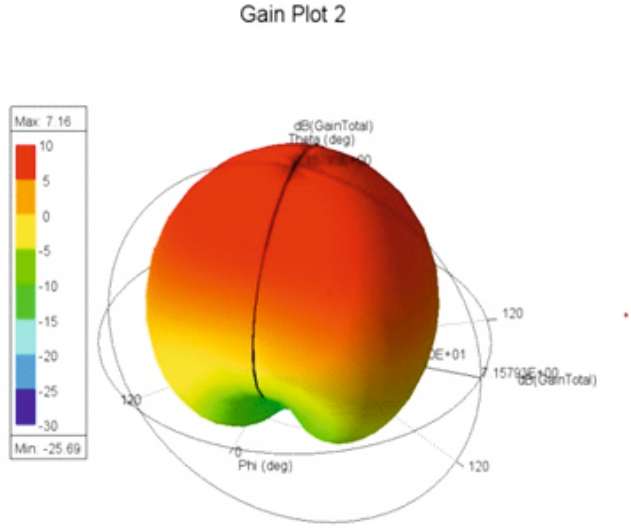

Fig9b: Gain plot of rectangular shape microstrip patch antenna with frequency 4.0GHz.

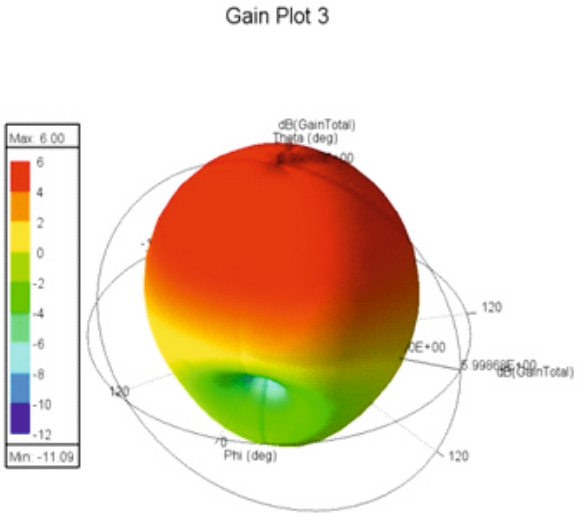

Fig9c. Gain plot of rectangular shape microstrip patch antenna with frequency 4.8GHz.

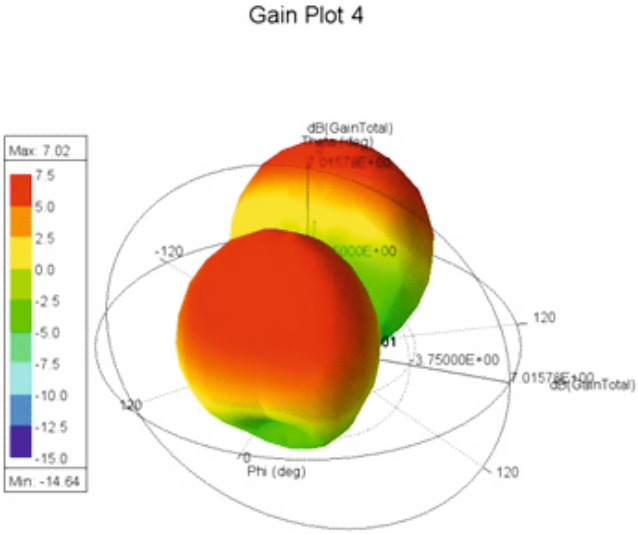

Fig9d. Gain plot of rectangular shape microstrip patch antenna with frequency 7.4GHz.

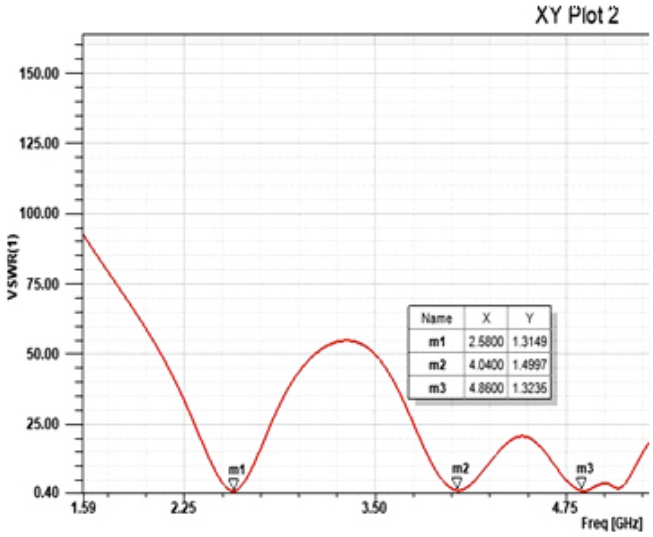

Fig10c. VSWR of rectangular shape microstrip patch antenna with Roger 4350 material.

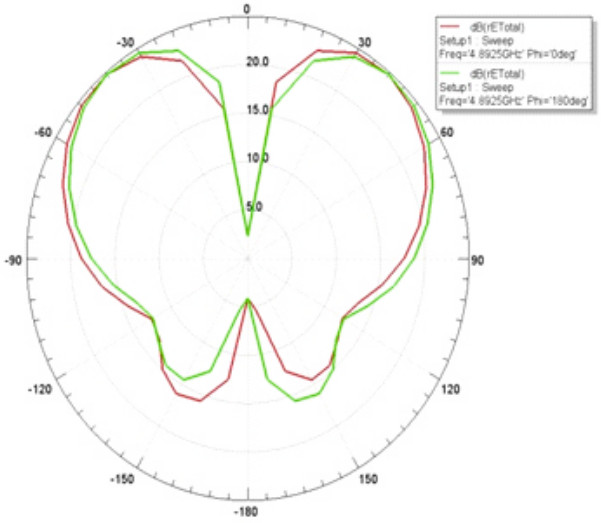

Fig11c. RE plot of rectangular shape microstrip patch antenna with frequency 4.8GHz.

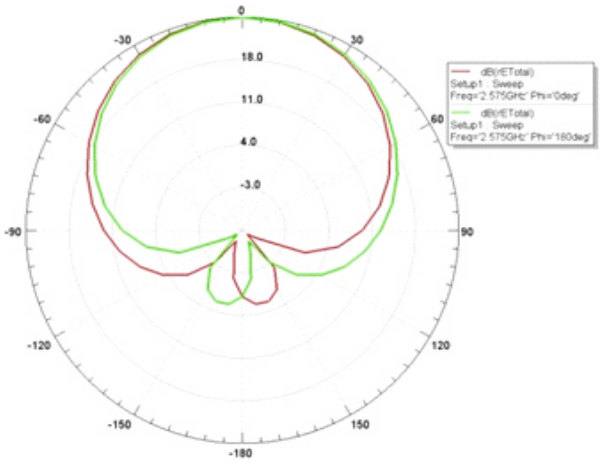

Fig11a. RE plot of rectangular shape microstrip patch antenna with frequency 2.5GHz.

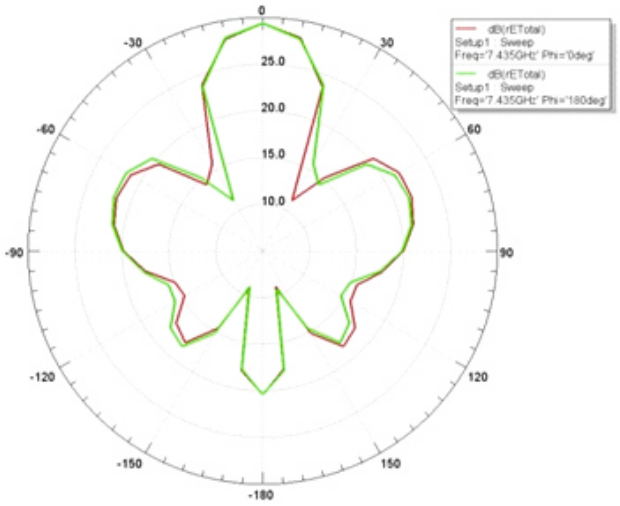

Fig11d. RE plot of rectangular shape microstrip patch antenna with frequency 7.8GHz.

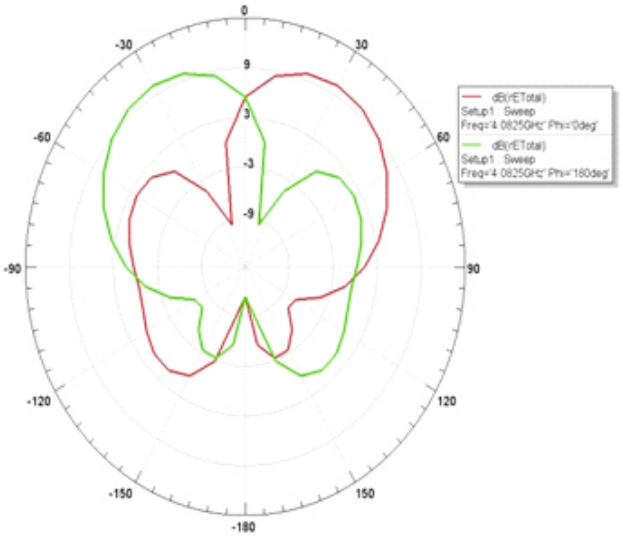

Fig11b. RE plot of rectangular shape microstrip patch antenna with frequency 4.0GHz.

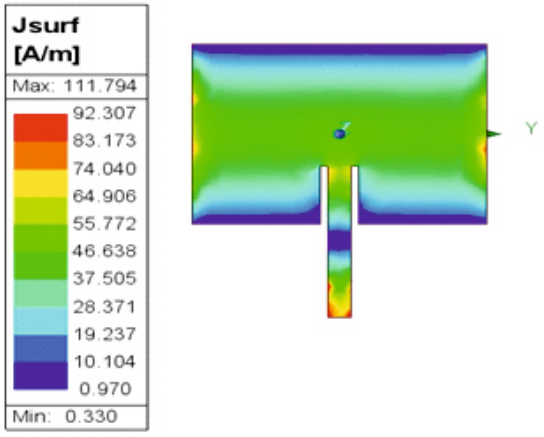

Fig12a. Current efficiency of rectangular shape microstrip patch antenna with frequency 2.5GHz

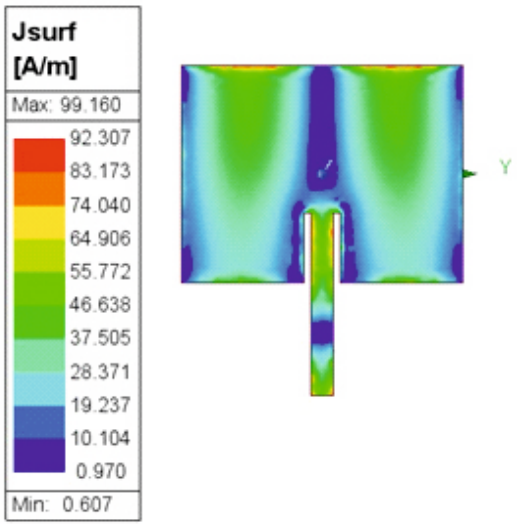

Fig12b:Current efficiency of rectangular shape microstrip patch antenna with frequency 4.0GHz.

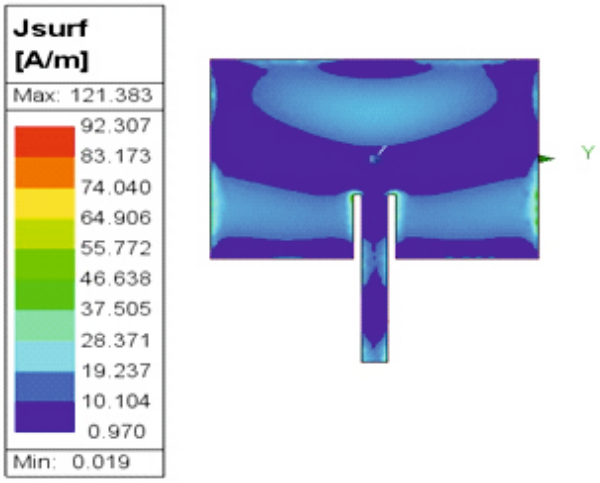

Fig12c. Current efficiency of rectangular shape microstrip patch antenna with frequency 5.7GHz.

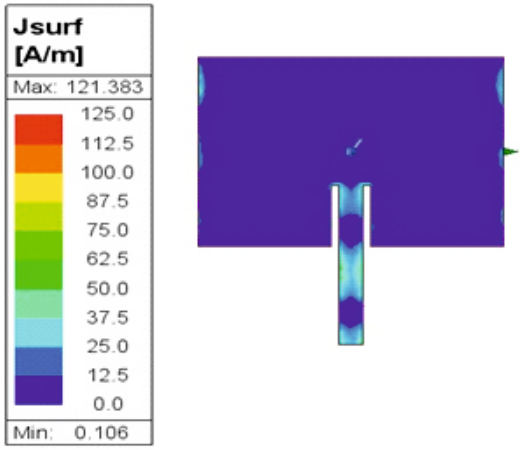

Fig12d. Current efficiency of rectangular shape microstrip patch antenna with frequency 7.8GHz.

Table 4 :Antenna Parameters

Frequency	S11	VSWR	Gain	η	Bandwidth
f_1	2.5GHz	1.314	7.01dB	58%	50.9MHz
f_2	4.0GHz	1.449	7.16dB	81%	52MHz
f_3	4.8GHz	1.323	6.0dB	61%	82MHz

Patch antenna with benzocyclobuten

Now we have replaced Roger 4350 substrate with benzocyclobuten material for same patch antenna and the following results are represented. The benzocyclobuten material has a permittivity of 2.6 [6].

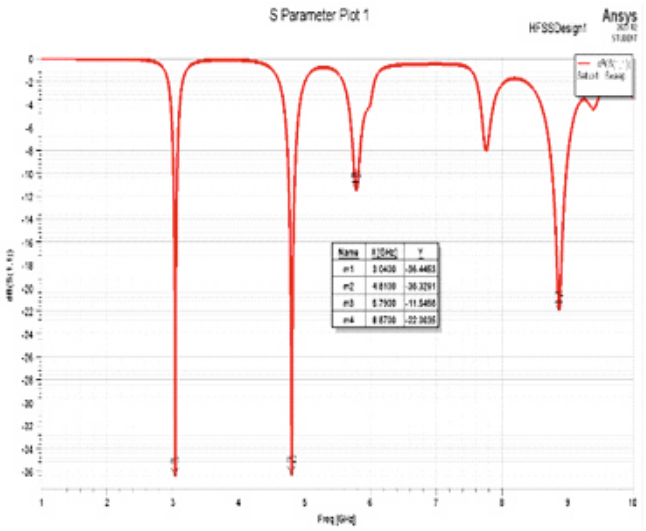

Fig13a. S11parameter of rectangular shape microstrip patch antenna with benzocyclobuten material.

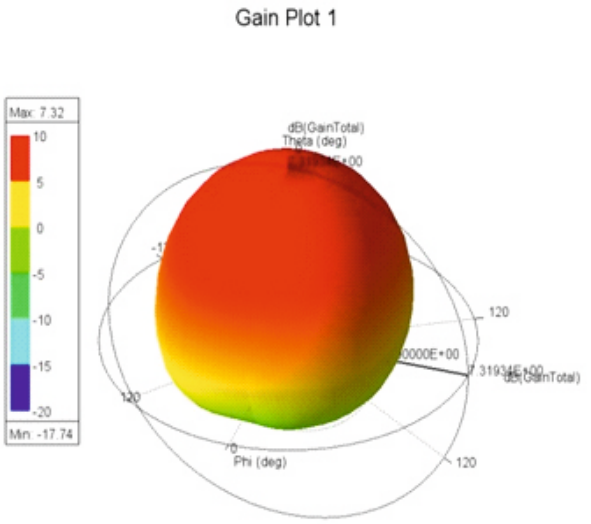

Fig14a. Gain plot of rectangular shape microstrip patch antenna with frequency 3.0GHz

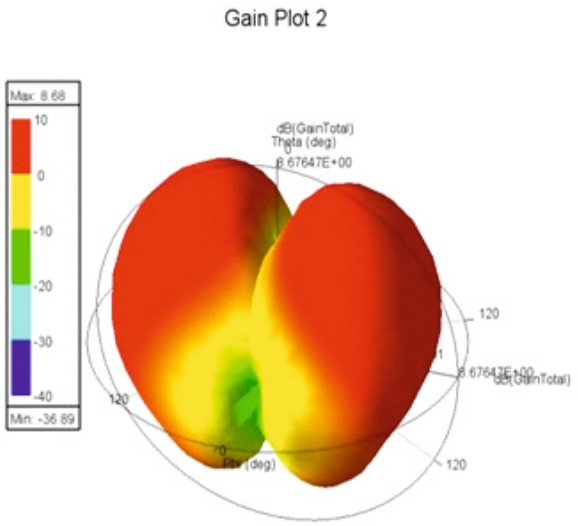

Fig14b. Gain plot of rectangular shape microstrip patch antenna with frequency 4.8GHz

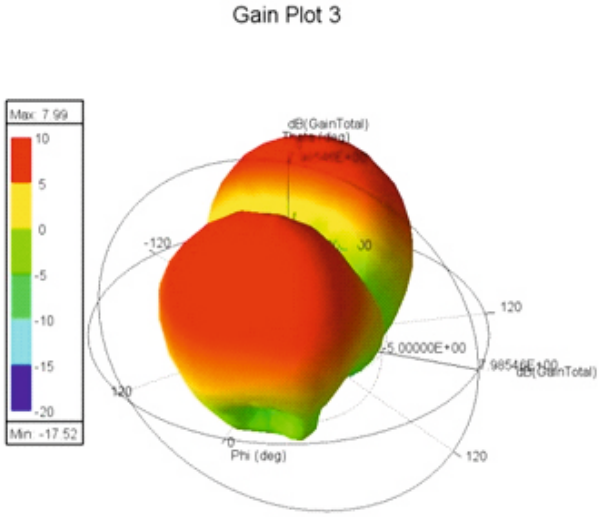

Fig14c. Gain plot of rectangular shape microstrip patch antenna with frequency 5.7GHz.

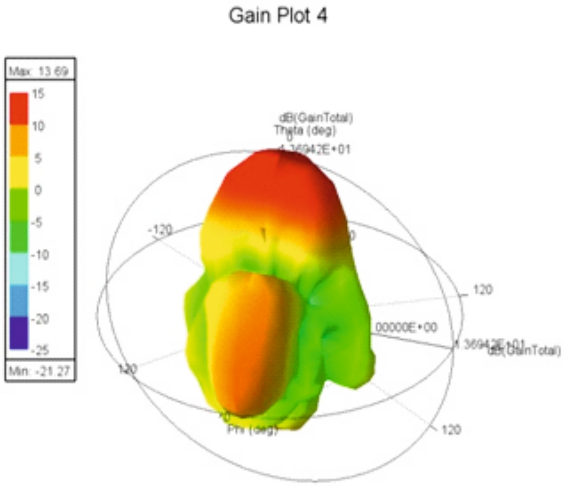

Fig14d. Gain plot of rectangular shape microstrip patch antenna with frequency 8.8GHz.

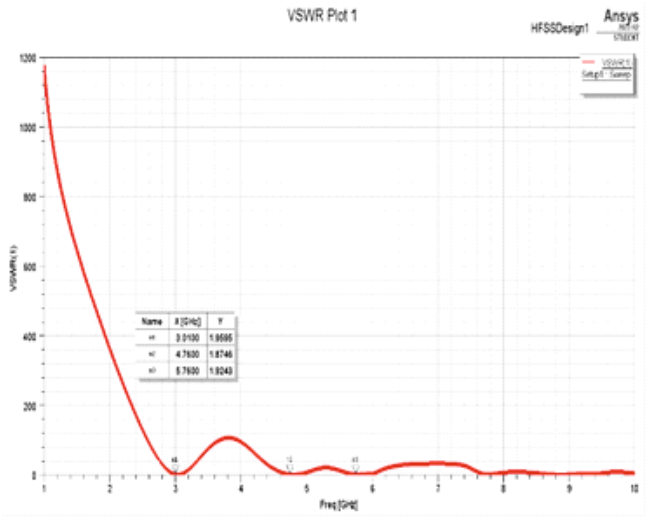

Fig17.VSWR of rectangular shape microstrip patch antenna with Benzocyclobuten material.

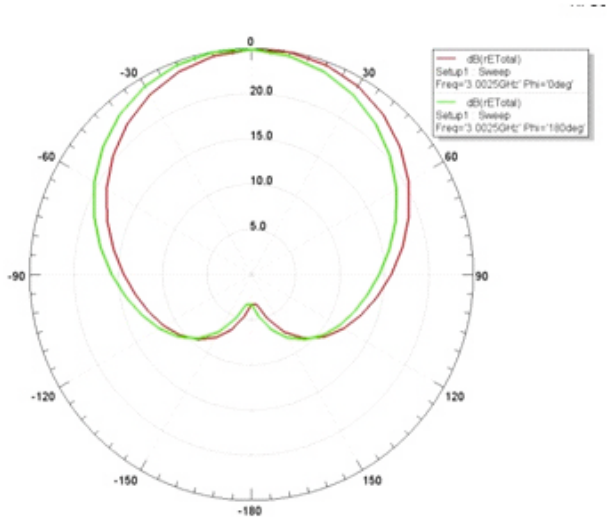

Fig15a. RE plot of rectangular shape microstrip patch antenna with frequency 3.0GHz.

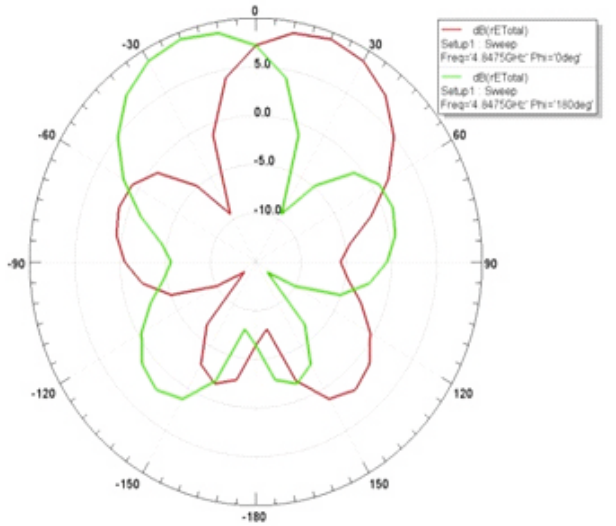

Fig15b.RE plot of rectangular shape microstrip patch antenna with frequency 4.8GHz.

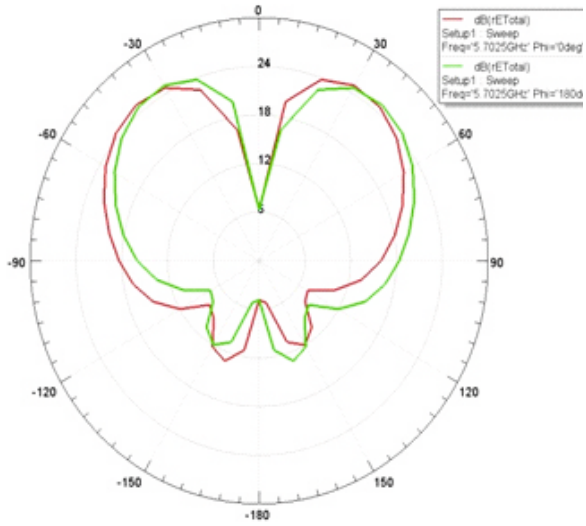

Fig15c. RE plot of rectangular shape microstrip patch antenna with frequency 5.7GHz

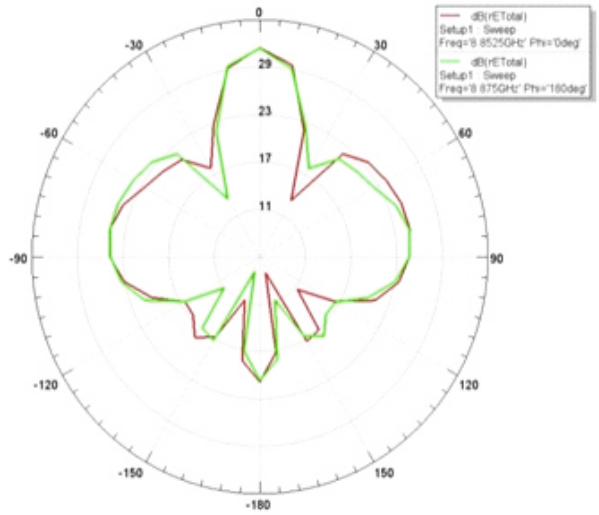

Fig15d.RE plot of rectangular shape microstrip patch antenna with frequency 8.8GHz.

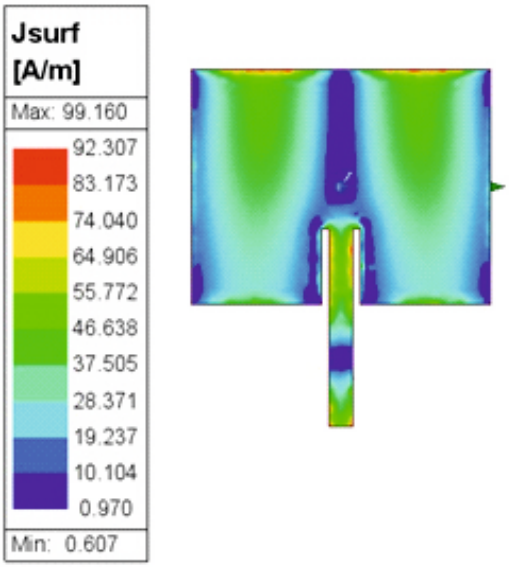

Fig16a. Current efficiency of rectangular shape microstrip patch antenna with frequency 3.0GHz.

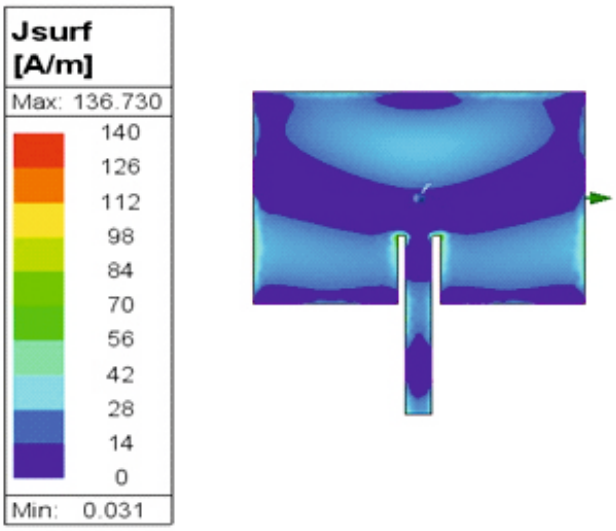

Fig16b. Current efficiency of rectangular shape microstrip patch antenna with frequency 4.8GHz.

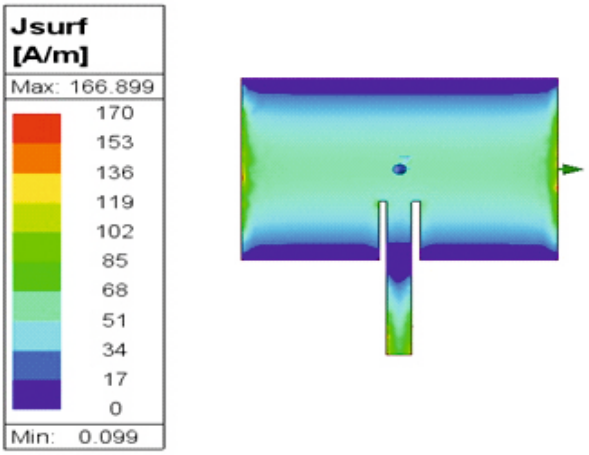

Fig16c. Current efficiency of rectangular shape microstrip patch antenna with frequency 5.7GHz.

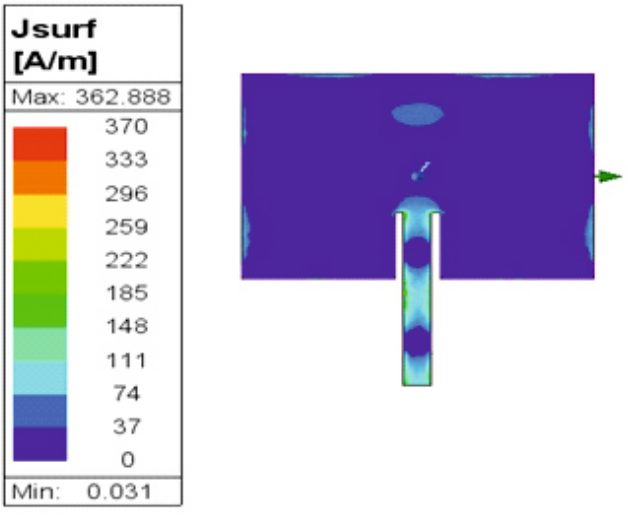

Fig16d. Current efficiency of rectangular shape microstrip patch antenna with frequency 8.8GHz.

Table 5. Antenna Parameters

Frequency	S11	VSWR	Gain	η	Bandwidth
f_1	3.0GHz	1.959	7.32dB	34%	54.9MHz
f_2	4.8GHz	1.874	8.68dB	77%	102MHz
f_3	5.7GHz	1.924	7.99dB	58%	59.3MHz

Conclusion

A comparative analysis was conducted on three different electric substrates ,namely Fr4epoxy ,Roger4350 and Benzocyclobuten in order to design a millimeter wave microstrip patch antenna that operates in the frequency band of 2.4GHz .

These substrates offers a diverse range of possibilities for achieving specific performances characteristics. Each substrates material brings unique advantages such as FR4's cost effectiveness, Benzocyclobuten's low dielectric loss ,and Roger 4350's high frequency capabilities.

The selection of substrates depends on the desired applications and performance requirements. Careful consideration of these substrate options allows for tailored designs that optimize factors rectangular shape microstrip like bandwidth, gain ,and efficiency in microstrip patch antenna implementations.

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