Analysis of C Band Rectangular Microstrip Patch Antenna in Varying Dielectric Substrates

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Abstract— **In this paper, we propose to design a Rectangular Microstrip Patch Antenna with an efficient substrate for various communication systems working in S-band and C-band zones using the user-friendly antenna design tool, Computer Simulation Technology (CST) studio. The C-band (4-8GHz) finds application in satellite communication due to reduced fading effect and in medical application for baby monitoring. This is a comparative study of four different types of substrates (Bakelite, FR-4, TLC-30 and RT 5880) based on their return loss, far-field radiation, and efficiency analysis which in turn will affect the antenna performance. The parameters are evaluated using the time-domain analysis which helps in understanding good impedance matching and distortion less properties of the antenna design.**

*Keywords- **Antenna, Bakelite, Communication system, CST, FR-4, Microstrip patch, RT 5880, Time domain, TLC-30***

I. INTRODUCTION

The wireless communication techniques are improving and expanding at a phenomenal rate. The need for microwave materials with greater versatility is high on demand as the need for sophisticated integrated circuits increase. This, in turn, has increased the necessity for efficient, small and low-cost antenna systems [1]. Due to its robust design, good performance, ease of fabrication and extent of usage, the Microstrip Patch Antennas are highly preferred for various applications in mobile and satellite communication, global positioning systems (GPS), Radio frequency identification (RFID), WiMax, Radar, Rectennas [2]. Nowadays, researched are being done to involve microstrip patch antennas in the area of medicine, in the development of implantable antennas with proper selection of substrate and superstrate materials. They are used in the development of bio-sensors and therapeutic applications [7].

The parameters that are taken into consideration while design of a microstrip patch antenna are type of substrate, shape of patch, dimensions of patch, feeding technique, resonant frequency, substrate thickness [8]. The Microstrip Patch Antenna consists of a metallic patch on a grounded substrate. The metallic patch can take many different configurations; however, the rectangular and circular patches are the most popular because of ease of analysis and fabrication, and their attractive radiation characteristics [5].

The substrate is a base or container on which microstrip patch (metallic sheet) antenna is fabricated and it plays an important role in microstrip antenna functioning. The substrate in microstrip antennas is principally needed for the mechanical support of the antenna. To provide this support, the substrate should consist of a dielectric material, which may affect the electrical performance of the antenna, circuits and transmission line. Right substrate selection is a must on the basis of cost, efficiency, and size.

The patch antenna is fabricated by etching the antenna element pattern in a metal trace bonded to an insulating dielectric substrate with a continuous metal layer bonded to the opposite side of the substrate which forms a ground plane [3]. For better antenna performance, a thick dielectric substrate having a low dielectric constant is desirable since this provides better efficiency, larger bandwidth, and better radiation.

Each substrate, based on the dielectric constant value, finds application in different frequency ranges [4]. We hereby propose a comparative study of four different types of dielectric substrates (Bakelite, FR-4, TLC-30 and Rogers RT5880) for a Rectangular Microstrip patch antenna, based on their Return loss, far-field radiation and efficiency using the Computer simulation technology (CST) studio.

II. DIELECTRIC SUBSTRATES

There are different substrate materials for designing of the microstrip patch antenna. A dielectric material is an electrical insulator that can be contrasted by applying electrical fields. Selection of proper substrate material is an important effort in designing of the patch antenna.

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The substrate materials have two basic properties such as dielectric constant & loss tangent. In general, for Microstrip Patch antenna, increase in loss tangent vitiates the performance of that antenna [1]. Different dielectric materials show striking variations in the performance parameters such as gain, directivity and return loss [6].

Table 1

Substrate	Bakelite	FR-4	TLC-30	RT 5880
Dielectric constant (εr)	4.78	4.36	3.2	2.2
Loss tangent (tan δ)	0.03	0.013	0.002	0.0004

II .1. BAKELITE SUBSTRATE

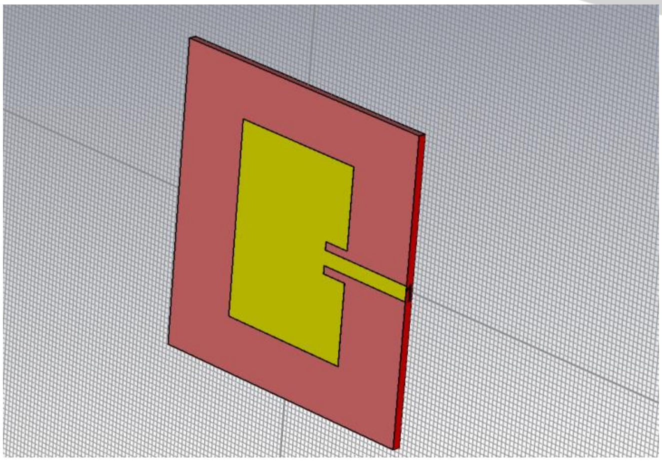
Bakelite is a synthetic plastic which is derived by the elimination reaction between formaldehyde and phenol and is revolutionary for its electrical non-conductivity and heat-resistant properties [10]. It also provides good mechanical strength. It can be molded easily and used in electronics, electrical power generation, automobile and aerospace industries.

SIMULATION RESULTS

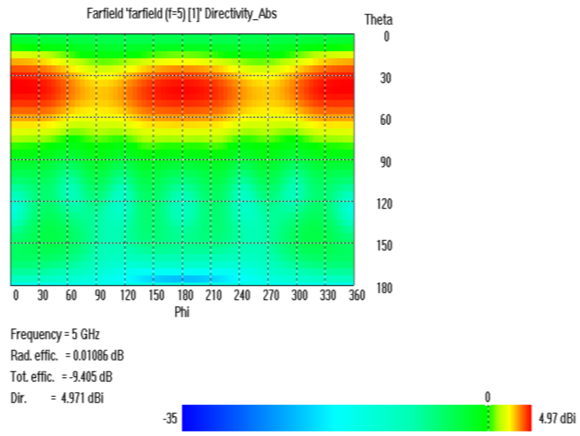
The following results were obtained during the simulation process under the time domain for the chosen parameters.

A. Antenna Design

The template settings of the ground plane for time domain analysis is as follows – length is 60mm, width is 60mm, the thickness is 0.03 mm and the material is copper. The Bakelite substrate has a length of 60mm, the width of 60mm and thickness of 1.59mm. Patch is of length 29mm, width 38.4mm with feed line dimensions 39 X 3 X 3.15(mm) and the material used for the patch is copper. The excitation is given at the end of line feed and the entire process is simulated and the return loss is observed.



B. Far-field radiation (f=5)

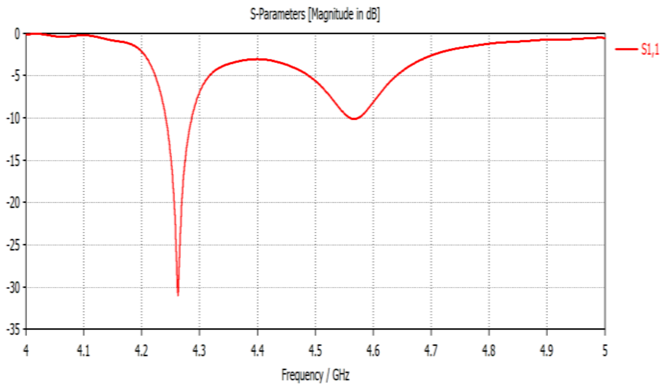


The far-field directive radiation at a frequency of 5GHz is 4.97dB.

C. S-Parameter- Return loss(S11)

S11 is a measure of how much power is reflected back at the antenna port due to mismatch from the transmission line. When connected to a network analyzer, S11 measures the amount of energy returning to the analyzer – not what's delivered to the antenna. The amount of energy that returns to the analyzer is directly affected by how well the antenna is matched to the transmission line. A small S11indicates a significant amount of energy has been delivered to the antenna. S11 values are measured in dB and are negative.

In this analysis, the return loss ripples between 4GHz and 5GHz and are obtained as follows:



The sudden dip occurs at 4.27GHz with -30db and almost nears 0dB at 5GHz.

D. Efficiency

The efficiency of an antenna is the ratio of the power delivered to the antenna, relative to the power radiated from the antenna. A high-efficiency antenna has most of the power present at the antenna's input radiated away. A low-efficiency antenna has most of the power absorbed as losses within the antenna or reflected away due to impedance mismatch.

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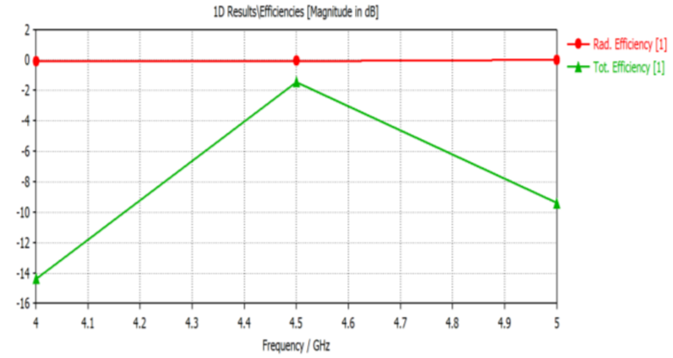


The radiation efficiency is found to be almost 0dB at 4.5GHz and 0.01086dB at 5GHz. The total efficiency is found to be -1.98dB at 4.5GHz and -9.405dB at 5GHz.

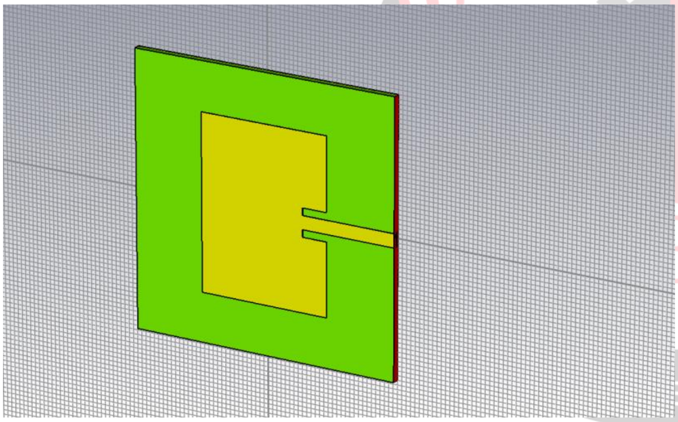
II.2. FR-4 SUBSTRATE

"FR" stands for flame retardant and denotes that the material complies with the standard UL94V-0. FR-4 is most commonly used as an electrical insulator possessing considerable mechanical strength. The material is known to retain its high mechanical values and electrical insulating qualities in both dry and humid conditions.

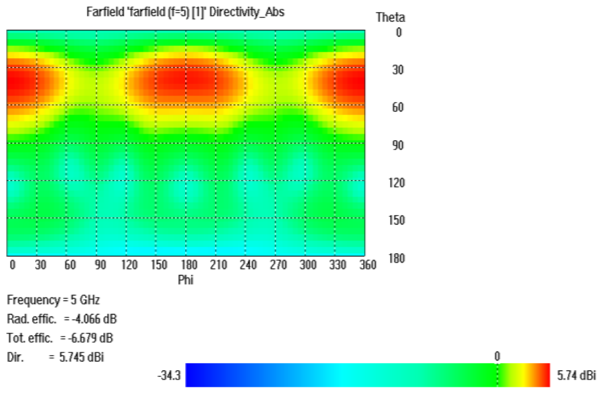
SIMULATION RESULTS

A. Antenna design

The FR-4(lossy) substrate has a length of 60mm, the width of 60mm and thickness of 1.59mm.



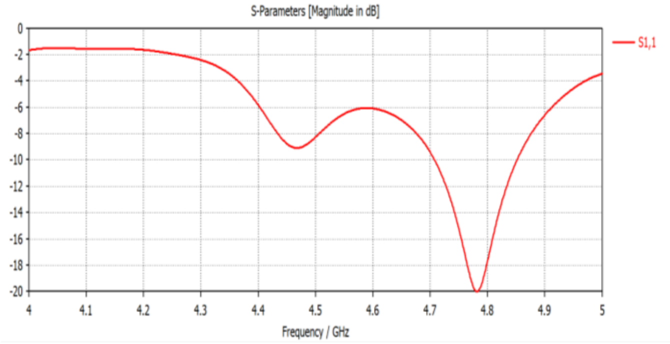
B. Far-field Radiation



The far-field directive radiation at a frequency of 5GHz is 5.74dB.

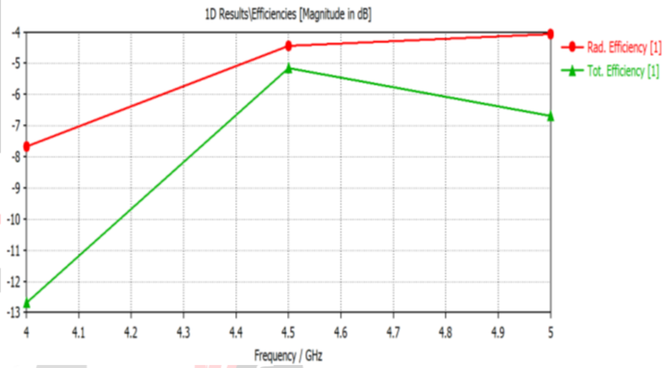
C. S-Parameter- Return loss(S11)

In this analysis, the return loss ripples between 4GHz and 5GHz and are obtained as follows:



The sudden dip occurs at 4.78GHz with -20Db and nearly reaches -4dB at 5GHz.

Efficiency



The radiation efficiency is found to be -4.4dB at 4.5GHz and -4.066dB at 5GHz. The total efficiency is found to be approximate -5.21dB at 4.5GHz and -6.679dB at 5GHz.

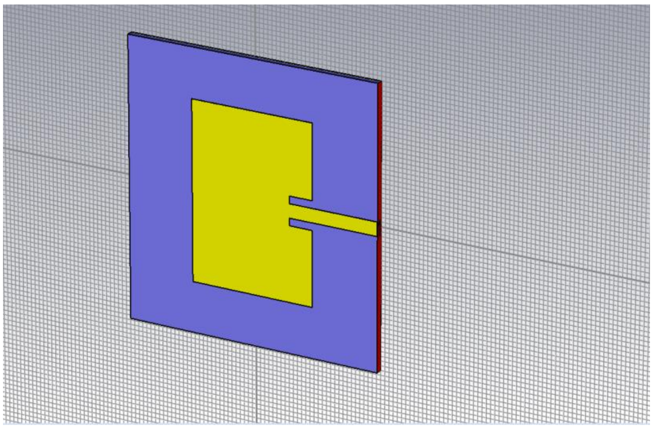
II .3. TLC-30 SUBSTRATE

Taconic TLC substrates are specifically designed to meet the low-cost objectives for newly emerging commercial RF/microwave applications.

SIMULATION RESULTS

A. Antenna design

The TLC-30(lossy) substrate has a length of 60mm, the width of 60mm and thickness of 1.59mm.



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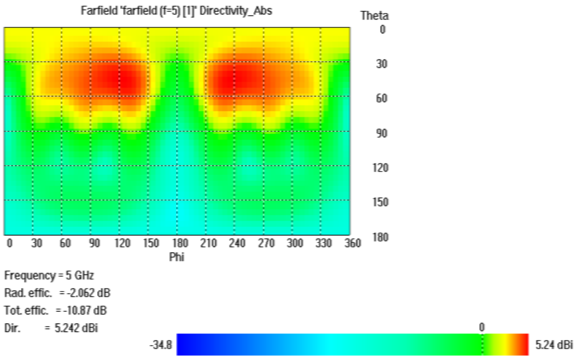
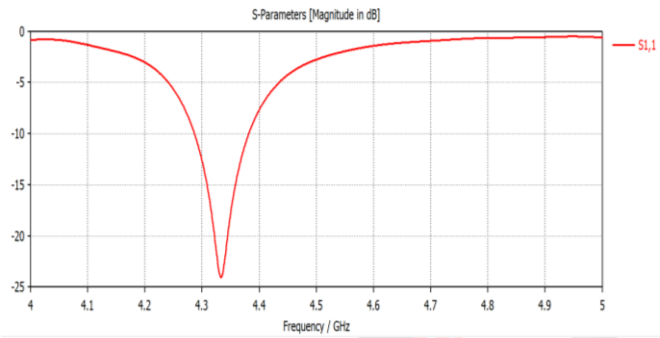
B. Far-field Radiation



The far-field directive radiation at a frequency of 5GHz is 5.24dB.

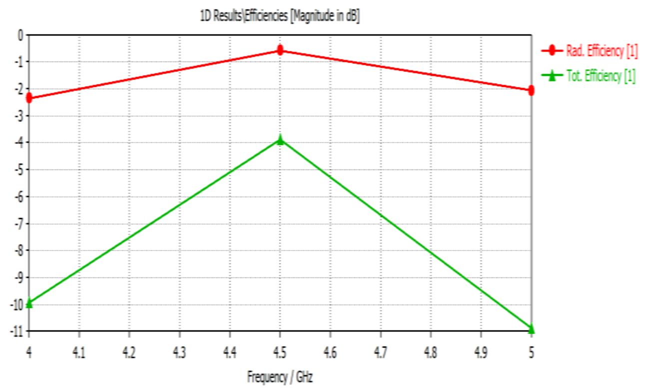
C. S-Parameter-Return loss(S11)

In this analysis, the return loss ripples within the range of 4GHz to 5GHz and is obtained as follows:



The sudden dip occurs at 4.34GHz with -24dB and around 1dB at 5GHz.

D. Efficiency



The radiation efficiency is found to be approximate -1.52dB at 4.5GHz and -2.062dB at 5GHz. The total efficiency is found to be -4.02dB at 4.5GHz and -10.87dB at 5GHz.

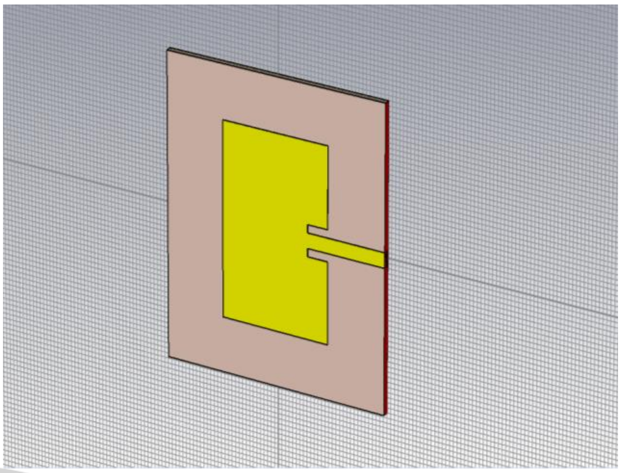
II.4. ROGERS RT 5880

RT 5880 high-frequency laminates are PTFE composites reinforced with glass microfibers. The randomly oriented microfibers result in exceptional dielectric constant uniformity. RT 5880 laminates have the lowest electrical loss of any reinforced PTFE material, low moisture absorption, are isotropic, and have uniform electrical properties over frequency.

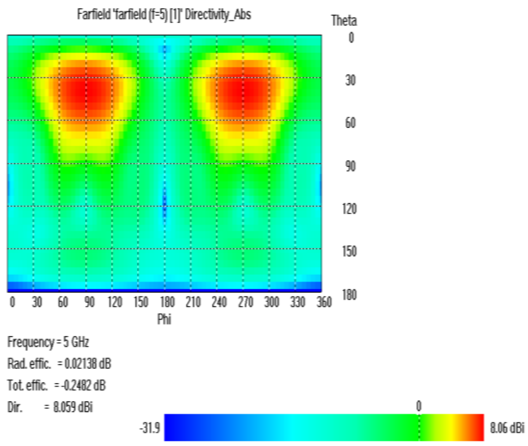
SIMULATION RESULTS

A. Antenna design

The Rogers RT 5880 (lossy) substrate has a length of 60mm, the width of 60mm and thickness of 1.59mm.

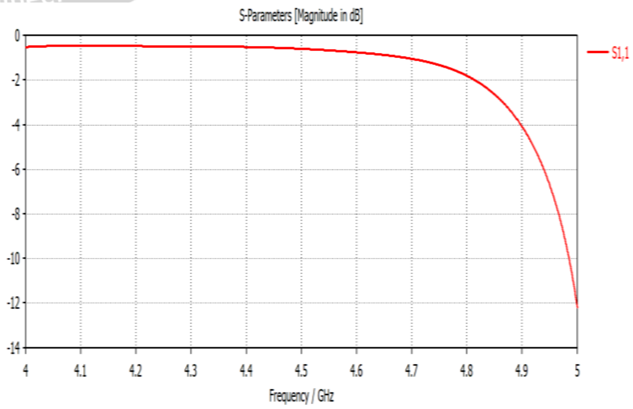


B. Far-field Radiation



The far-field directive radiation at a frequency of 5GHz is 8.06dB.

C. S-Parameter – Return loss(S11)



In this analysis, the return loss is monitored between 4GHz and 5GHz. It is found that the return loss value remains consistent at approximately -0.8dB up to 4.5GHz and the major dip occurs a little beyond 5GHz with nearly -14dB.

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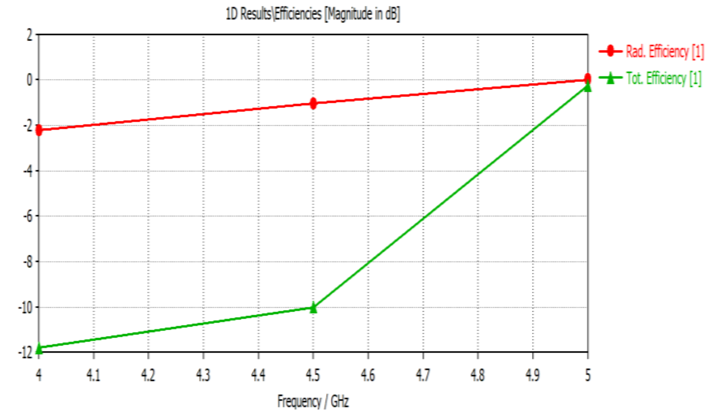
D. Efficiency



The radiation efficiency is found to be approximate -1.25dB at 4.5GHz and 0.02138dB at 5GHz. The total efficiency is found to be -10.02dB at 4.5GHz and -0.2482dB at 5GHz.

III. CONCLUSION

On an overall basis, this paper was a comparative study of four different types of substrates used in designing Microstrip Patch Antenna in the UHF range specifically between 4GHz and 5GHz using the CST software studio. The use of substrate material with a higher dielectric constant in microstrip patch antenna design results in degradation of antenna performance but the size of the antenna reduces.

Depending on the analysis based on the performance of the antenna system, the results are found to be the best for Rogers RT 5880 substrate as it gives a total efficiency of 97.182% (-0.2482dB) at the considered frequency of 5GHz. The far-field radiative directivity is comparatively higher for RT 5880, thus making it more essential for long distance communicative analysis. Thus, RT Duroid substrate proves to be more suitable for high frequency applications [9]. On an overall basis, looking into the values of dielectric constant and the tangent loss of the substrate, Rogers RT 5880 can be given preference over other three substrates which were considered. Such antennas are very much demanding in real time applications employing a wide range of microwave frequencies.

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