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Design & Comparison of Linearly Polarized Rectangular Micro strip Patch Antenna Using Different Substrate CST Microwave Studio

[1]Md. Ashraful Haque, [2]A.H.M. Golam Sarwar, [3]Md.Abdur Rashid

[1, 2]Department of Electrical and Electronic Engineering Islamic University of Technology, Board Bazar, Gazipur-1704, Bangladesh

[3]Lecturer & coordinator of Department of Computer Science & Engineering City University

Abstract: **The project report presents a design studies and performance analysis of a lightweight, low volume, low profile Inset Feed Rectangular Microstrip Patch Antenna using CST microwave studio 2012. The aim of the thesis is to Design an inset fed rectangular Microstrip Antenna for mobile phone operating at 1.8GHz and to do the performance analysis. I also did comparison with different substrate using FR-4 and Roger RT5880 substrate. Low dielectric constant substrates are generally preferred for maximum radiation. As we know the conducting patch can take any shape but rectangular and circular configurations are the most commonly used configuration. But the other configurations are complex to analyze and due to difficult numerical computations. The length of the antenna is nearly half wavelength in the dielectric; it is a very critical parameter, which governs the resonant frequency of the antenna. In perspective of designing, the selection of the patch width and length are the major parameters along with the feed line depth, for impedance matching, which are done by mathematical calculations. Patch antenna design simulation is done by using simulation software CST microwave studio 2012 and the its performance has been analyzed by analyzing the VSWR curve, The S parameters, the Smith Chart for both impedance and admittance, the directivity curve, far-field radiation pattern, both the radiation efficiency and total efficiency of the patch antenna at the resonating frequency and also the real and imaginary part of impedance.**

Keywords: **CST Microwave Studio, Patch Antenna, Radiation pattern, S parameter, VSWR.**

1. INTRODUCTION

Antennas are key components of any wireless communication system. They are the devices that allow for the transfer of a signal (in a wired system) to waves that, in turn, propagate through space and can be received by another antenna. The receiving antenna is responsible for the reciprocal Process, i.e., that of turning an electromagnetic wave into a signal or voltage at its terminals that can subsequently be processed by the receiver. The fast growing in communication systems leads by the revolution in Antenna Engineering, which creates various geometries of antennas like dipoles, Yagi-Uda, horns and Patch & Microstrip Patch Antenna. Patch Antenna is our main concern in this report.[2]

An antenna (or aerial) is an electrical device which converts electric power into radio waves, and vice versa. It is usually used with a radio transmitter or radio receiver. In transmission, a radio transmitter supplies an oscillating radio frequency electric current to the antenna's terminals, and the antenna radiates the energy from the current as electromagnetic waves (radio waves). In reception, an antenna intercepts some of the power of an electromagnetic wave in order to produce a tiny voltage at its terminals that is applied to a receiver to be amplified. [3]

An isotropic antenna is an ideal antenna that radiates its power uniformly in all directions, *Fig 1* There is no actual physical isotropic antenna. However, an isotropic antenna is often used as a reference antenna for the antenna gain. The antenna gain is often specified in dBi, or decibels over isotropic. This is the power in the strongest direction divided by the power that would be transmitted by an isotropic antenna emitting the same total power. [4]

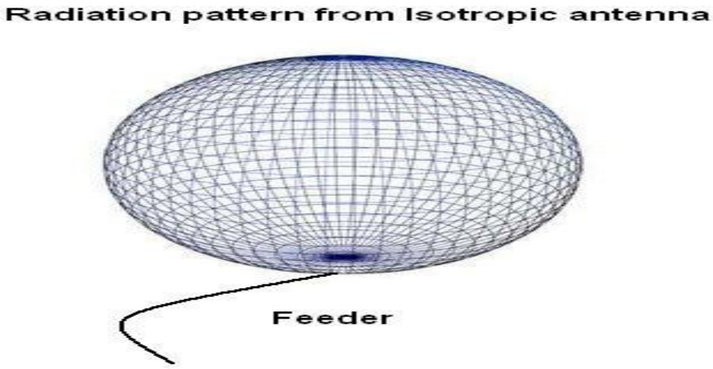
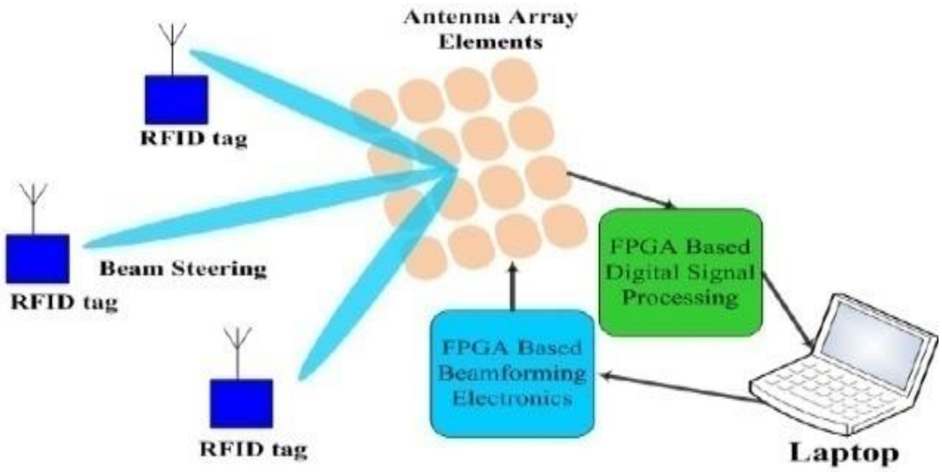


Fig 1:Radiation pattern of an isotropic antenna [28]

2. APPLICATION OF PATCH ANTENNA

Patch antenna is widely used in many communication systems like GPS satellites which operate at frequency of 1575 MHz, wireless Local Area Network (LAN) -2.4 GHz and 5.2 GHz -,Broadband Stacked Patch Antenna for Bluetooth Applications and in Cellular Networks[9]. Amongst them RFID tag design is another important application.



One important application of the patch antenna is in RFID technology

3. CST MICROWAVE STUDIO

CST MICROWAVE STUDIO (CST MWS) is a specialist tool for the 3D EM simulation of high frequency components. CST MWS unparalleled performance making it first choice in technology leading R&D departments.CST MWS enables the fast and accurate analysis of high frequency (HF) devices such as antennas, filters, couplers, planar and multi-layer structures and SI and EMC effects. Exceptionally user friendly, CST MWS quickly gives you an insight into the EM behavior of your high frequency designs.

4. DESIGN SPECIFICATIONS

The three essential parameters for the design of a rectangular Microstrip Patch Antenna:

• Frequency of operation (f_o): The resonant frequency of the antenna must be selected appropriately. The Mobile Communication Systems uses the frequency range from 300-3000 MHz. Hence the antenna designed must be able to operate in this frequency range. The resonant frequency selected for my design is 1.8 GHz.

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• Dielectric constant of the substrate (ε_r): The dielectric material selected for our design is FR-4 lossy which has a dielectric constant of 4.3. A substrate with a high dielectric constant has been selected since it reduces the dimensions of the antenna.

• Height of dielectric substrate (*h*): For the microstrip patch antenna to be used in cellular phones, it is essential that the antenna is not bulky. Hence, the height of the dielectric substrate is selected as 4.5 mm.

Hence, the essential parameters for the design are:

• f_o = 1.8 GHz

• ε_r = 4.3

• *h* = 4.5 mm

And we have to calculate the length of the Patch and also the width of the Patch we will work with.

• Dielectric constant of the substrate (ε_r): The dielectric material selected for our design is Roger RT5880 which has a dielectric constant of 2.2. For comparison study for same dimension the substrate is chosen different (Roger RT5880 of ε_r = 2.2, to get the resonant frequency at 2.4GHz

5. DESIGN PROCEDURE

Here we will design the patch antenna step by step.

Calculation of the width and length:

Calculation of the Width (*W*):

The width of the Microstrip patch antenna is given as:

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

Calculation of length of patch (*L*):

The length of the Microstrip patch antenna is given as (neglecting the effective dielectric constant and the length extension):

$$L_{eff} = \frac{c}{2 f_o \sqrt{\varepsilon_{eff}}}$$

Substituting *c* = 3×10^8 m/s, ε_r = 4.3 and f_o = 1.8 GHz, we get:

Length of the Patch (*L*) = 38 mm (approx)
Width of the Patch (*W*) = 51 mm (approx)
Height of the substrate (*h*) = 4.5 mm

Thickness of the Patch (M_t) = 0.1 mm

Length of the transmission line (L_f) = 31.5 mm

Width of the transmission line (W_f) = 8.7 mm

Inset feeding length (F_i) = 12.5 mm

Gap at both side of the transmission line with the Patch (G_{pf}) = 1 mm

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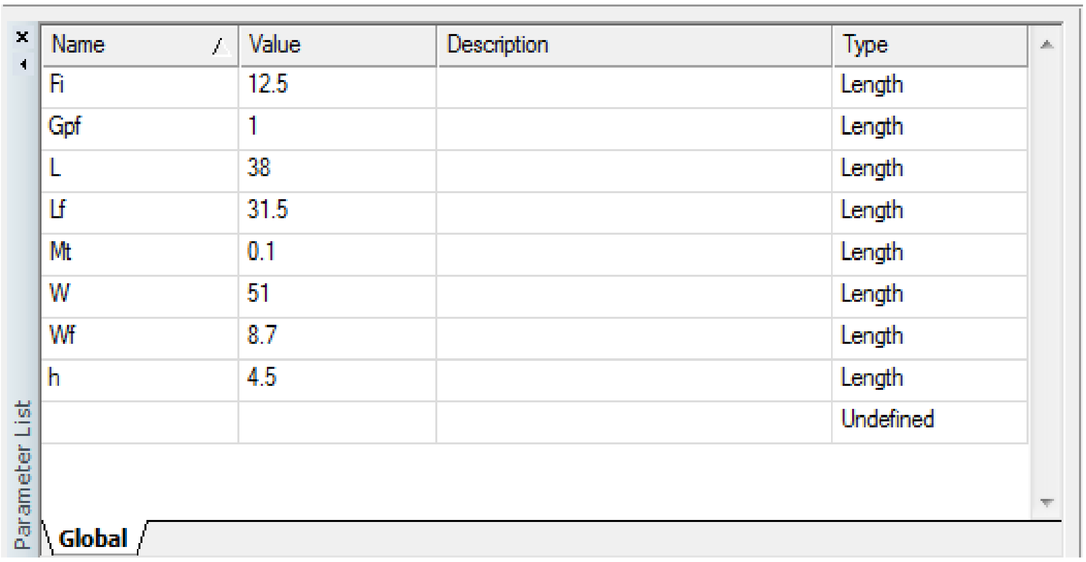
6. PARAMETERIZATION

Before starting to design, we have to define the design parameters of our microstrip patch antenna. All the parameters are set, those are the Length of the Patch (*L*) = 38 mm ; Width of the Patch (*W*) = 51 mm ; Height of the substrate (*h*) = 4.5 mm; Thickness of the Patch (M_t) = 0.1 mm ; Length of the transmission line (L_f) = 31.5 mm; Width of the transmission line (W_f) = 8.7 mm; Inset feeding length (F_i) = 12.5 mm ; Gap at both side of the transmission line with the Patch (G_{pf}) = 1 mm and all the parameters are of type length.



Name	Value	Description	Type
Fi	12.5		Length
Gpf	1		Length
L	38		Length
Lf	31.5		Length
Mt	0.1		Length
W	51		Length
Wf	8.7		Length
h	4.5		Length
			Undefined

Figure 3.6 : Parameter list

7. CREATING THE SUBSTRATE

For creating the substrate, we have to select brick and then give the substrate parameters and substrate material, which we used FR-4 (lossy) which has epsilon of 4.3. Referring *Figure 3.7* and for another similar design Roger RT5880 is used.

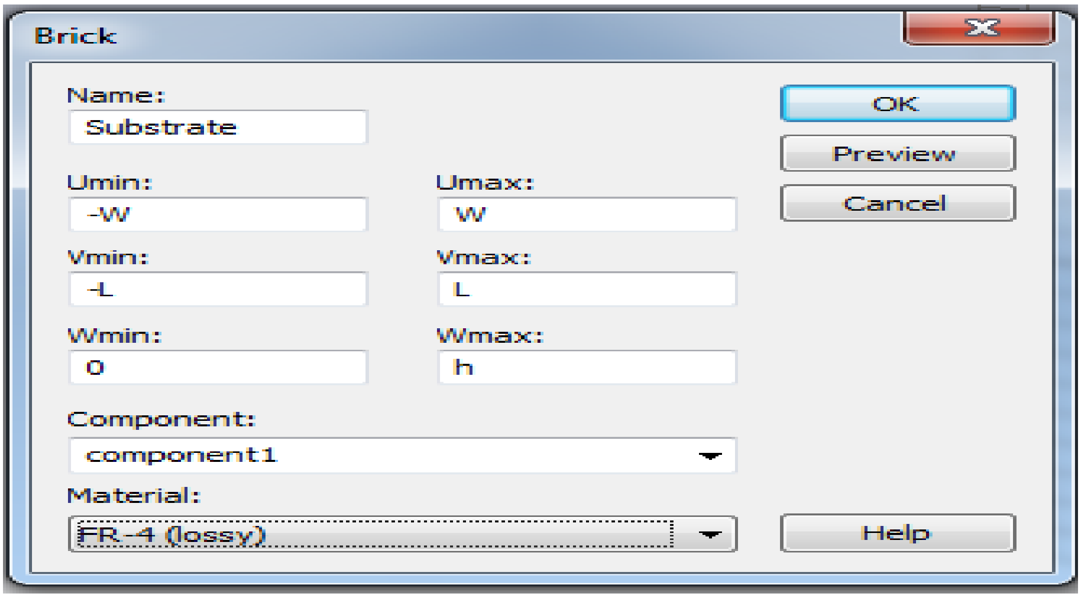


Figure 3.7 : FR-4 (lossy) substrate formation

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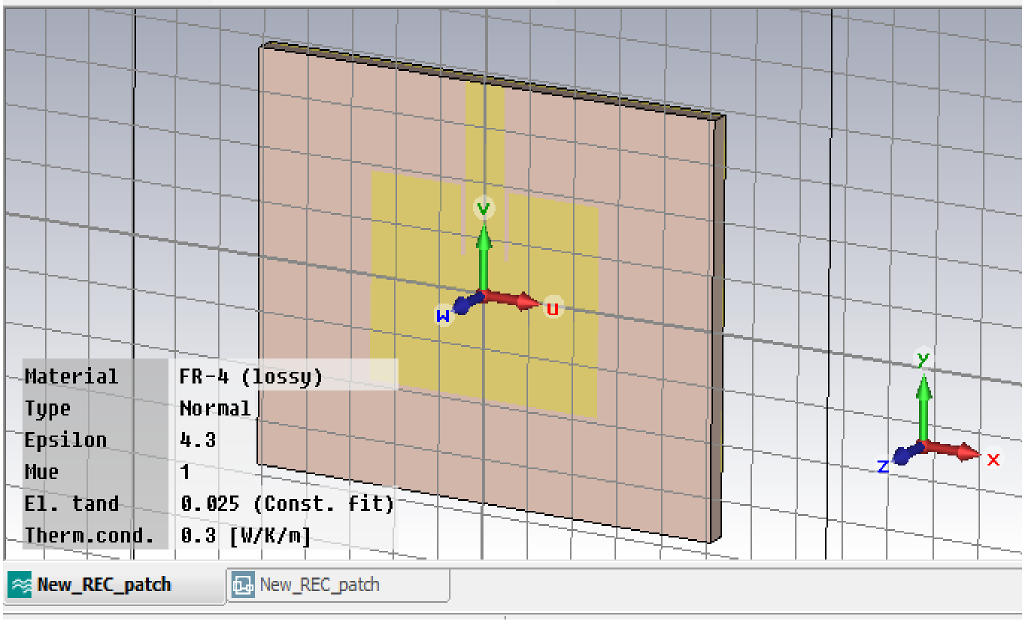

Figure 3 .8a: FR-4 (lossy) substrate

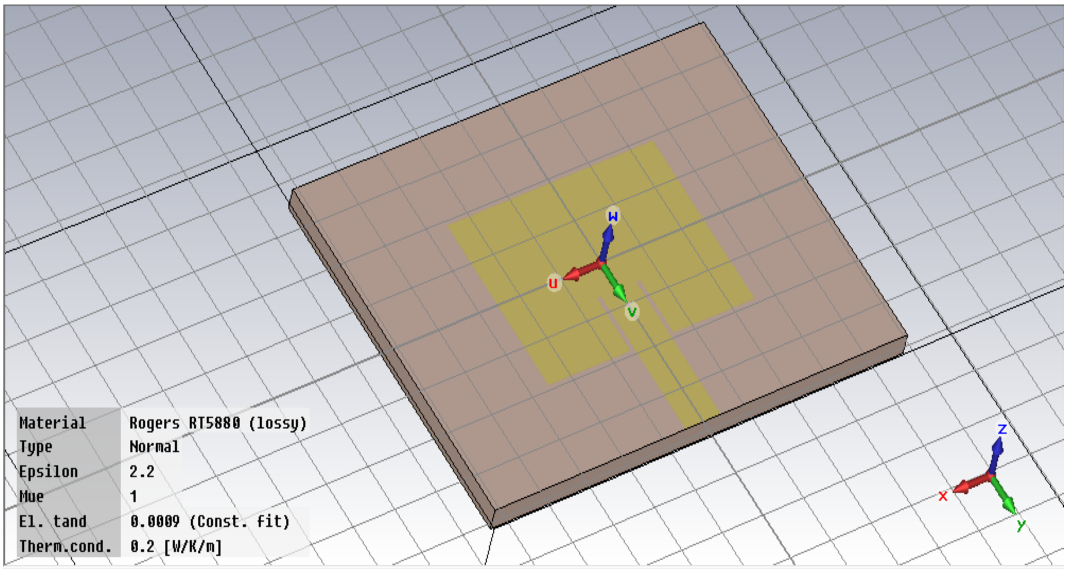

Figure 3.8b : Roger RT5880 (lossy) substrate

8. RESULT AND PERFORMANCE ANALYSIS

The results obtained from the simulations of the micro strip Patch antenna in CST microwave studio, are demonstrated and analyzed in this chapter.

S-Parameters (Reflection Coefficient):

As we know from S_{11} represents how much power is reflected from the antenna, and hence is known as the reflection coefficient (sometimes written as gamma: or return loss).

For FR-4 substrate here the frequency is along x-axis and the return loss is along y axis. It tells us whether the antenna is single band or multi band. From Figure *4.1* it tells us that, return loss value is almost 0 dB in all frequencies except at 1.8 GHz. The resonant frequency at 1.8 GHz there is a sharp deep which is -11.13 dB crossing -10 dB only once, which means it is a single band antenna.

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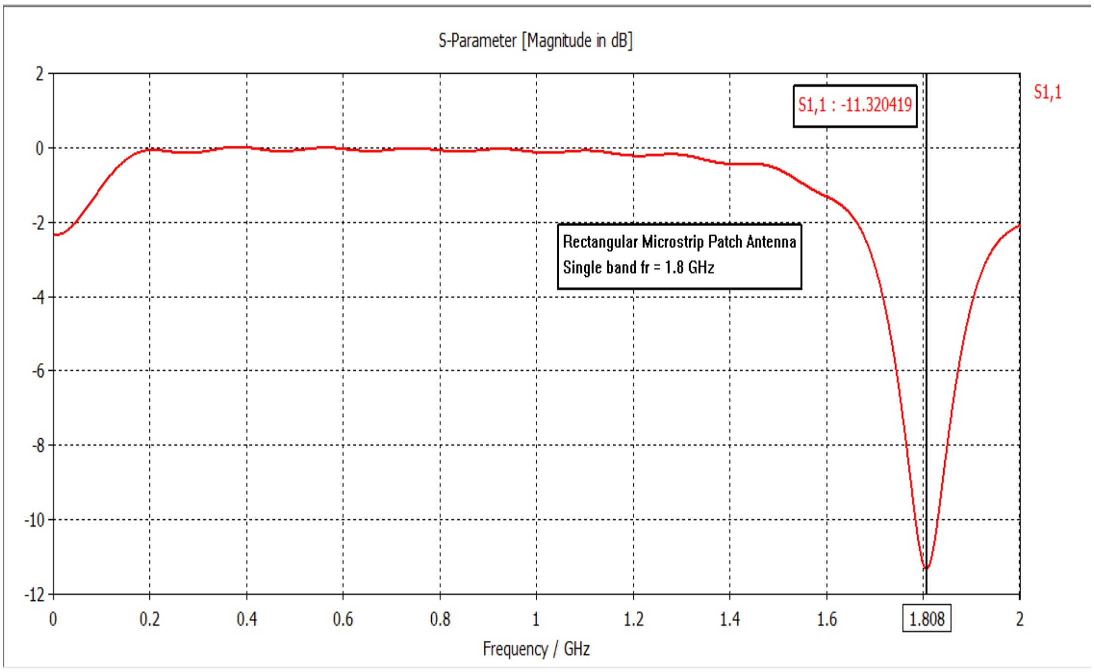

Figure 4.1 : Reflection coefficient (S-Parameter in dB) for FR-4 Substrate vs frequency plot

If S_{11} =0 dB, then all the power is reflected from the antenna and nothing is radiated. If S_{11} = -10 dB, this implies that if 3 dB of power is delivered to the antenna, -7 dB is the reflected power. The remainder of the power was "accepted by" or delivered to the antenna.

From Figure *4.2* it tells us that for Roger RT5880, the return loss value is almost 0 dB in all frequencies except at 2.45 GHz, which is the resonant frequency for the next Patch.

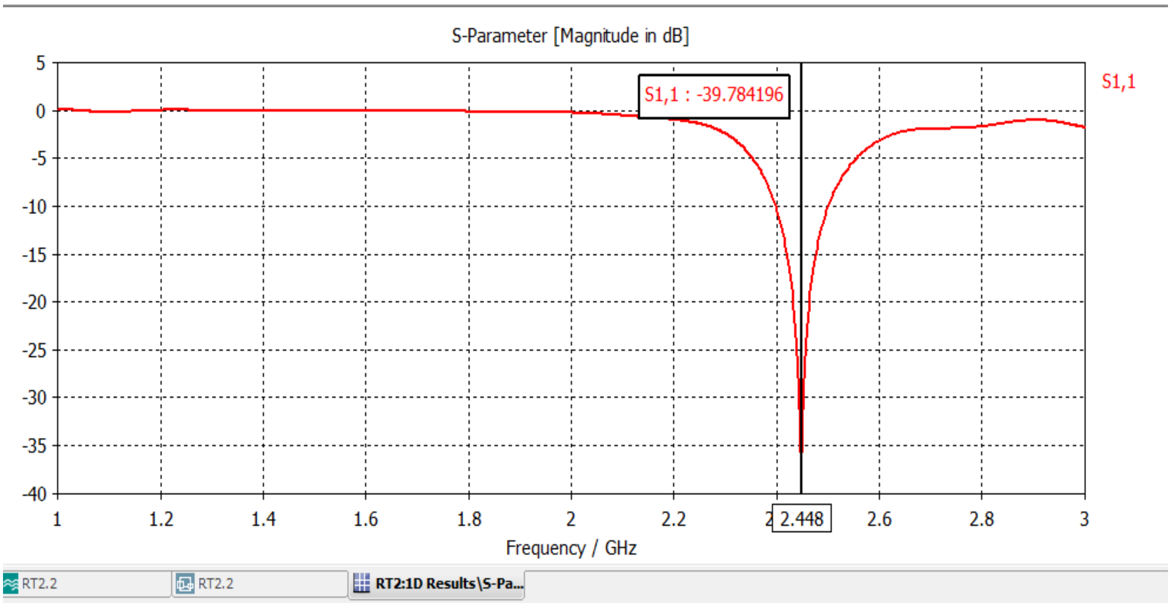

Figure 4.2: Reflection coefficient (S-Parameter in dB) for Roger RT 5880 vs frequency plot

VSWR (Voltage Standing Wave Ratio) curve:

As we know, the smaller the VSWR is, the better the antenna is matched to the transmission line and the more power is delivered to the antenna. Ideally the VSWR should be 1. The VSWR at the resonant frequency is 1.745 which is acceptable in real case for FR-4 substrate.

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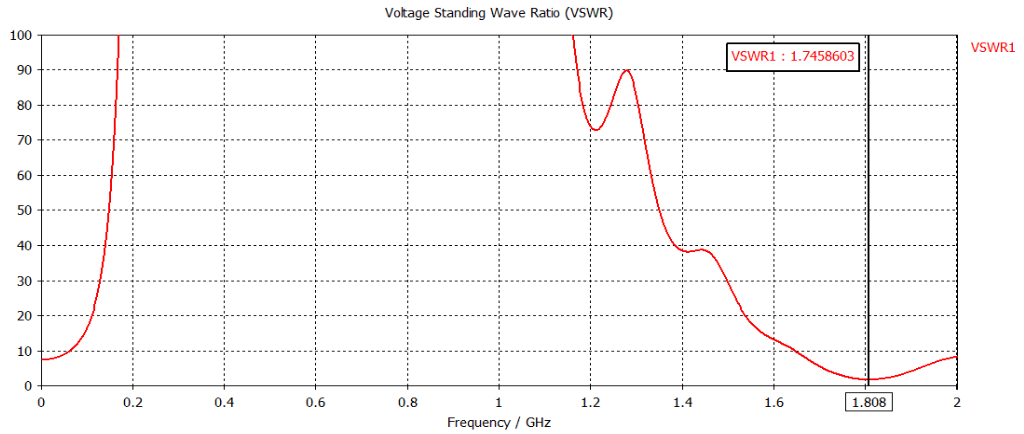
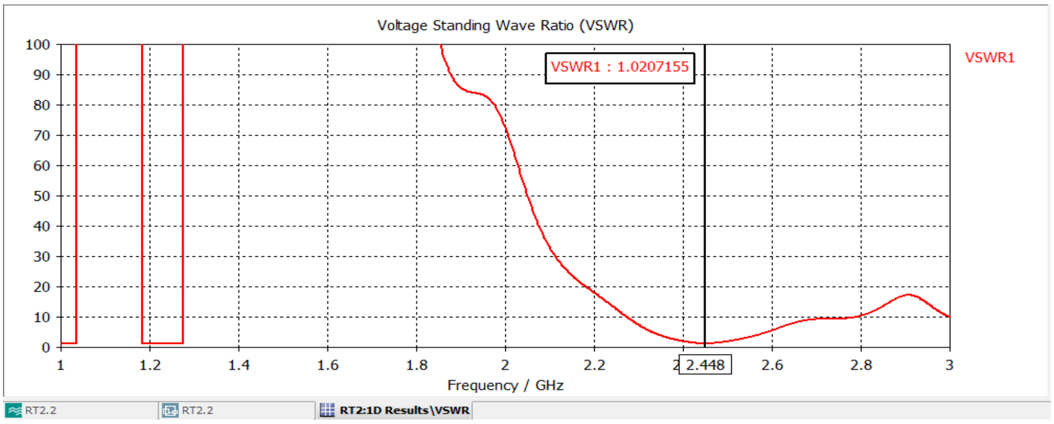


Voltage standing wave ratio variation(FR-4 substrate) with the frequency plot

But the VSWR at the resonant frequency is 2.45Ghz for Roger RT5880 is 1.02 which is more better then the previous Patch of FR-4 substrate



Voltage standing wave ratio variation(Roger RT5880 substrate) with the frequency plot

Directivity:

Directivity is a measure of how 'directional' an antenna's radiation pattern is. *Figure 4.6 and 4.7* tells us the directivity of the antenna at the resonant frequency for FR-4 substrate and Roger RT5880. The antenna radiation is mostly directive where theta is 0, that is at normal to the radiating patch and it decreases as the value of theta is increased and the radiation is minimum when theta is 180 degree which is the back side of the patch for both the antenna.

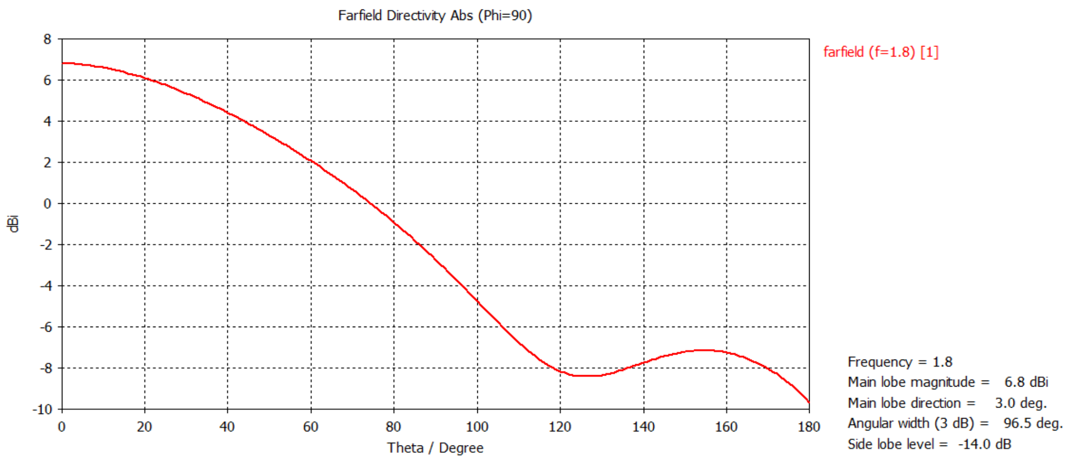


Fig:4.6 Directivity of the antenna the variation of Theta/Degree (FR-4)

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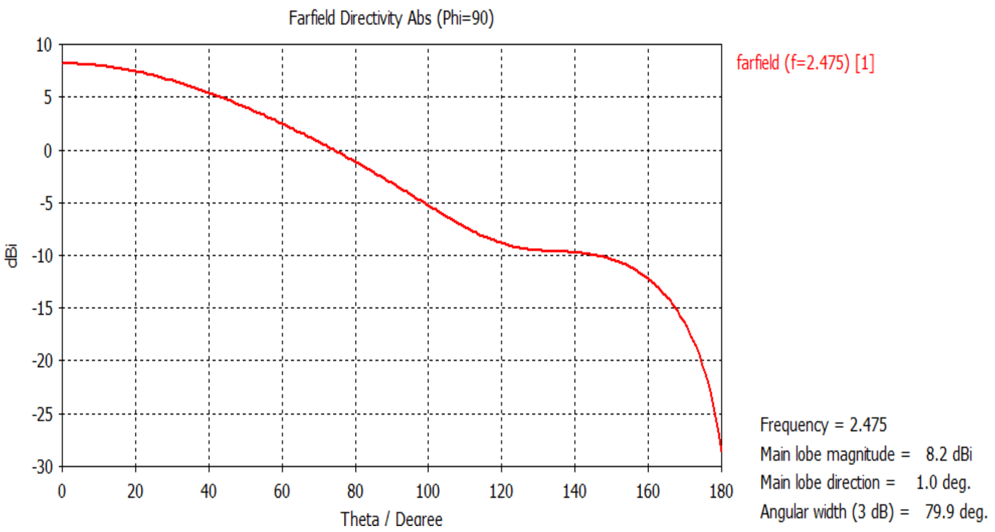


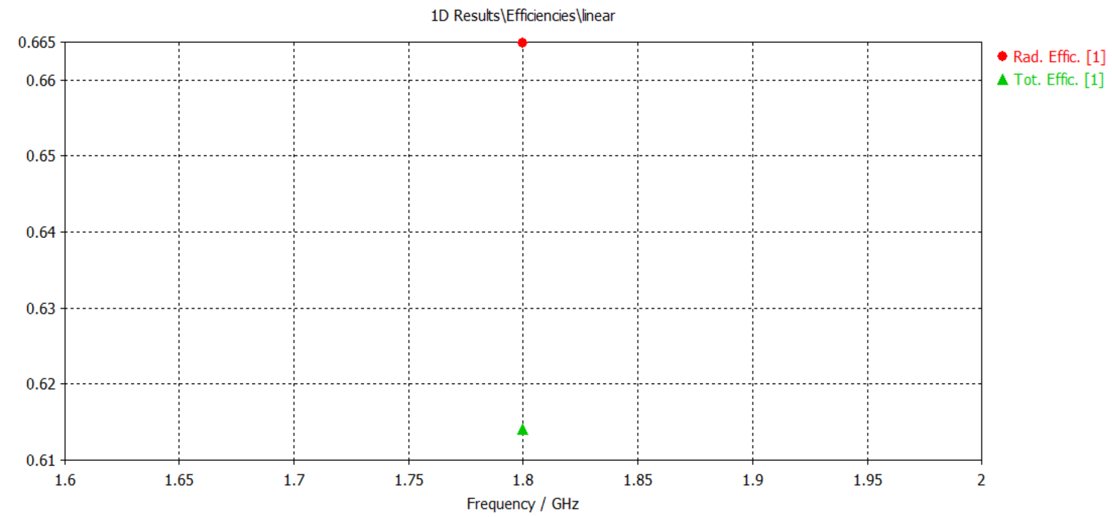
Fig:4.7 Directivity of the antenna the variation of Theta/Degree (Roger RT5880)

Antenna Efficiency:

The efficiency of an antenna relates the power delivered to the antenna and the power radiated or dissipated within the antenna.

$$\varepsilon_T = M_L \bullet \varepsilon_R$$

Since M_L is always a number between 0 and 1, the total antenna efficiency is always less than the antenna's radiation efficiency, where ε_T is the antenna's total efficiency, M_L is the antenna's loss due to impedance mismatch, and ε_R is the antenna's radiation efficiency.



Antenna Radiation efficiency and Total efficiency at the resonant frequency for FR 4 substrate

Input Impedance Curve:

Input impedance curve represents the changes of impedance with the variations of frequency.

Input Resistance part of the antenna :

From *Figure 4.10*, we can see a resistance rise near the midpoint of the line, which is theoretically similar behavior of antenna.

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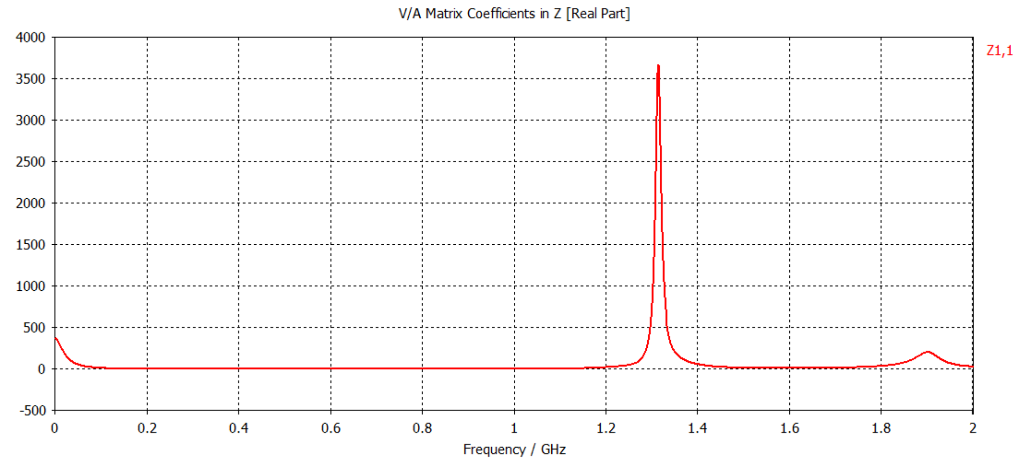


Figure 4.10:Variation of the resistance of the antenna with frequency

Input Reactance part of the antenna:

A very rapid shift from inductive to capacitive reactance is seen from *Figure 4.11*. This latter shift is characteristic of every line, although the position of the shift and the magnitude of the peak values are functions of the feedpoint impedance and the line Zo.

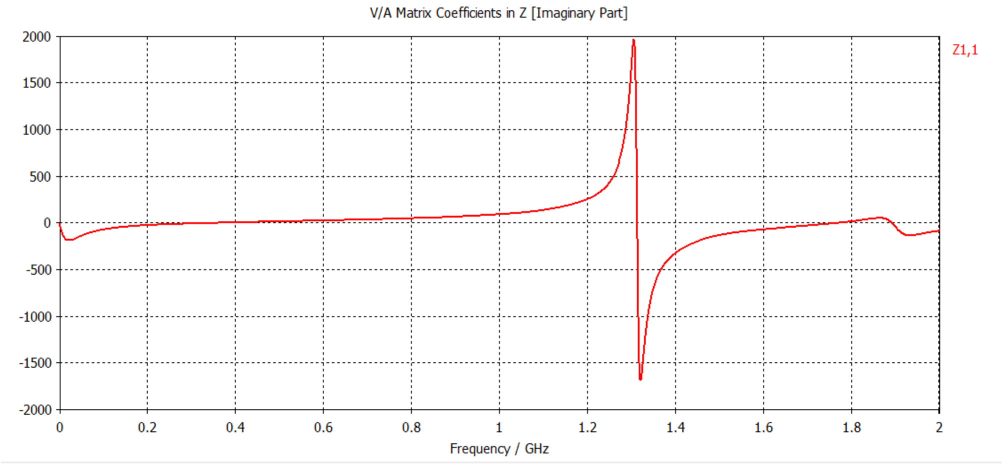
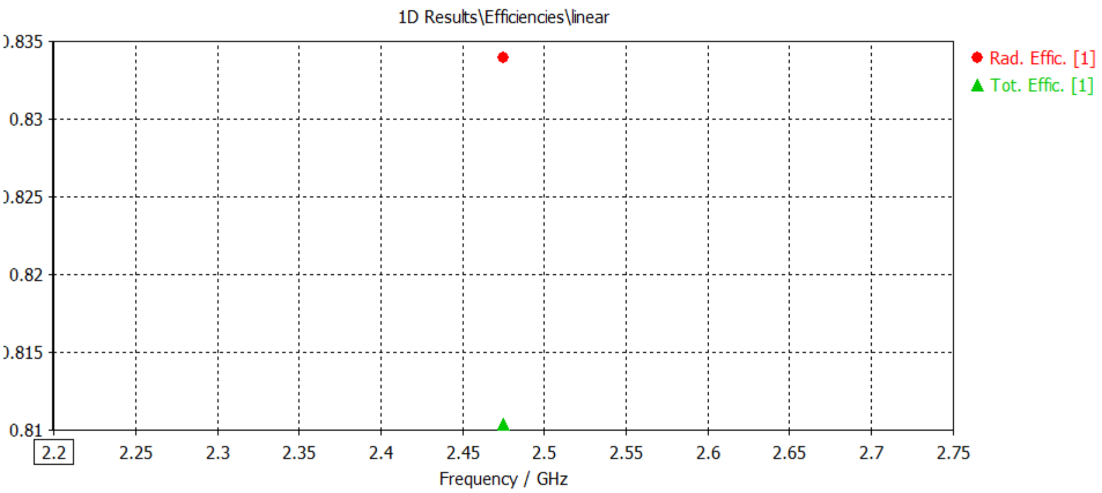


Figure 4.11 : Variation of the reactance of the antenna with frequency



Antenna Radiation efficiency and Total efficiency at the resonant frequency for Roger RT5880

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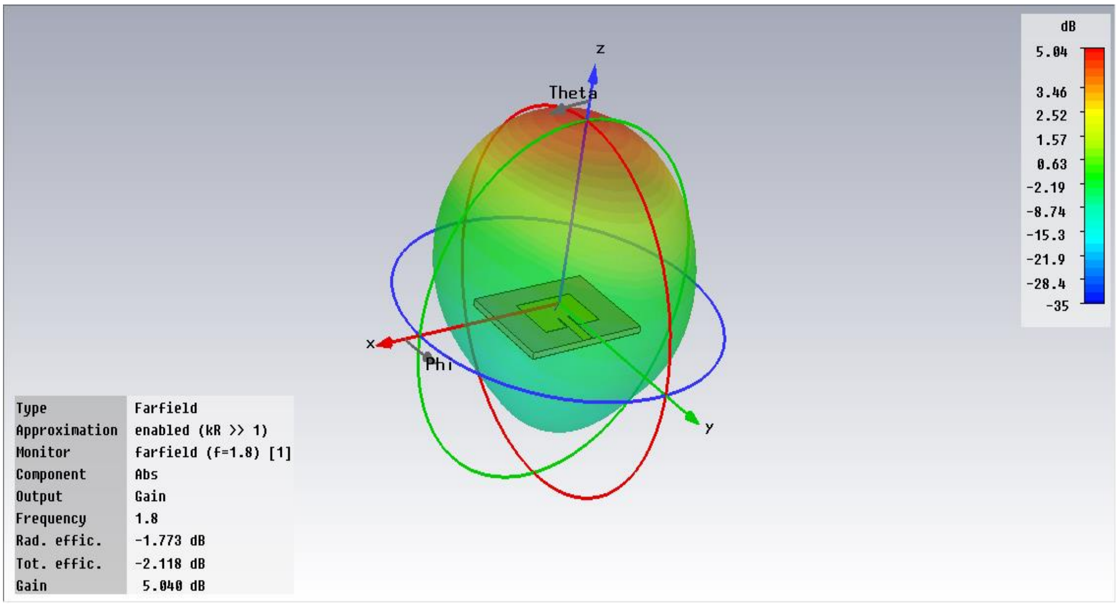
Here from *Figure 4.8* , for FR-4 substrate, we can see that the radiation efficiency is 0.665, which is 66.5%, and the total efficiency is 0.615, which is 61.5% at the resonant frequency. But the radiation efficiency for Roger RT5800 is much better than FR-4, for Roger RT5880 the radiation efficiency is just above 83% and total efficiency is81%. Mobile phone antennas, or wifi antennas in consumer electronics products, typically have efficiencies from 20%-70% (-7 to -1.5 dB). So the radiation frequency and total efficiency are both feasible for the real case.

3-D Radiation Pattern of the Patch Antenna:

From *Figure 4.10* we can the variation of the magnitude of gain surrounding the patch antenna at the resonating frequency of 1.8 GHz.



Pattern Figure 4.16 : 3-D Radiation of the Patch Antenna(FR-4)

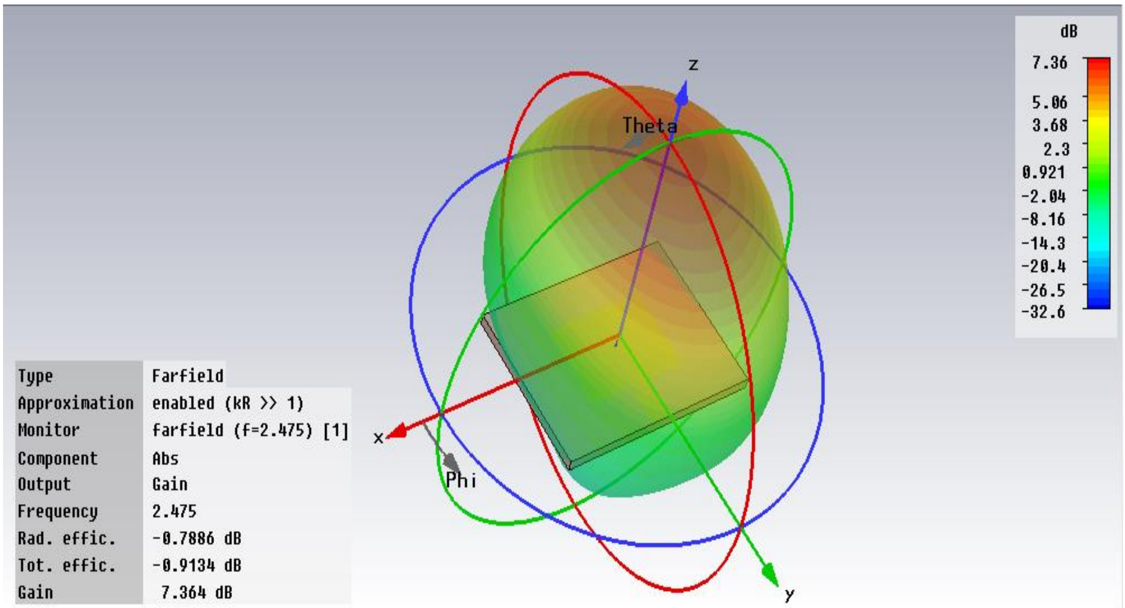


Figure 4.17 : 3-D Radiation Pattern of the Patch Antenna (Roger RT5880)

And it is very clear from the *Figure 4.16*, the gain is maximum of 5.04 dB, which is perpendicular to the radiating patch, that is to the normal. The gain mostly varies with the changes of theta and almost symmetrical with the variation of Phi. The gain is minimum at the back side of the patch. But for Roger RT5880 *Figure 4.17*, its gain much better 7.36 dB.

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The polar representation of radiation Pattern of the Patch Antenna:

From *Figure 4.18*, we can tell that at the resonant frequency of 1.8 GHz , far field main lobe magnitude is 5 dB with the direction slightly 3 degree away from the centre (to the normal to the Patch) and the half power beamwidth, the angular separation in which the magnitude of the radiation pattern decrease by 50% that is 3 dB gain is 96.5 degree. And also the side lobe level is -14.0 dB. This tells us the Patch Antenna is well directive to the normal to the patch.

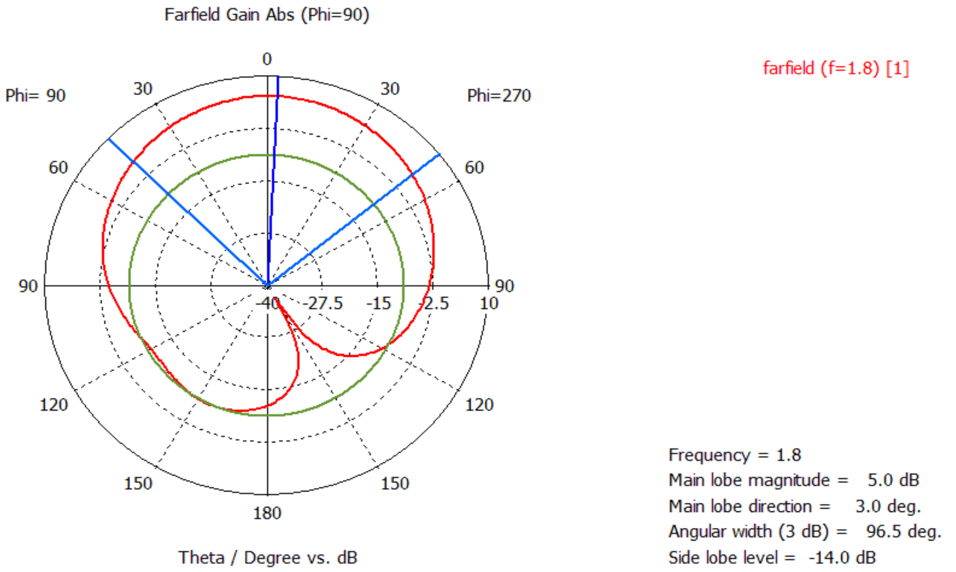

Figure 4.18 : The polar representation of radiation pattern of the Patch Antenna(FR-4)

Similar radiation pattern for Roger RT5880, but its gain is more than the FR 4 substrate

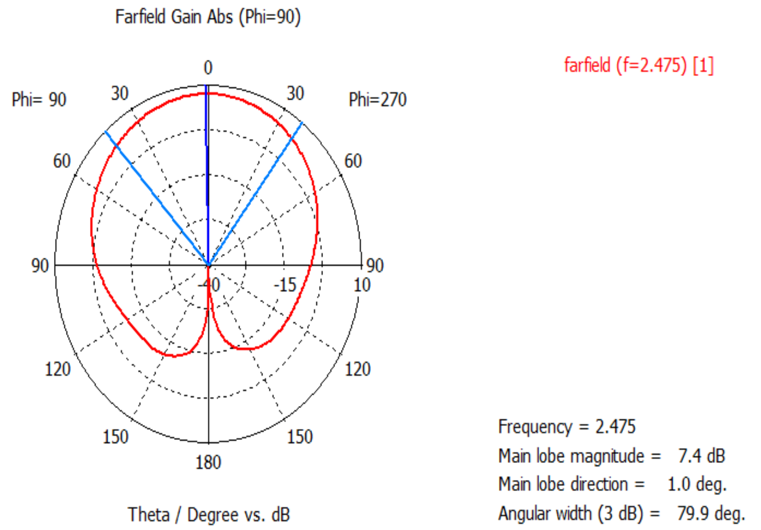

Figure 4.19 : The polar representation of radiation pattern of the Patch Antenna(Roger RT 5880)

9. CONCLUSION

Microstrip patch antennas have become the favorite of antenna designers because of its versatility and advantages of planar profile, ease of fabrication, compatibility with integrated circuit technology, and conformability with a shaped surface. This project gives us the study and performance analysis of a transmission line microstrip rectangular patch antenna for mobile phone communication working at 1.8GHz frequency and also I checked the variation of results due to substrate different material using Roger RT 5880 (lossy). And we can design our and at our desired frequency, by adjusting the dimensions of the patch. By doing this project I have learnt to use simulations software to design such antennas, which would be helpful to work in the relevant field of engineering. This learning will help me in the future, studying modern antennas.

There are many scope of further continuing the research work in the future, to design multi band antenna, which could be used in designing the low cost radio frequency identifier (RFID) tag.

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