CHAPTER 1

INTRODUCTION

1.1 OVERVIEW OF RF TWCHNOLOGY

RF technology has changed quite a bit since the days of Marconi and Tesla-both the men who enabled radio communication. Modern radio frequency engineering is an exciting and dynamic field. Due to the beneficial inter dependency between recent development in electronics device technology and the increase in demand for voice, data and video communication capacity. prior to this revolution in communications, RF technology was the nearly exclusive domain of the defence industry but the recent increase in demand for communication system with application such as wireless paging, broadcast video, Bluetooth transceiver, Wi- Fi (WLAN) Wi-Max, CDMA,WCDMA, EGPRS, GSM and many more in revolutionizing the technology[1-2].RF technology is important for these application because these require higher operational frequencies which allow both large number of independent channels as well as significant available bandwidth per channel for high speed communication. Figure 1.1 shows some disciplines that requires RF design.

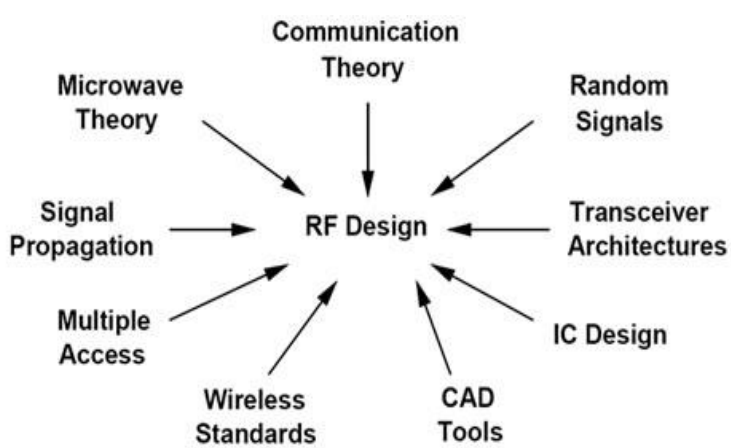

Figure 1.1: Disciplines requiring RF design [1]

The field of design in the electronics system that employs RF and Microwave Engineering includes the frequencies ranging from 300 kHz to over 100GHZ. RF engineering refers to to thr circuits/device operating in frequency range 300kHz to over 1GHZ while the microwave engineeringrefers to the circuits/device operating in the frequency range between 300kHZ or 1GHz to 100GHz .unfortunately,RFIC design is quite complex when tested results are obtain that differ drastically from the simulation result. The reasons for this disparity may normally be traced to one of the following[2].

- The frequency of operation is such that the circuit`s elements display complex behavior , not represented by pure element definitions utilized during the design.
- The circuit layout includes coupling path not account for in the design.
- The ratio of transverse dimension of transmission line to wavelength is non negligible thus, additional unwanted stores modes become available.
- The package that house the circuit becomes an energy storage cavity, thus absorbing some of the energy propagating through it.
- The perfect(ideally) dc bias source is not adequately decoupled from the circuit.
- The degree of impedance match among interconnected circuits is not good enough, so that large voltage standing ratio(VSWR) is present, which give rise to inefficient power transfer and to ripples in the frequency response

.

1.2 MOTIVATION

Today scenario transmitting and receiving antennae are required to transmit radio signals, which are compact, light weight and simple circuitry. There has been many research on this area. A microstrip patch antenna gives such requires features. The first step in installing a antenna is feeding. Various feeding techniques also extensively studied to get more accurate result .Our work is primarily focused on feeding techniques. These techniques include of metallic slot and sorting pins, adjusting the thickness of substrate. Here we use two feeding technique first one is pin feed and second one is edge feed. By comparing the result of these two feeding technique we find edge feed give more acceptable reflection coefficient.

1.3 AIM AND OBJECTIVE

The aim of the project is to design edge fed micro strip patch antenna. This dissertation provides an in depth explanation of antenna pattern measurement techniques used to determine the performance of edge fed microstrip patch antenna. The performance comparison is based on radiation pattern, bandwidth, return loss, vswr and gain. The length ,width and height of dielectric material which is known as substrate , length and width of the patch, length and width of transformer line are the parameter to be varied in order to obtain optimum result.

1.4 THESIS STRUCTURE

The thesis report is divided into five chapters, each having ample information for comprehending the concept of this project.

Chapter 1 introduces the background history of RF technology and objective of research of microstrip patch antenna.

Chapter 2 discussed the basic theory of microstrip patch antenna and its different parameter to analyze the performance of antenna. In this chapter also shows the different application of patch antenna.

Chapter 3 in this chapter we discussed the different feeding technique of microstrip patch antenna.

Chapter 4 here we discussed about the design, simulation, and analysis result of the Edge-fed technique of patch antenna and some basic step for calculating the components parameters.

Chapter 5 concludes the thesis with comparison of result to some reported works and then suggestion for further research has discussed.

CHAPTER 2

MICROSTRIP PATCH ANTENNA AND LITRATURE REVIEW

2.1 General structure of Microstrip Patch Antenna

A microstrip antenna consists of a dielectric material that is substrate sandwiched between two conducting plate as shown in Figure 2.1. Upper plate is radiating patch and other plate is grounded. The patch is generally made of copper or gold and can take any possible shape. The radiating patch and the feed lines are usually photo etched on the dielectric substrate.

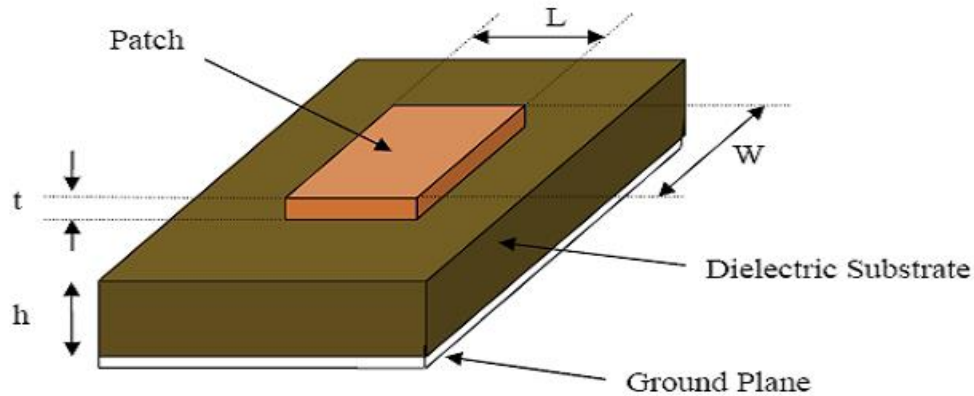

Figure2.1 structure of microstrip patch antenna

For simplicity of analysis, the patch is may be a square, rectangular, circular, triangular, and elliptical or some other symmetrical shape. For a rectangular patch, the length L of the patch is usually in the range of 0.3333 $\lambda_0 < L < 0.5\lambda_0$, where λ_0 is the free space wavelength. The patch is selected to be very thin such that $t << \lambda_0$ (where t is the patch thickness). The height h of the substrate is usually 0.003 $\lambda_0 \leq h \leq 0.05\ \lambda_0$. The dielectric constant of the substrate ε_r is typically in the range $2.2 \leq \varepsilon_r \leq 12$ [3].

These patch antennas are narrow band devices with a bandwidth 10% of the λ, poor radiation efficiency is always more than expected from these patch antennas. A good performance from the patch antenna can be expected with a thick dielectric substrate with a low dielectric constant as this gives better efficiency, larger bandwidth and a better radiation [21]. These types of antennas are larger than expected in the construction. But the case with us is completely different as to design a compact device needs high dielectric constant which is less efficient, having a narrow bandwidth as discussed above.

2.1.1 Patch Antenna Materials

In the wide range of antenna models there are different structures of Microstrip antennas, but on the whole we have four basic parts in the antenna [25]:

These are

- The patch
- Dielectric Substrate
- Ground Plane
- Feed Line

The dielectric material is commonly known as 'substrate' [16] there is features that are to be considered in the selection of the substrate such as dielectric constant [17], cost of the material, dielectric loss tangent, the surface adhesion properties for the conductor coatings, and the ease of fabrication[18]. We have a wide range of materials for the substrate selection which are in use for the planar and also for the conformal antenna configurations. The dielectric constant material range from 1.17 to ≈ 25 [26].

2.2 Dimensions

2.2.1 Length

The resonant length determines the resonant frequency and is about $\lambda/2$ for a rectangular patch excited in its fundamental mode. The patch is, in fact, electrically a bit larger than its physical dimensions due to the fringing fields. The deviation between electrical and physical size is mainly dependent on the PC board thickness and dielectric constant. A better approximation for the resonant length is calculated by formula [19]:

$$L \approx 0.49\lambda_d = 0.49 \frac{\lambda_0}{\sqrt{\varepsilon_r}}$$

This formula includes a first order correction for the edge extension due to the fringing fields, With

- L = Resonant length
- λ_d= wavelength in substrate
- λ_0 = wavelength in free space
- ε_r= dielectric constant of the substrate material

2.2.2 Width

Width of microstrip patch antenna can given by[20]

$$\text{Width} = \frac{c}{2f_0}\sqrt{\frac{2}{\varepsilon_r+1}}$$

Where

- C= speed of light
- f_r= the resonant frequency which is equal to 1GHz

2.2.3 Length Extension (ΔL)

The calculation of the extension of the length is given by a very popular relation for the normalized extension of the length is [20] [21]:

$$\Delta L = 0.412\text{h} \frac{[\varepsilon_{reff}+0.3]}{[\varepsilon_{reff}-0.258]} \frac{[\frac{w}{h}+0.264]}{[\frac{w}{h}+0.8]}$$

Where

- h = height of substrate
- w = width of patch
- ε_{reff}= Effective dielectric constant

2.3 Impedance Matching

Looking at the magnetic field that is current and electrical field or voltage variation along the patch, the magnetic field is maximum at the center and minimum near the edges, and the electrical field is zero at center and maximum at left edge and minimum at the right edge. The figures below show these quantities.

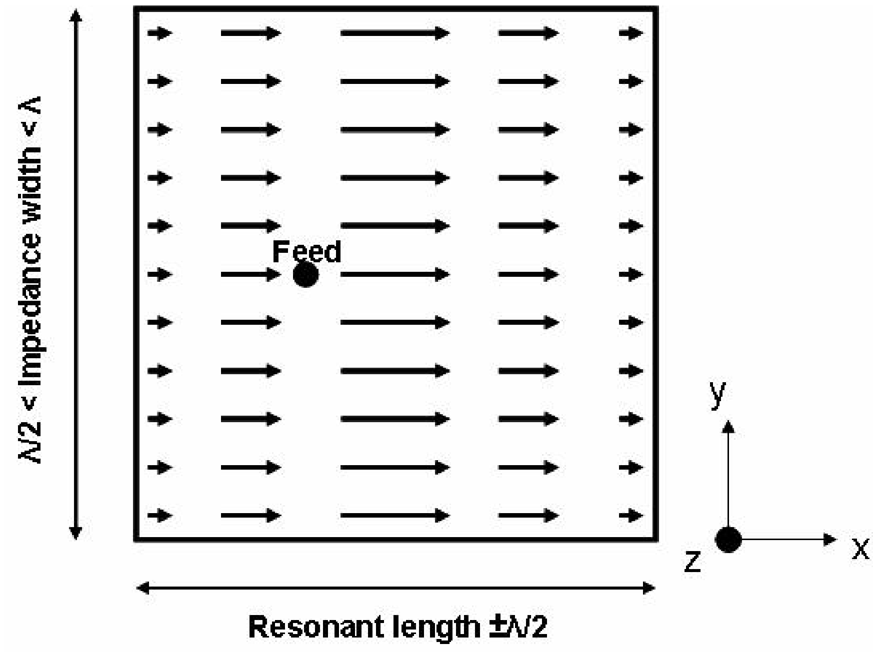

Figure2.2 Current distribution on patch surface

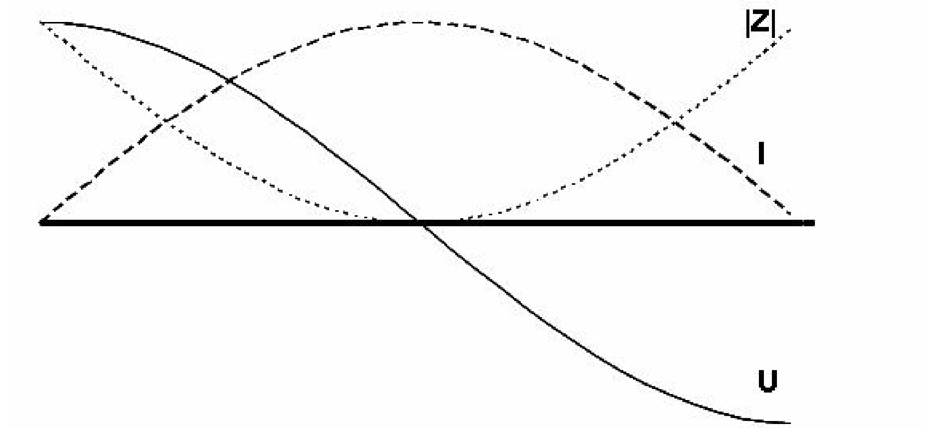

Figure 2.3 Voltage (U), current (I) and Impedance $|Z|$ Distribution along the patch resonant length

From the magnitude of the current and the voltage, we can conclude the impedance is minimum (theoretically zero W) in the middle of the patch and maximum (typically around 200 W, but depending on the Q of the leaky cavity) near the edges. Put differently, there is a point where the impedance is 50 W somewhere along the "resonant length" (x) axis of the element.

2.4 Fundamental Specifications of Patch Antennas

2.4.1 Radiation Pattern

Microstrip Patch Antenna has radiation patterns that can be calculated easily. The source of the radiation of the electric field at the gap of the edge of the Microstrip element and the ground plane is the key factor to the accurate calculation of the pattern for the patch antenna.

The radiation pattern of a generic dimensional antenna can be seen below, which consist of side lobe, black lobes, and are undesirable as they represent the energy that is wasted for transmitting antennas and noise sources at the receiving end.

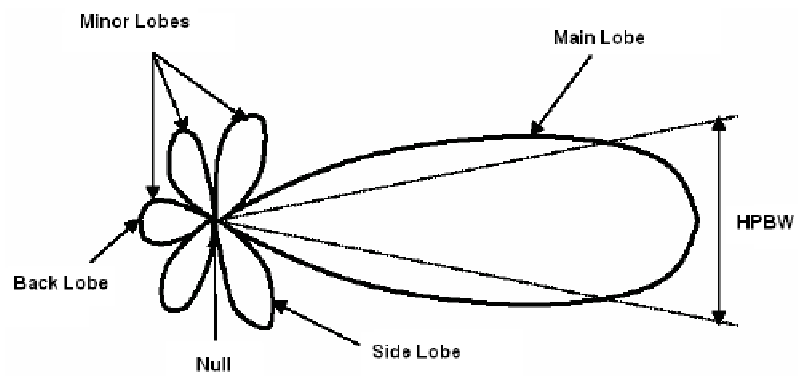

Figure 2.4 Radiation Pattern of a generic dimensional antenna [22]

The rectangular patch excited in its fundamental mode has a maximum directivity in the direction perpendicular to the patch (broadside). The directivity decreases when moving away from broadside towards lower elevations. The 3 dB beam width (or angular width) is twice th angle with respect to the angle of maximum directivity, where this directivity has rolled off 3dB with respect to the maximum directivity. An example of a radiation pattern can be found as.

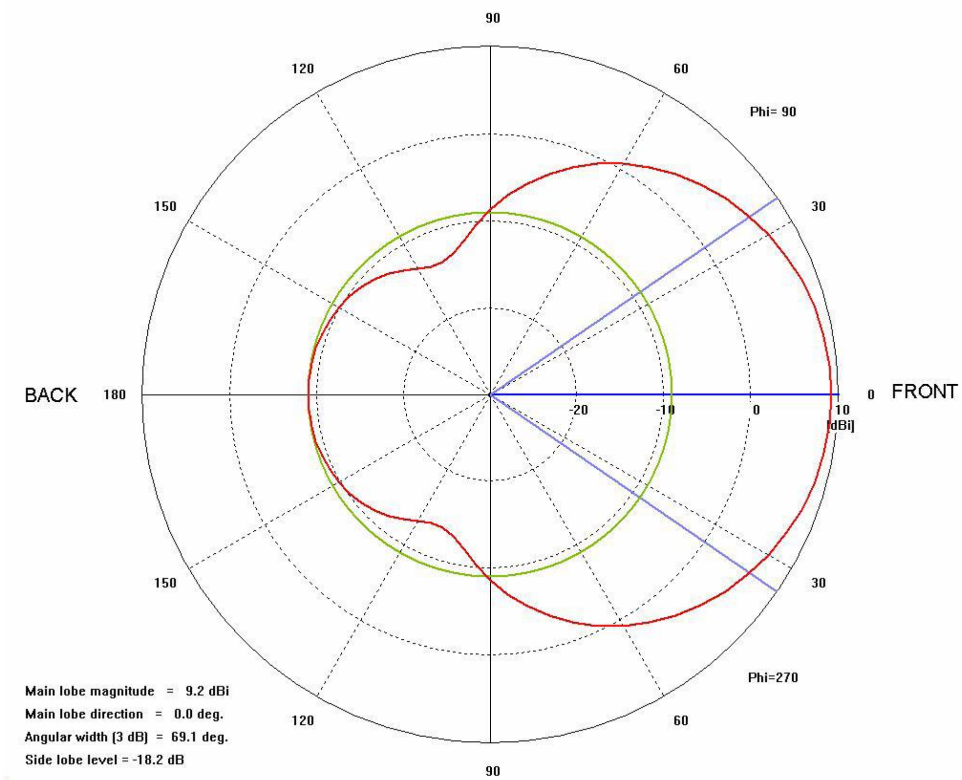

Figure 2.5 Typical radiation pattern of simple patch antenna

2.4.2 Antenna Gain

Antenna gain is defined as antenna directivity times a factor representing the radiation efficiency. This efficiency is defined as the ratio of the radiated power (Pr) to the input power (Pi). The Input power is transformed into radiated power and surface wave power while a small portion is dissipated due to conductor and dielectric losses of the materials used. Surface waves are guided waves captured within the substrate and partially radiated and reflected back at the substrate edges. Surface waves are more easily excited when materials with higher dielectric constants and/or thicker materials are used. Surface waves are not excited when air dielectric is used. Several techniques to prevent or eliminate surface waves exist, but this is beyond the scope of this article.

Antenna gain can also be specified using the total efficiency instead of the radiation efficiency only. This total efficiency is a combination of the radiation efficiency and efficiency linked to the impedance matching of antenna.

2.4.3 Reflection Coefficient |Γ| and Character Impedance (Z0)

There is a reflection that occurs in the transmission line when we take the higher frequencies in to consideration. There is a resistance that is associated with each transmission line which comes with the construction of the transmission line. This is called as character impedance (***Z0***). The standard value of this impedance is 50ohm. Always the every transmission line is being terminated with an arbitrary load *ZL* and this is not equivalent to the impedance i.e. *Z0*. Here occurs the reflected wave.

Reflection coefficient can be calculated by [23]

$$\Gamma = \frac{V_0^-}{V_0^+} = \frac{Z_L - Z_0}{Z_L + Z_0}$$

2.4.4 Voltage Standing Wave Ratio

There should be a maximum power transfer between the transmitter and the antenna for the antenna to perform efficiently. This happens only when the impedance *Zin* is matched to the transmitter impedance, *Zs*.

In the process of achieving this particular configuration for an antenna to perform efficiently there is always a reflection of the power which leads to the standing waves, which is characterized by the Voltage Standing Wave Ratio (*VSWR*).

VSWR can be given by [24] .

$$\text{VSWR} = \frac{V_{max}}{V_{min}} = \frac{1+|\Gamma|}{1-|\Gamma|} = \frac{1+S_{11}}{1-S_{11}}$$

2.4.5 Input Impedance

This is the ratio of the voltage to current at the pair of terminals or the ratio of the appropriate components of the electric fields to the magnetic fields at a point. Or in other words we can say it is the impedance presented by the antenna at the input terminal.

$$Z_{in} = (R_{in} + jX_{in})$$

Where

- $R_{in} =$ The real part, representing the power dissipated though heat or through radiation losses.
- X_{in} = Imaginary part, representing the reactance of the antenna & the power stored in the near field of the antenna.

2.4.6 Polarization

The plane wherein the electric field varies is also known as the polarization plane. The basic patch covered until now is linearly polarized since the electric field only varies in one direction. This polarization can be either vertical or horizontal depending on the orientation of the patch. A transmit antenna needs a receiving antenna with the same polarization for optimum operation. The patch mentioned yields horizontal polarization, as shown. When the antenna is rotated 90°, the current flows in the vertical plane, and is then vertically polarized.

A large number of applications, including satellite communication, have trouble with linear polarization because the orientation of the antennas is variable or unknown. Luckily, there is another kind of polarization circular polarization. In a circular polarized antenna, the electric field varies in two orthogonal planes (x and y direction) with the same magnitude and a 90° phase difference. The result is the simultaneous excitation of two modes, i.e. the TM10 mode (mode in the x direction) and the TM01 (mode in the y direction). One of the modes is excited with a 90° phase delay with respect to the other mode. A circular polarized antenna can either be right-hand circular polarized (RHCP) or left-hand circular polarized (LHCP). The antenna is RHCP when the phases are 0° and 90° for the antenna in the figure below when it radiates towards the reader, and it is LHCP when the phases are 0° and 90°.

2.4.7 Bandwidth

Another important parameter of any antenna is the bandwidth it covers. Only impedance bandwidth is specified most of the time. However, it is important to realize that several definitions of bandwidth exist, impedance bandwidth, directivity bandwidth, polarization bandwidth, and efficiency bandwidth. Directivity and efficiency are often combined as gain Bandwidth.

The impedance bandwidth depends on a large number of parameters related to the patch antenna element itself (e.g., quality factor) and the type of feed used. The plot below shows the return loss of a patch antenna and indicates the return loss bandwidth at the desired S11/VSWR (S11 Wanted/VSWR wanted). The bandwidth is typically limited to a few percent. This is the major disadvantage of basic patch antennas.

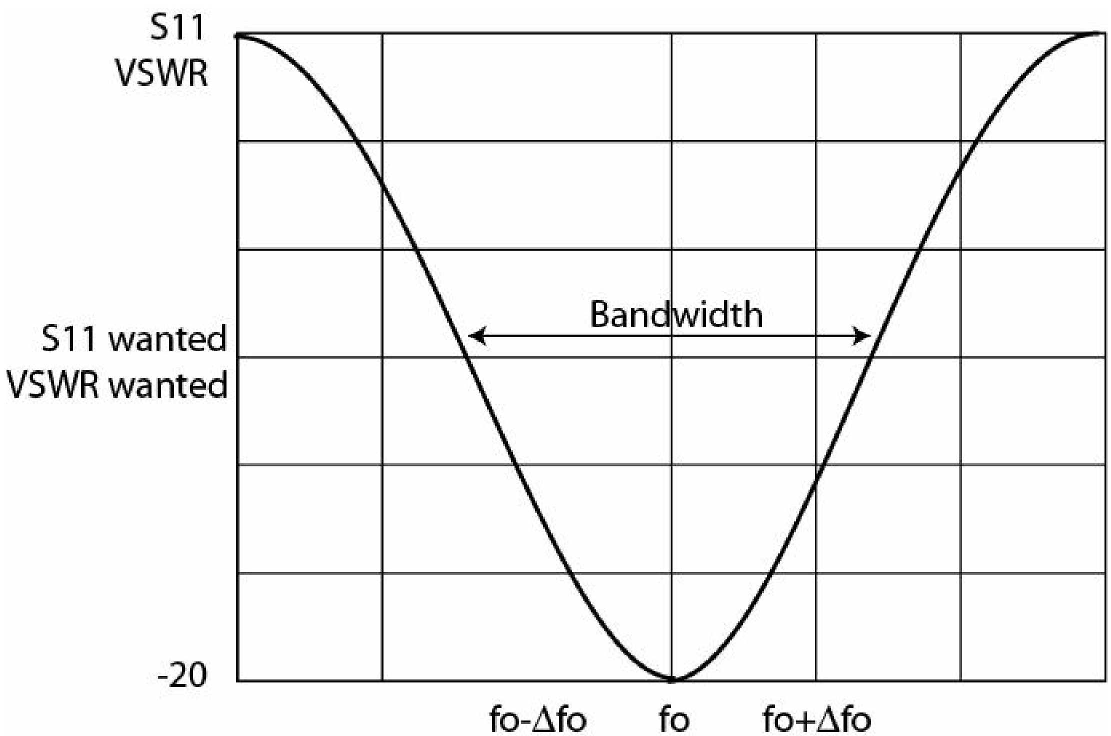

Figure 2.6 Return loss Bandwidth

2.5 Advantages and Disadvantages

Microstrip antennas are used as embedded antennas for wireless devices such as cellular phones, Satellite communications etc. The major advantages of patch antennas are given below

- Light weight and low fabrication cost.
- Can be easily integrated with microwave integrated circuits.
- Supports both, linear as well as circular polarization.
- Mechanically robust when mounted on rigid surfaces.

Microstrip patch antennas have some drawbacks as compared to conventional antennas. Some of their major disadvantages are given as

- Low efficiency and Gain.
- Narrow bandwidth.
- Low power handling capacity.
- Extraneous radiation from feeds and junctions.
- Surface wave excitation.

2.6 Literature survey

Lot of research is being currently done in feeding technique of microstrip patch antenna. some of important work related to this thesis work have been divided into three sub group:

1. Application of microstrip patch antenna
2. Pin-fed microstrip patch antenna
3. EDGE-fed microstrip patch antenna

The discussions on the literature belonging to above subgroup are given below:

2.6.1 Application of microstrip patch antenna

Microstrip patch antenna intended for use in RFID discussed by Raied A.R. Ibrahim, Mustpha C.E Yagoub and Raidh W.Y. Habash[4]. Patch antenna is design at 865 MHz for 116 mm patch length.

Practical novel design component of microstrip patch slot antenna mspsa for RFID applications

discussed by Raied A.R. Ibrahim, Mustpha C.E Yagoub and Raidh W.Y. Habash[5]. Discussion on the necessity of microstrip patches and slot antennas for RFID applications.

E Shaped Patch Microstrip Antenna for WLAN Application Using Probe Feed and Aperture Feed presented by Mamta Devi Sharma, Abhishek Katariya and Dr. R. S. Meena [6]. **A** low profile patch antenna for WLAN application is proposed . This antenna is made by using the probe feeding and aperture coupled feeding scheme. This antenna is designed in order to improve the impedance bandwidth and get the circular polarization without using truncated corners in conducting patch.

H-Shaped Microstrip Patch Antenna Using L-Probe Fed for Wideband Applications, presented by M.T Ali, N.Nordin, I.Pasya and M.N.Md Tan[7]. This paper proposed on constructing and optimizing the design of H-shaped microstrip patch antenna with L-probe feeding technique for wideband applications. The structure generally consists of air-filled substrate.

A Compact Slotted Microstrip Patch Antenna for RFID applications presented by M. H. okhtar, M. K. A. Rahim, N. A. Murad and H. A. Majid [8]. This antenna is design a compact slotted microstrip patch antenna for RFID applications.

Multiple T Slot Compact & Ultra Wide Band Microstrip Patch Antenna for Wimax Applications presented by Rajan Mishra, Nitin Muchhal and Ravi Shankar Mishra[9]. A compact Microstrip patch antenna having a slit associated with the slot for WiMAX application is presented. Instead of semiinfinite ground plane, the proposed antenna adopts the partial ground plane.

Table 2.1 Summary of microstrip patch antenna application

Parameter	[4]	[5]	[6]	[7]	[8]	[9]
Year	2009	2010	2012	2011	2013	2014
Patch length(mm)	116	60	40	38	35	21.95
S_{11}(dB)	-34	-23.8	-31.2	-12	-25	-22.25
Gain(dB)	5.6	6.07	6.0	7.517	2.5	
Operating Frequency	865MHz	865MHz	2.43 GHz	2.6 GHz	2.40 GHz	3.22 GHz
Bandwidth			380MHz	570MHz	57 MHz	

2.6.2 Pin-fed microstrip patch antenna

Design of a Modified L-Probe Fed Microstrip Patch Antenna presented by Jongkuk Park, yung-gi Na and Seung-hun Baik[10]. A improved L-probe fed (pin-fed) microstrip patch antenna is design. By replacing the bent part of an L-probe with a printed strip on a suspended substrate and by placing a conducting patch beneath the substrate, this antenna can be more reliable fabricated as a planar antenna.

Signal Flow Graph for a Probe-Fed Microstrip Patch Antenna proposed by J. E. Ruyle and J. T. Bernhard[11]. Signal flow graphs offer an analysis method for such networks, allowing network elements to be treated individually. These elements can then be reintegrated and ultimately analyzed using Mason's Gain Rule.

Novel design of dual-polarization broad-band printed l-shaped probe fed microstrip patch antenna, presented by Yaping Chen, Houjun Sun and Xin Lv[12]. It can be designed for Broad-band dual-polarization SAR applications. By using crossed printed L-shaped probe and air substrate, It has advantages of simple structure, easy fabrication cost efficient.

Design and Characterization of Pin Fed Microstrip Patch Antennae presented by Kashwan K R, Rajeshkumar V, Gunasekaran T and Shankar Kumar K R[13]. Two different materials of Teflon (dielectric constant 2.2) and glass epoxy ($dielectric\ constant$ 4.4) are analyzed for substrate design. The simulated results are compared for analysis. The compact rectangular microstrip patch antenna design procedure.

Center-Fed Microstrip Patch Antenna presented by Zhi Ning Chen and Michael Yan Wah[14]. In this paper a coaxial probe and shorting pin separated by a narrow slot centrally cut at the onducting patch.

Table 2.2 Summary of pin-fed microstrip patch antenna

Parameter	[10]	[11]	[12]	[13]	[14]
Year	2004	2009	2007	2011	2003
Patch Length(mm		40	52	24.50	
Gain(dB)	5.8			3.55	5.3
S_{11}(dB)	-31	-23.8	-15	-26	-25
Operating frequency(GHz)	2.2	2.4		3.5	1.715
Bandwidth	26.5%	24%	35%		

2.6.3 EDGE-fed microstrip patch antenna

A 2.45GHz Sierpinski Carpet Edge-fed Microstrip Patch FractalAntennafor WPT Rectenna by S. Sheik Mohammed and C.Renald[15]. It is proposed for size reduction of rectenna of Wireless Power Transmission (WPT) System.

A Novel Approach of Feeding, Impedance Matching and Frequency Tuning of Microstrip Patch Antenna by Single Microstrip line given by Nazifa Tahir and Graham Brooker [16]. This paper presents a practical technique of using a single microstrip line-feeding, impedance matching and frequency tuning of patch antenna instead of using separate transmission line and stubs.

Simultaneous Optimization of Aperture and Feed Line of a Microstrip Patch Antenna given by Fadi Deek and Changhua Wan[17]. In this paper is an aperture coupled patch antenna [4]. In the literature there exist numerous variations of aperture coupled antennas. The variations include the shape of the aperture, the shape of the strip line or the radiating patch. Any variation in the geometry of the antenna will show alter the performance. This could be reflected in polarization, resonances, bandwidth and impedance matching.

Design of Edge Fed Microstrip Patch Array Antenna Configurations for WiMAX given by T. Gunasekaran, N. Veluthambi, P. Ganeshkumar and K.R. Shankar Kumar[18]. WiMAX provides wireless transmission by a variety of transmission modes, from point-to-multipoint links to portable and fully mobile internet access with the help of MIMO technology. MIMO stands for Multiple Input and Multiple Output, where base station has multiple antennas and the mobile device has multiple antennas.

Table 2.2 Summary of EDGE-fed microstrip patch antenna

Parameter	[15]	[16]	[17]	[18]
Year	2010	2011	2012	2013
Size of transformer(mm^2)	1×10	1.7×5.5	10 ×1.27	28× 1.422
dielectric constant(ε_r)	4.4	2.2	2.33	4.6
s_{11}	-21	-20	-28	-16
Operating frequency	2.45	10.5	4.54	2.4

CHAPTER 3

Feeding Techniques of Microstrip Patch Antenna

3.1 Feed Techniques

Microstrip patch antennas can be fed by a several techniques. These techniues can be broadly classified into two types

- contacting feed technique.
- non-contacting feed technique.

In the contacting feeding technique, the RF power is fed directly to the metallic patch using a connecting element such as a microstrip line. In the non-contacting feeding technique, electromagnetic field is coupled by transfer power between the microstrip line and the metallic patch. The four most popular feed techniques are microstrip line, coaxial probe (both contacting techniques), aperture coupling and proximity coupling (both non-contacting techniques).

3.1.1 Conducting feed technique

In this feed technique power is fed directly to the metallic patch using a connecting element. Conducting feed technique can further classified in two type

- Pin feed technique
- EDGE feed technique

1. Pin feed technique

This technique is also known as coaxial feed. The Coaxial feed or pin feed is one of the most important techniques used for power fed to the microstrip patch antennas. As shown in figure 2.3, the inner conductor of the coaxial connector extends through the dielectric and is connected to the conducting patch, while the outer pin of probe is connected to the ground plane.

The main advantage of this type of feeding method is that the feed can be placed at any suitable position inside the patch in order to get impedance matching. This feed scheme is easy to design and has low spurious radiation effects.

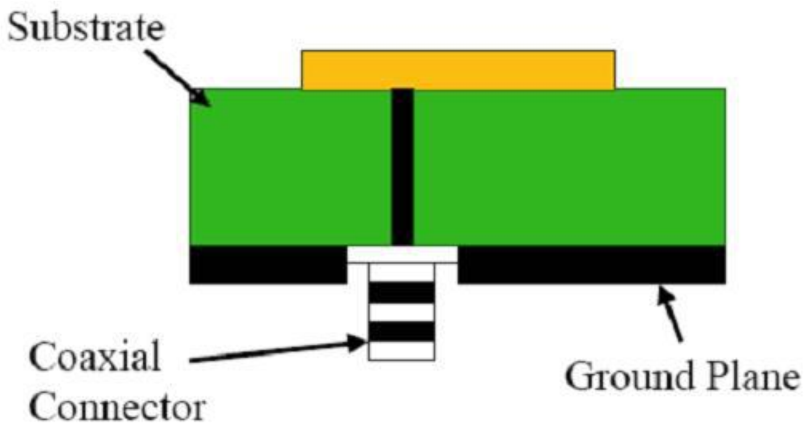

Figure 3.1 Pin feed

However, its major disadvantage is that it gives narrow bandwidth and is difficult to model since a hole has to be drilled into the substrate. even, for thicker substrates, the increased pin length of probe makes the input impedance more inductive, according to matching problems.

2. EDGE feed technique

This feed technique is also known as microstrip line feed or offset feed technique. In this type of feed technique, a metal strip is connected directly to the edge of the microstrip conducting patch as shown in figure 2.3. The conducting strip is smaller in width as compared to the patch. This kind of feed method has the advantage that the feed can be etched on the same substrate to provide a planar structure.

An inset cut can be incorporated into the patch in order to obtain impedance matching without any other additional matching element. This is achieved by properly placing the inset position. So that, it is an easy feeding technique, since it provides ease of manufacture and simplicity in designing the antenna, as well as impedance matching.While the thickness of the dielectric substrate increases, the surface waves and spurious feed radiation also increases, which affect the bandwidth of the antenna.

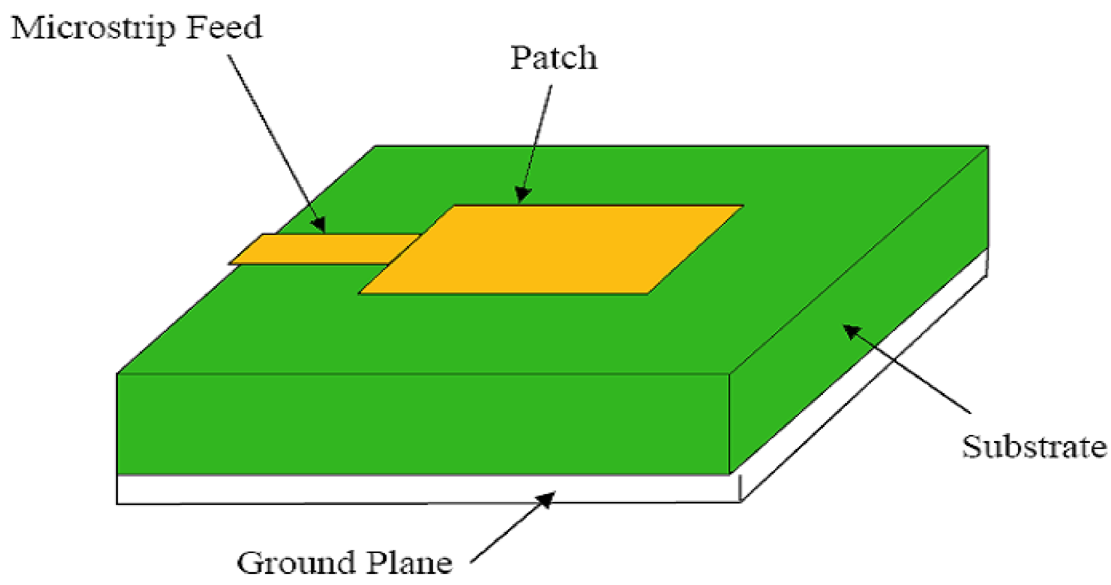

Figure 3.2 EDGE feed

This type of feeding technique results in undesirable cross polarization effects.

By using a thick dielectric substrate to increase the bandwidth, the microstrip line feed and the coaxial feed suffer from numerous disadvantages such as spurious feed radiation and matching problem.

3.1.2 Non- conducting feed technique

In the non-contacting feeding technique, electromagnetic field is coupled by transfer power between the microstrip line and the metallic patch. Non-conducting feeding technique can further classified in two types

- Proximity Coupled Feed technique
- Aperture Coupled Feed technique

1. Proximity Coupled Feed

This type of feed technique is also known as the electromagnetic coupling technique. As shown in figure 2.4, two dielectric substrates are used so that the feed line is between the two substrates and the conducting patch is on top of the upper substrate. The main merit of this feed technique is that it reduces the spurious feed radiation and gives very high bandwidth of about 13%, due to increase in the electrical thickness of the microstrip patch antenna. This technique also allow us to choices between two different dielectric media, one for the patch and one for the feed line to optimize the individual result.

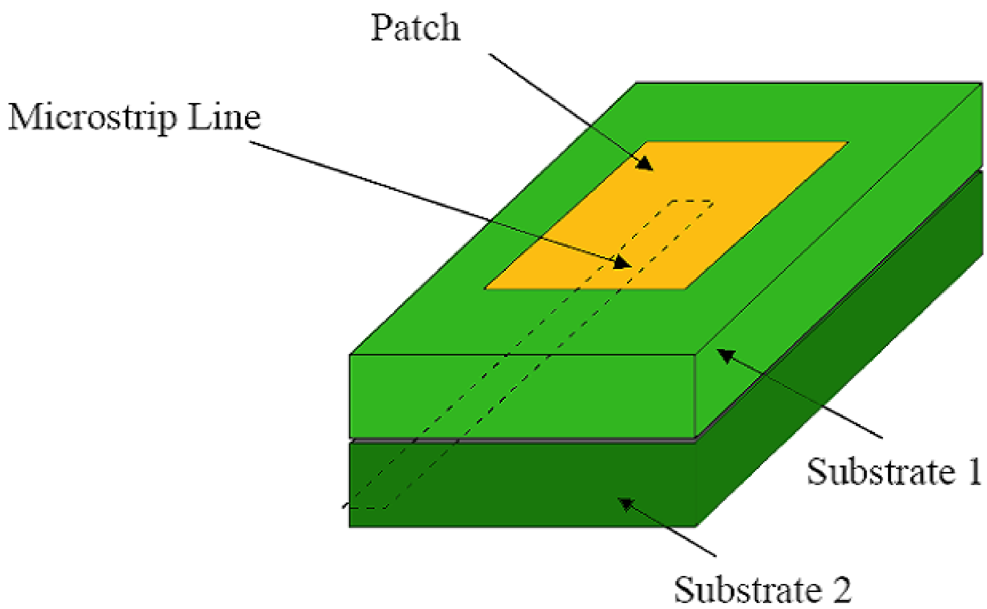

Figure 3.3 Proximity Coupled Feed

The major demerits of this feed technique are to fabricate it because of the two dielectric layers that need proper alignment and there is an increase in the overall thickness of antenna.

2. Aperture Coupled Feed

In aperture coupling as shown in figure 2.5 the conducting microstrip patch element is etched on the top of the antenna substrate, and the microstrip feed line is etched on the bottom of the feed substrate to obtain aperture coupling. The thickness and dielectric material of these two substrates can be chosen independently to obtain the distinct electrical functions of radiation and circuitry. The coupling aperture is generally centered under the patch, leading to lower cross-polarization due to symmetrical structure. The amount of coupling from the feed line to the patch is measure by the shape, size and location of the aperture. Because of the ground plane separates the patch and the feed line, spurious radiation is reduced.

In General a high dielectric material is used for lower substrate and a thick, low dielectric constant material is used for the top substrate to obtain radiation from the patch.

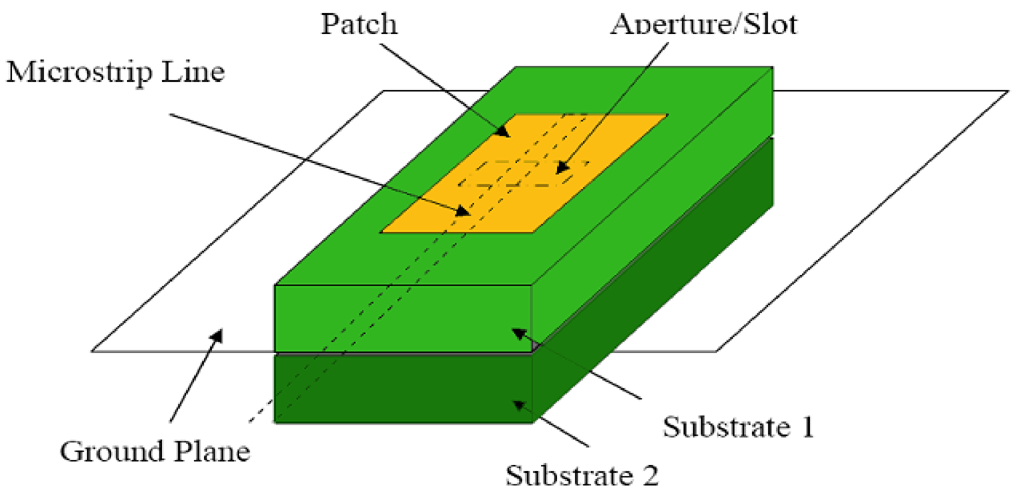

Figure 3.4 Aperture Coupled Feed

This type of feeding technique can provide very high bandwidth of about 21%. Also the affect of spurious radiation is much less as compared to other feed techniques. The main demerits of this feed technique are that it is difficult to design due to multiple layers, which also increases the thickness of antenna.

CHAPTER 4

DESIGN, SIMULATION AND RESULT

4.1 Design of the rectangular patch antenna

4.1.1 Design calculation

1. **Dielectric constant of the substrate(ε_r)**

The dielectric material that is used in my design of the Microstrip Patch Antenna is Alumina with ε_r= 2.45, as this one of the maximum values of the dielectric substrate has been taken in order to reduce the size of the antenna.

2. **The Frequency of operation (f_0)**

   The frequency of operation for the Patch antenna I am trying to design has been selected as 4.55 GHz.

3. **The height of substrate (h)**

   Microstrip Patch antenna has been designed in order to rule out the conventional antenna as the patch antennas are used in most of the compact devices. Therefore the height of the antenna has been decided as 3.175mm.

4. **Calculation of width (w)**

   Formula

$$\text{Width} = \frac{c}{2f_0}\sqrt{\frac{2}{\varepsilon_r+1}}$$

By substituting the value of c= $3\times 10^8\ m/s$, $\varepsilon_r = 2.45$ and $f_0 = 4.16\ GHz$
We get

Width (w) = 0.0266m = 26.6 mm

5. **Calculation of effective dielectric constant (ε_{reff})**

   Formula

$$\varepsilon_{reff} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2}\left[1 + 12\ \frac{\mathbf{h}}{w}\right]^{-\frac{1}{2}}$$

With the substituting the values $\varepsilon_r = 2.45$, h = 3.175 mm and w= 26.6 mm

We get Effective Dielectric Constant $\varepsilon_{reff} = 2.19$

6. **Calculation of effective length (L_{eff})**

Formula

$$L_{eff} = \frac{c}{2f_0\sqrt{\varepsilon_{reff}}}$$

With the substituting the values c= $3\times 10^8\ m/s$, $\varepsilon_{reff} = 2.19$ and $f_0 = 4.16\ GHz$

We get

$$L_{eff} = 0.0243m = 24.3\ mm$$

7. Calculation of the length of extension (ΔL)

Formula

$$\Delta L = 0.412h\ \frac{[\varepsilon_{reff}+0.3]}{[\varepsilon_{reff}-0.258]}\ \frac{[\frac{w}{h}+0.264]}{[\frac{w}{h}+0.8]}$$

With the substituting the values h= 3.175, w = 27 mm and $\varepsilon_{reff} = 2.19$

We get

$$\Delta L = 1.58\ mm$$

8. Calculation of length of patch (L)

Formula

$$L = L_{eff} - 2\ \Delta L$$

By putting the value of $L_{eff} = 24.30\ mm$ and $\Delta L = 1.588mm$

We get

L = 21.1242 mm

4.2 **SIMULATION**

FEKO-EM simulation software is used in order to produce the design and the responses for the Rectangular Microstrip patch antenna and its design.

The table 4.1 below gives the possible parameters for the design of the Microstrip patch antenna which will be used in the software for the results to examine. The width and the length of the patch have been rounded up to the close integer value.

Table 4.1 Parameters used in the software for the responses and simulations.

Parameter	
Dielectric constant of substrate (ε_r)	2.45
Frequency of operation (f_0)	4.16 GHz
Width of patch (W)	26.6 mm
Length of patch (L)	21.124 mm
Height of substrate (h)	3.175
Z_0	50 Ohm

As there feed type has been specified and the parameters are calculated. The matching impedance is 50Ω. In order to have a matching of the impedance the connecter has to be placed at some distance from the edge which has a match of 50Ω. There is a trial and error method that has been adopted to check the minimum value of the Return loss.

4.2.1 Design procedure

Now in this section we discuss about the Design of the microstrip patch Antenna with edge-fed Technique Using FEKO-EM simulation software.

As per the calculated Dimension Parameters let us design the Rectangular Patch Antenna with the edge-fed Technique.

FEKO-EM simulation software is extensively used for the Design and the Simulation of the Patch Antenna. Let us see the procedure of the design step by step and finally the responses and the simulation.

The calculated measurements can be found in the table in the previous section.

With the length = 19.09mm and the width = 22mm a rectangle is drawn as below:

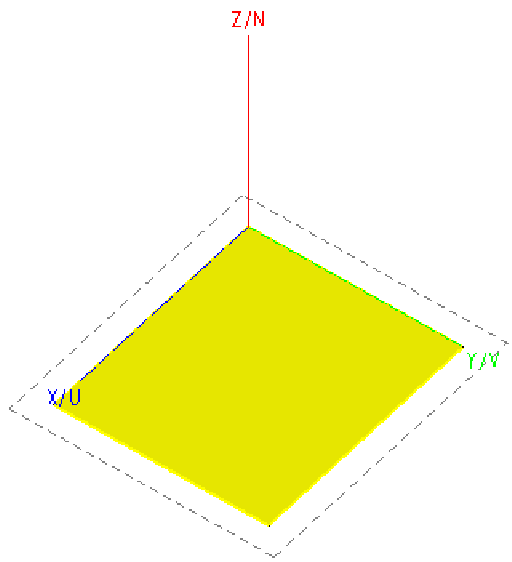

Figure 4.1 Rectangle drawn with L & W

The rest of the structure of the antenna is drawn now connecting the vertices and the Microstrip feed line as shown in figure 4.2.

A feed line is to be installed to the antenna in order to get the RF power to the patch and now we design the feed line and a port number is assigned in order to have a reference while calculating the S-Parameters.

The feeding Microstrip line is a 50 Ohm line and the impedance of the antenna is matched to 50 Ohm by the edge feed.

Now the stage has come to setup the excitation. The port that is already numbered is taken in to consideration for the excitation. Then we next come to the simulation as the antenna has to be meshed up with the Method of Moment (MoM) calculation.

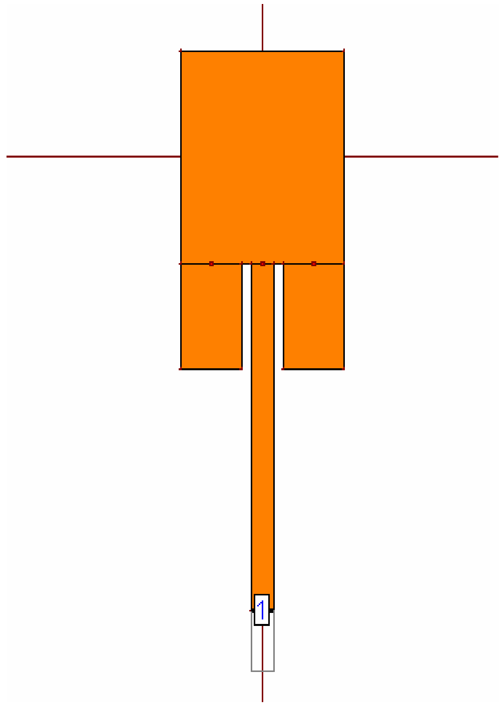

Figure 4.2 Port number has been assigned in order to give an excitation.

The centre frequency for this design is taken to be 4.1 GHz, so for the MoM the maximum frequency is given as 4.5 GHz i.e. the range of the frequency is given as 4 to 4.5Hz, and 30 cells per wavelength(CPW) is selected which determines the density of the mesh.(Higher the number of the CPW, so is the simulation accuracy). In most of the simulations 20 to 30 CPW are used which said that they should provide enough accuracy.

The meshed antenna can be seen in the figure 4.3

As now we have the excitation and the meshed antenna we can proceed for the simulation with the starting frequency as 4.0 GHz and highest frequency as 4.5 GHz, with the number of frequency = 101 i.e. the field is spaced evenly with 101 frequency points between the starting and the highest frequency.

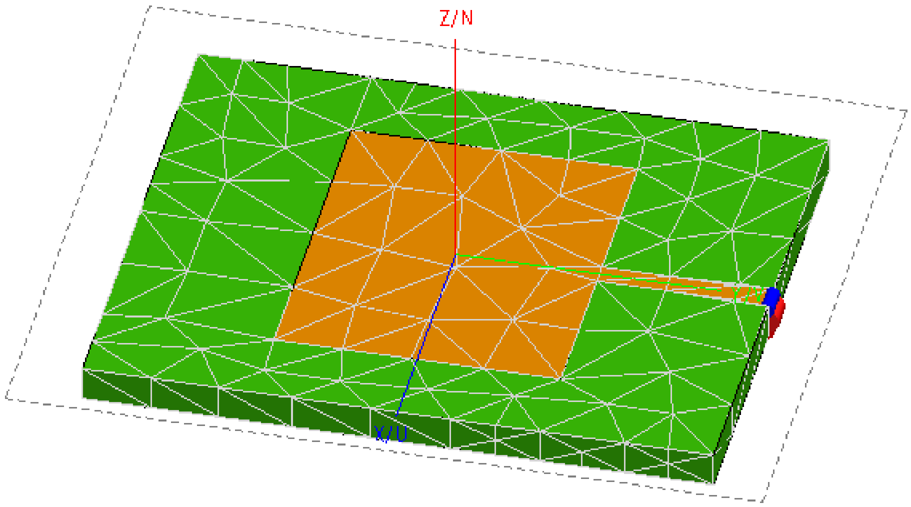

Figure 4.3 A meshed Rectangular Patch Antenna

But before we run the simulation we can have a look at the 3D structure of the meshed antenna with the simple Microstrip feed line in the figure 43

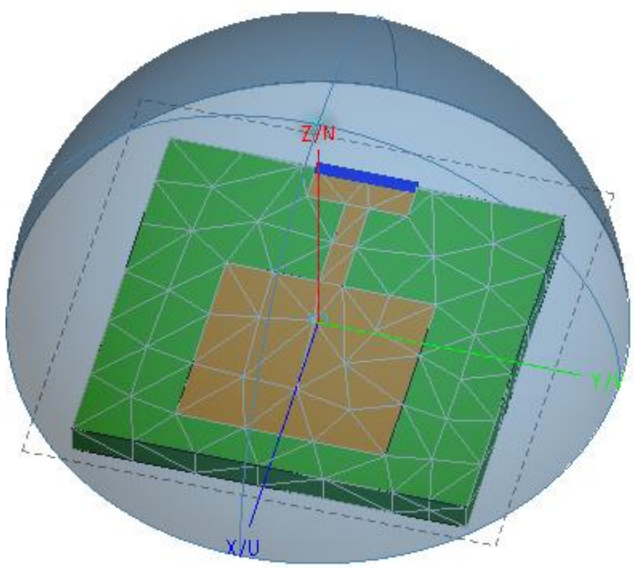

Figure 4.4 3D Structure of the meshed Rectangular Patch Antenna with Simple Edge feed

The simulation is run and is completed which gives the S-Parameters of the simulated structure.

4.3 Result

As the design process goes the calculation of the parameters is done above and with the dimensions the rectangular patch antenna has been designed by Edge feed techniques.

Software used:

FEKO-EM simulation software is used in order to produce the design and the responses for the Rectangular Microstrip patch antenna and its design.

The following results are obtain

4.3.1 Electric field pattern

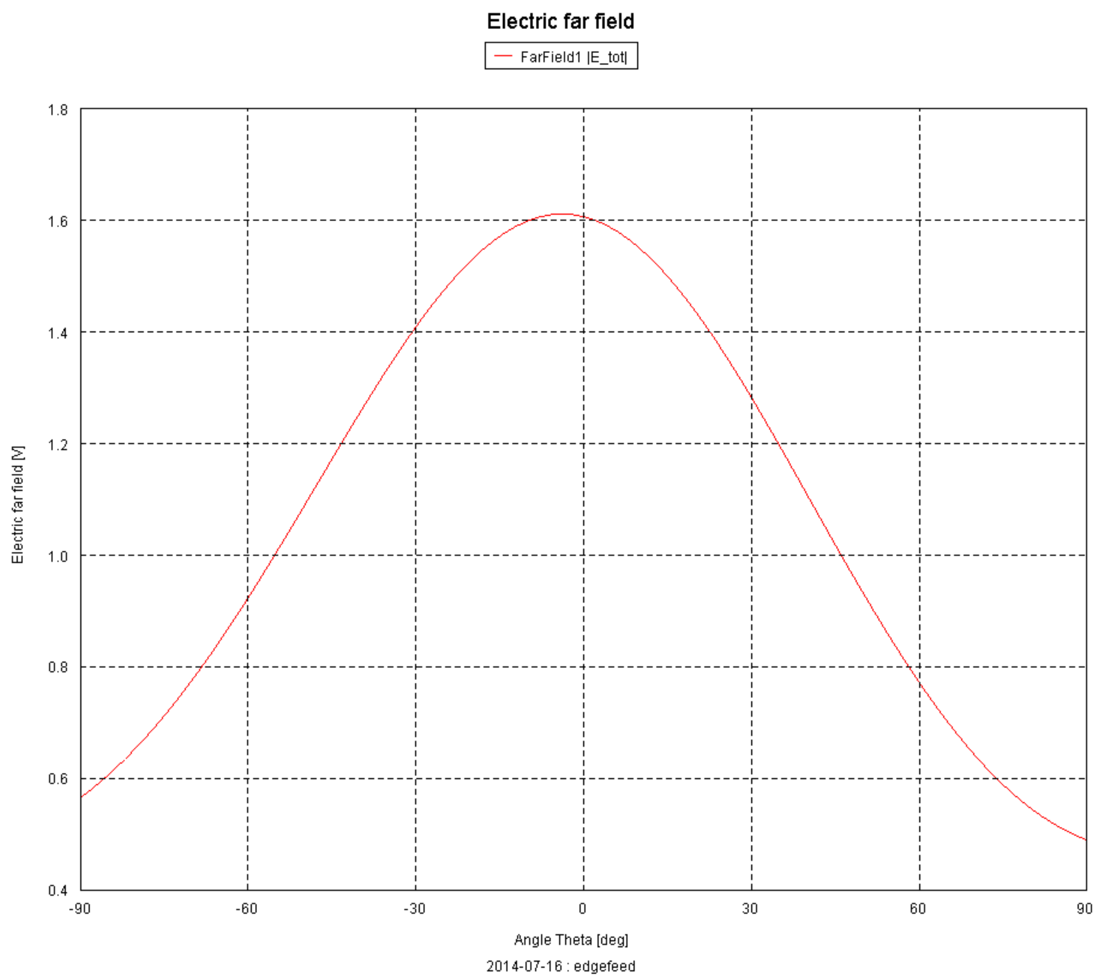

Figure 4.5 Electric field pattern of edge-fed patch antenna

4.3.2 Return loss

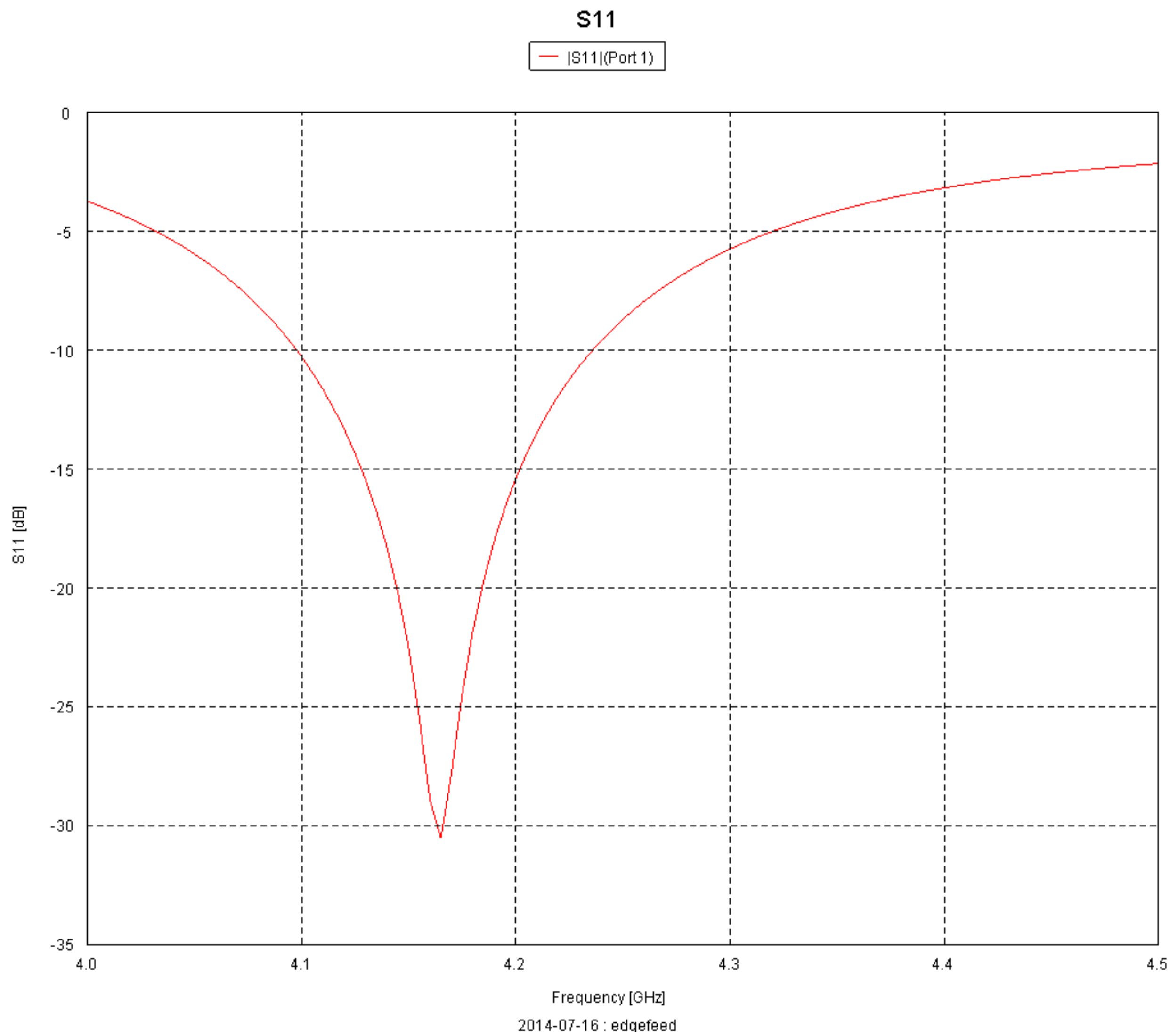

Figure 4.6 Return loss in dB

Return loss is minimum at frequency 4.16 that is -30.51 dB. This is acceptable for designing of antenna for wireless communication.

4.3.3 Voltage standing wave ratio

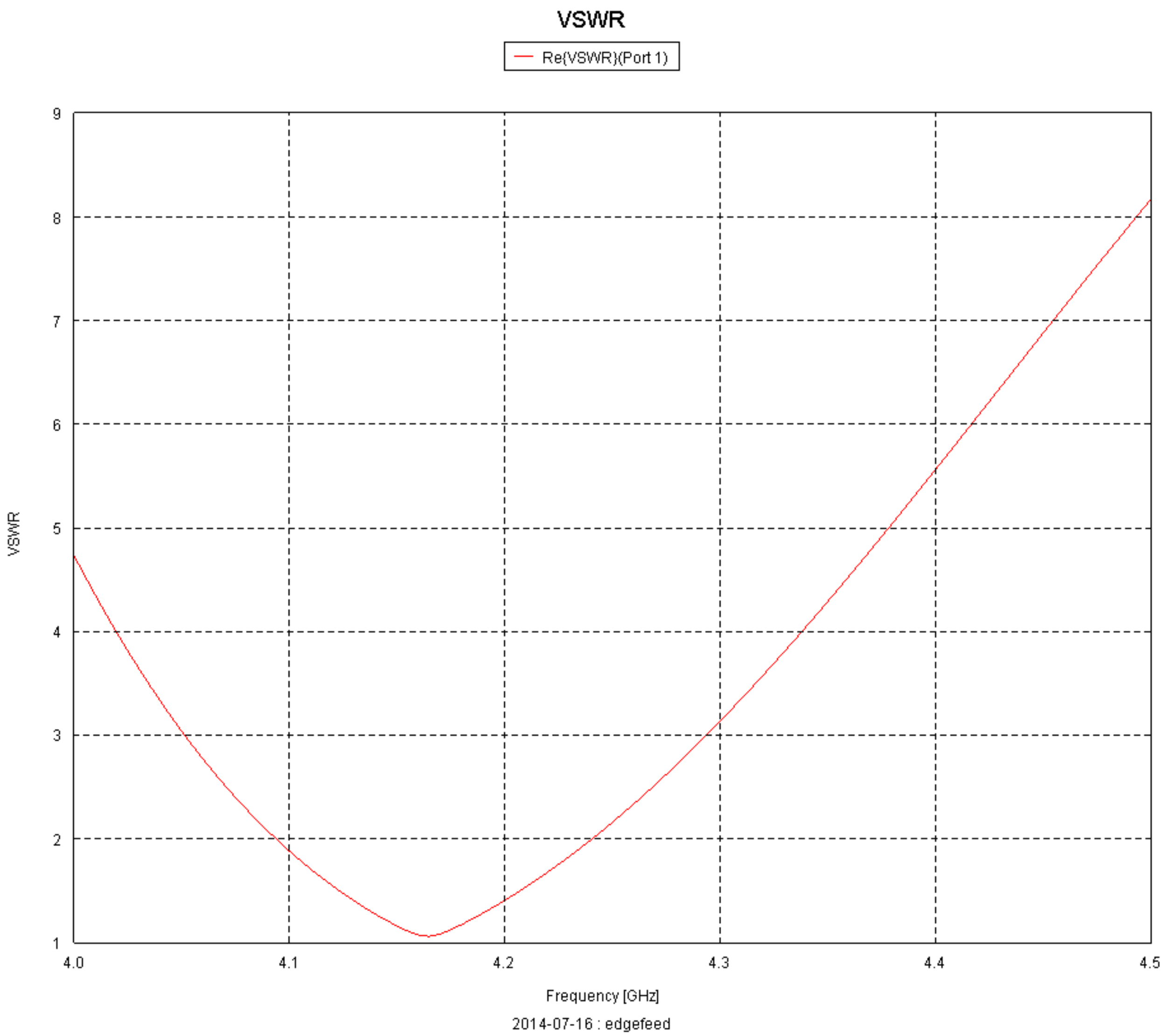

Figure 4.7 VSWR pattern of Edge-fed microstrip patch antenna.

Voltage standing wave ratio is 1.04 at resonating frequency 4.16 GHz. Which is less than two and acceptable of wireless communication.

4.3.4 Directivity

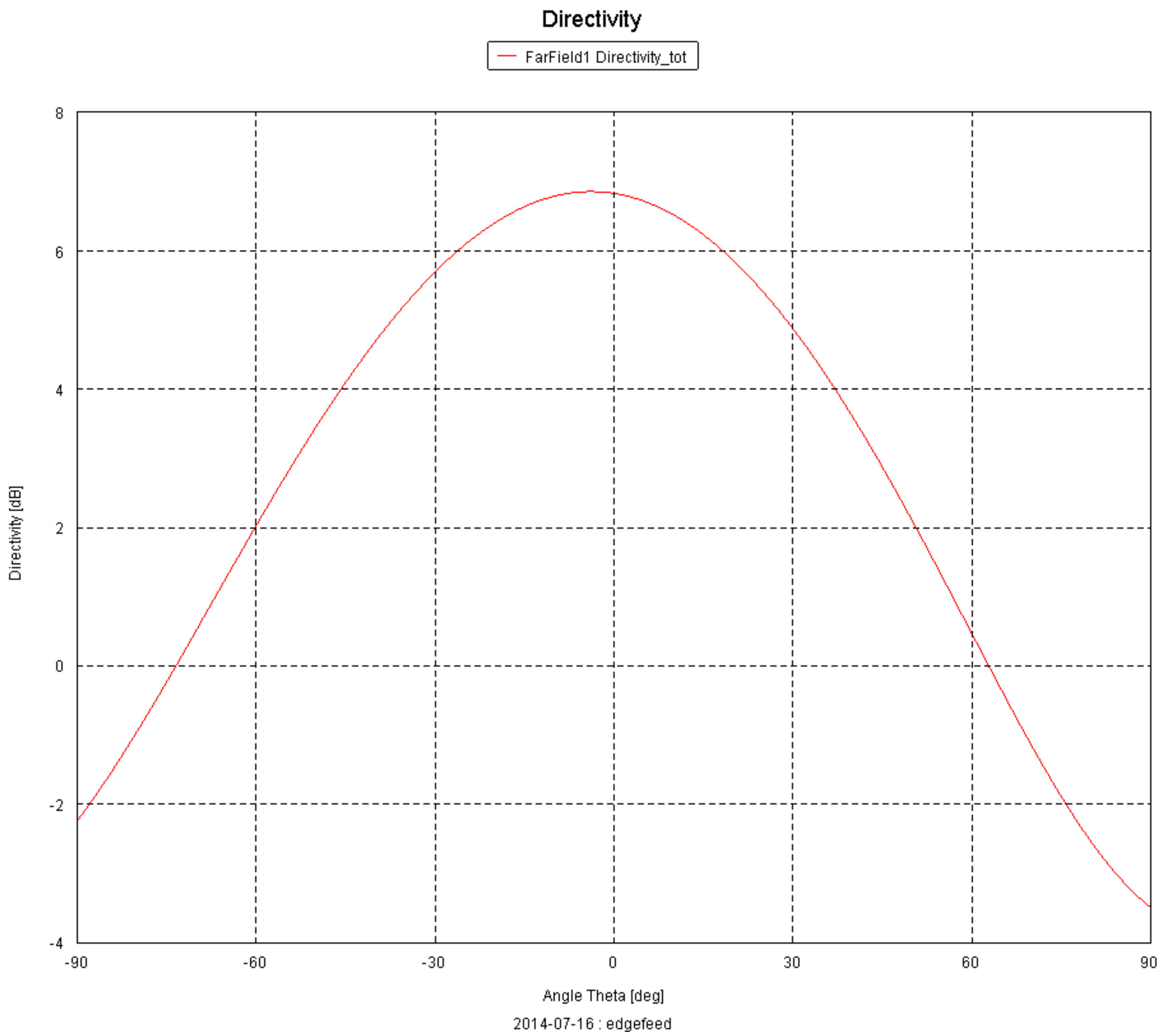

Figure 4.8 Directivity of edge-fed patch antenna

Directivity of antenna is 7 dB at resonating frequency 4.16 GHz. This is quite acceptable.

4.3.5 Gain

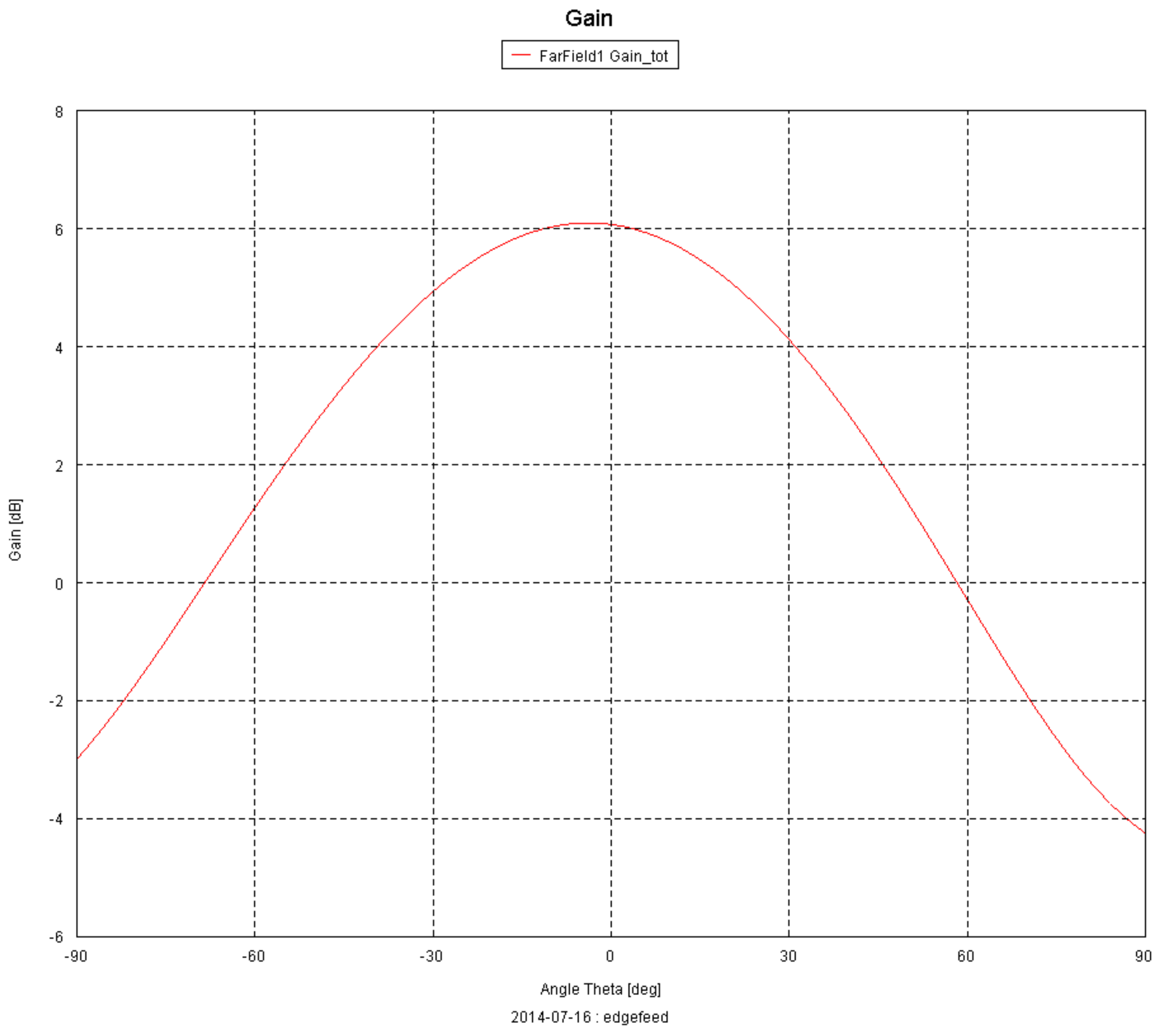

Figure 4.9 Gain of edge-fed patch antenna

Gain of antenna is 6dB at resonating frequency. This is good for designing of antenna for wireless communication.

As now we have simulated the structure and the response is shown, we shall study the radiation parameters. After this response from the range of the frequencies we can see that the operation point is at 4.16 GHz for this design. The antenna is well matched to 50ohms at 4.16 GHz.

Table 4.2: The result after the simulation by FEKO-EM simulation software

Resonating frequency	4.16 GHz
Source power	10.6 mW
Antenna efficiency	84 %
Reflection coefficient (S_{11})	30.50 dB
Gain	6.4 dB
Directivity	7 dB
3 dB beam-width	79^0

Now for the radiation pattern the antenna shall be simulated only at 4.16 GHz, which is the operating frequency for this design of the patch antenna. Here we have a few different specifications than for the S-Parameters, as frequency at 4.16 GHz.

CHAPTER 5

CONCLUSION AND FUTURE WORK

5.1 CONCLUSION

The aim of this project is to design a rectangular patch Microstrip antenna and to study the responses and the radiation properties of the same. In this project an antenna has been designed with Edge-fed technique.

An antenna has been designed with the dimension parameters Length- 21.124 mm, Width – 26.6mm, height – 3.175 mm, with a dielectric constant 2.45 at 4.16 GHz with Microstrip feed line at 4.16 GHz.

It is good to see that the return loss has a negative value in all the cases which states that the losses are minimum during the transmission. In the design the *RL* is -30.51dB in edge feed line technique.

Taking all this in to consideration we can say that there are many aspects that affect the performance of the antenna. Dimensions, selection of the substrate, feed technique and also the Operating frequency can take their position in effecting the performance.

A edge-fed Rectangular Microstrip Patch Antenna with the dimension parameters *h*-3.175mm, *L*-21.124 mm, *W*- 26.6mm with a dielectric constant of 2.45 at an operating frequency of 4.16GHz from this project can be said as the optimized design.

5.2 Future work

A Microstrip Line fed Rectangular Microstrip Patch Antenna with the dimension parameters *h*- 3.175mm, *L*- 21.124mm, *W*- 26.6mm with a dielectric constant of 2.45 at an operating frequency of 4.16GHz from this project can be said as the optimized design.

In future other different type of feed techniques can be used to calculate the overall performance of the antenna without missing the optimized parameters in the action. Extensively and exclusively focusing on the area of different design methods especially in enhancing the impedance bandwidth, and the efficiency.

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