PROJECT REPORT

DESIGNING OF

MICROSTRIP PATCH ANTENNA and DIELECTRIC ROD ANTENNA

Project Report submitted in partial fulfillment of the requirement for the degree of

Bachelor of Technology.

in

Electronics and Communication Engineering

under the Supervision of

Ms.PRAGYA GUPTA

By

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to

Jaypee University of Information and Technology

Certificate

This is to certify that project report entitled "Designing and study of Microstrip Patch Antenna and Dielectric Rod Antenna.", submitted by Gauri Basant Sharma, Bharat Wadhwa Ananya Awasthi in partial fulfillment for the award of degree of Bachelor of Technology in Electronics and Communication Engineering to Jaypee University of Information Technology, Waknaghat, Solan has been carried out under my supervision.

This work has not been submitted partially or fully to any other University or Institute for the award of this or any other degree or diploma.

Date: 31/05/2012

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Acknowledgement

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Daie 31/05/2012

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INTRODUCTION

1.1 Aim and Objectives

The aim of the project is to design a Microstrip Patch Antenna and Dielectric Rod Antenna, and study the effect of antenna dimensions Length (L), and substrate parameters like relative Dielectric constant (€), substrate height (h) on the Radiation pattern, gain, S-parameters.

1.2 Overview

1.2.1 Overview of Microstrip Patch Antenna

A Microstrip antenna consists of conducting patch on a ground plane separated by dielectric substrate. This concept was undeveloped until the revolution in electronic circuit miniaturization and large-scale integration in 1970. After that many authors have described the radiation from the ground plane by a dielectric substrate for different configurations. The early work of Munson on micro strip antennas for use as a low profile flush mounted antennas on rockets and missiles showed that this was a practical concept for use in many antenna system problems. Various mathematical models were developed for this antenna and its applications were extended to many other fields. The number of papers, articles published in the journals for the last ten years, on these antennas shows the importance gained by them. The micro strip antennas are the present day antenna designer's choice. Low dielectric constant substrates are generally preferred for maximum radiation. The conducting patch can take any shape but rectangular and circular configurations are the most commonly used configuration. Other configurations are complex to analyze and require heavy numerical computations. A Microstrip antenna is characterized by its Length, Width, Input impedance, and Gain and radiation patterns. Various parameters of the Microstrip antenna and its design considerations were discussed in the subsequent chapters. 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. There are no hard and fast rules to find the width of the patch.

1.2.2 Overview of Dielectric Rod Antenna

Today's wireless technology shows a significant shift towards millimeter wave frequencies. Not only does the lower part of the electromagnetic spectrum becomes saturated, mm-wave frequencies allow for wider bandwidths and high-gain antennas are physically small. At millimeter-wave frequencies, dielectric rod antennas provide significant performance advantages and are a low cost alternative to free space high gain antenna designs such as Yagi-Uda and horn antennas, which are often more difficult to manufacture at these frequencies .The aim of this report is to demonstrate the relative ease of obtaining high gain and broad-band performance from dielectric rod antennas that are at the same time easy and cheap to construct.

1.3 Waves on Microstrip

The mechanisms of transmission and radiation in a Microstrip can be understood by considering a point current source (Hertz dipole) located on top of the grounded dielectric substrate (fig. 1.1) This source radiates electromagnetic waves.

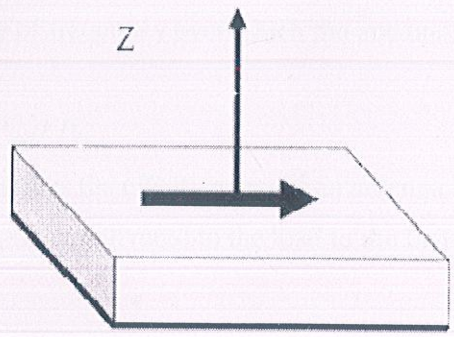


Fig 1.1 Hertz Dipole on a Microstrip substrate

1.4 Guided Waves

When realizing printed circuits, one locally adds a metal layer on top of the substrate, which modifies the geometry, introducing an additional reflecting boundary. Waves directed into the dielectric located under the upper conductor bounce back and forth on the metal boundaries, which form a parallel plate waveguide. The waves in the metallic guide can only exist for some Particular values of the angle of incidence, forming a discrete set of waveguide modes. The guided waves provide the normal operation of all transmission lines and circuits, in which the electromagnetic fields are mostly concentrated in the volume below the upper conductor. On the other hand, this buildup of electromagnetic energy is not favorable for patch antennas, which behave like resonators with a limited frequency bandwidth.[1]

1.5 Antenna Characteristics

An antenna is a device that is made to efficiently radiate and receive radiated electromagnetic waves[1]. There are several important antenna characteristics that should be considered when choosing an antenna for your application as follows:

- **Radiation pattern**: The relative distribution of radiated power as a function of direction in space – an (hypothetical) isotropic antenna radiates equally in all directions.
- **Gain** G:

  Absolute gain: ratio of intensity in particular direction to isotropically radiated intensity.

  Relative gain: :ratio of power gain in particular direction to power gain of reference antenna
- **Beamwidth**: The angle between the two directions in which the radiated power is half of the maximum value of the beam.
- **Bandwidth**: It is the range of frequency over which the antenna can properly radiate or receive the energy
- **Antenna efficiency**: $e = P_{rad} / P_{in}$
- **Effective aperture**: It describes the effectiveness of an antenna in the receiving mode. It is defined as the ratio of the power delivered to the load to the incident power density.

CHAPTER 2

MICROSTRIP PATCH ANTENNA

Microstrip antennas are attractive due to their light weight, conformability and low cost. These antennas can be integrated with printed strip-line feed networks and active devices. This is a relatively new area of antenna engineering. The radiation properties of micro strip structures have been known since the mid 1950's. The application of this type of antennas started in early 1970's when conformal antennas were required for missiles. Rectangular and circular micro strip resonant patches have been used extensively in a variety of array configurations. A major contributing factor for recent advances of Microstrip antennas is the current revolution in electronic circuit miniaturization brought about by developments in large scale integration. As conventional antennas are often bulky and costly part of an electronic system, micro strip antennas based on photolithographic technology are seen as an engineering breakthrough.

2.1 Introduction

In its most fundamental form, a Microstrip Patch antenna consists of a radiating patch on one side of a dielectric substrate which has a ground plane on the other side as shown in Figure 2.1. The patch is generally made of conducting material such as copper or gold and can take any possible shape. The radiating patch and the feed lines are usually photo etched on the dielectric substrate.

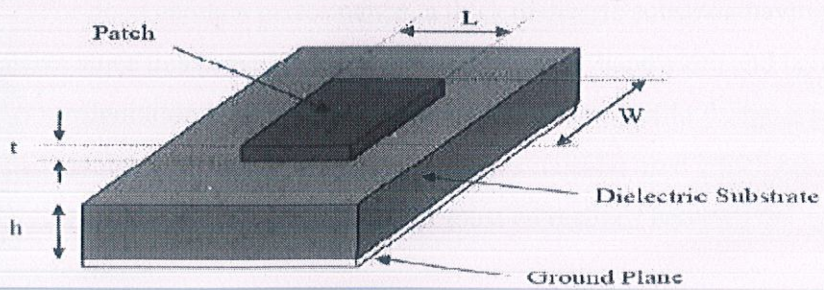


Fig 2.1 Structure of a Microstrip Patch Antenna

In order to simplify analysis and performance prediction, the patch is generally square, rectangular, circular, triangular, and elliptical or some other common shape as shown in Figure 2.2. For a rectangular patch, the length L of the patch is usually $0.3333\lambda o < L < 0.5\ \lambda o$, where λo is the free-space wavelength. The patch is selected to be very thin such that $t << \lambda o$ (where *t* is the patch thickness). The height *h* of the dielectric substrate is usually $0.003\ \lambda o \leq h \leq 0.05\ \lambda o$. The dielectric constant of the substrate (εr) is typically in the range $2.2 \leq \varepsilon r \leq 12$.

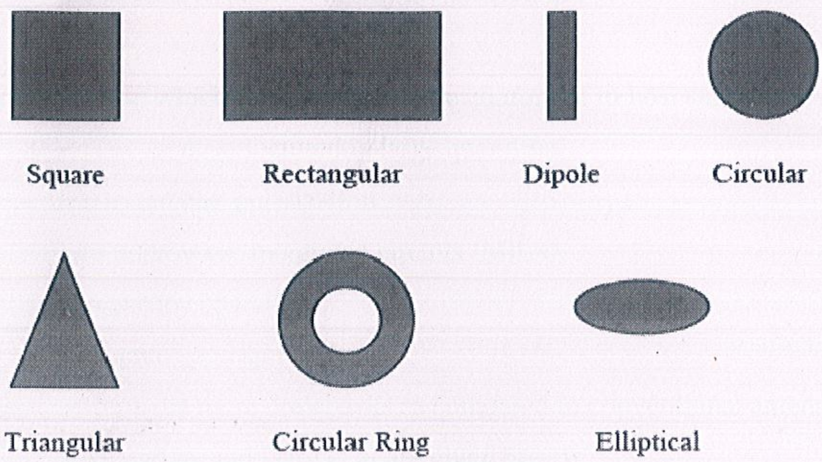


Fig 2.2 Common Shapes of Microstrip patch elements[Ref.1]

Microstrip patch antennas radiate primarily because of the fringing fields between the patch edge and the ground plane. For good antenna performance, a thick dielectric substrate having a low dielectric constant is desirable since this provides better efficiency, larger bandwidth and better radiation. However, such a configuration leads to a larger antenna size. In order to design a compact Microstrip patch antenna, substrates with higher dielectric constants must be used which are less efficient and result in narrower bandwidth. Hence a trade-off must be realized between the antenna dimensions and antenna performance.

2.2 Advantages and Disadvantages

Microstrip Patch Antennas are increasing in popularity for use in wireless applications due to their low-profile structure. Therefore they are extremely compatible for embedded antennas in handheld wireless devices such as cellular phones, pagers etc... The telemetry and communication antennas on missiles need to be thin and conformal and are often in the form of Microstrip patch antennas. Another area where they have been used successfully is in Satellite communication. Some of their principal advantages discussed by Kumar and Ray are given below:

- Light weight and low volume.
- Low profile planar configuration which can be easily made conformal to host surface.
- Low fabrication cost, hence can be manufactured in large quantities.
- Supports both, linear as well as circular polarization.
- Can be easily integrated with microwave integrated circuits (MICs).
- Capable of dual and triple frequency operations.
- Mechanically robust when mounted on rigid surfaces.

Microstrip patch antennas suffer from more drawbacks as compared to conventional antennas. Some of their major disadvantages discussed by and Garg et al are given below:

- Narrow bandwidth.
- Low efficiency.
- Low Gain.
- Extraneous radiation from feeds and junctions.
- Poor end fire radiator except tapered slot antennas.
- Low power handling capacity.
- Surface wave excitation.

Microstrip patch antennas have a very high antenna quality factor (Q). It represents the losses associated with the antenna where a large Q leads to narrow bandwidth and low efficiency. Q can be reduced by increasing the thickness of the dielectric substrate. But as the thickness increases, an increasing fraction of the total power delivered by the source goes into a surface wave. This surface wave contribution can be counted as an unwanted power loss since it is ultimately scattered at the dielectric bends and causes degradation of the antenna characteristics. Other problems such as lower gain and lower power handling capacity can be overcome by using an array configuration for the elements.

2.3 Feed Techniques

Microstrip patch antennas can be fed by a variety of methods. These methods can be classified into two categories- contacting and non-contacting. In the contacting method, the RF power is fed directly to the radiating patch using a connecting element such as a Microstrip line. In the non-contacting scheme, electromagnetic field coupling is done to transfer power between the Microstrip line and the radiating patch. The four most popular feed techniques used are the Microstrip line, coaxial probe (both contacting schemes), aperture coupling and proximity coupling (both non-contacting schemes).

2.3.1 Microstrip Line Feed

In this type of feed technique, a conducting strip is connected directly to the edge of the Microstrip patch as shown in Figure 2.3. The conducting strip is smaller in width as compared to the patch and this kind of feed arrangement has the advantage that the feed can be etched on the same substrate to provide a planar structure.

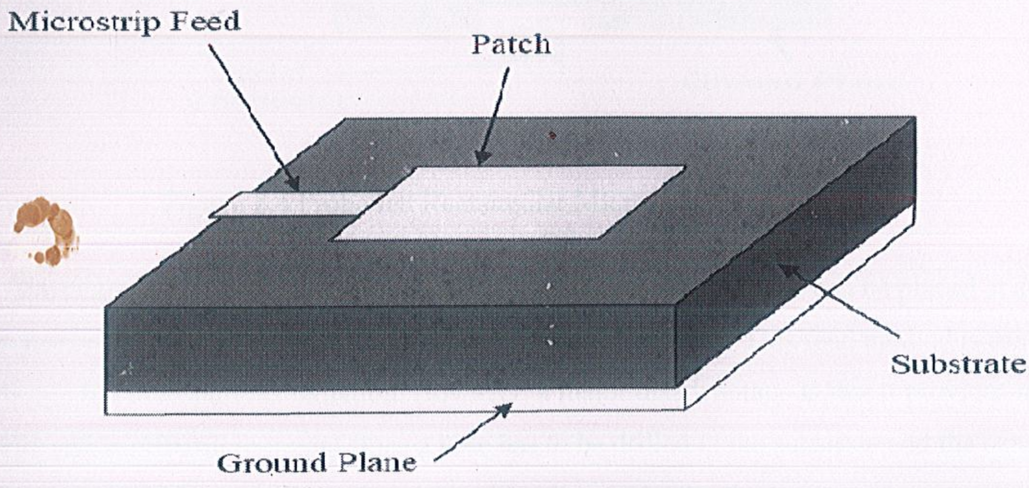


Fig 2.3 Microstrip Feed Line[1]

The purpose of the inset cut in the patch is to match the impedance of the feed line to the patch without the need for any additional matching element. This is achieved by properly controlling the inset position. Hence this is an easy feeding scheme, since it provides ease of fabrication and simplicity in modeling as well as impedance matching. However as the thickness of the dielectric substrate being used, increases, surface waves and spurious feed radiation also increases, which hampers the bandwidth of the antenna. The feed radiation also leads to undesired cross polarized radiation.

2.3.2 Coaxial Feed

The Coaxial feed or probe feed is a very common technique used for feeding Microstrip patch antennas. As seen from Figure 2.4, the inner conductor of the coaxial connector extends through the dielectric and is soldered to the radiating patch, while the outer conductor is connected to the ground plane.

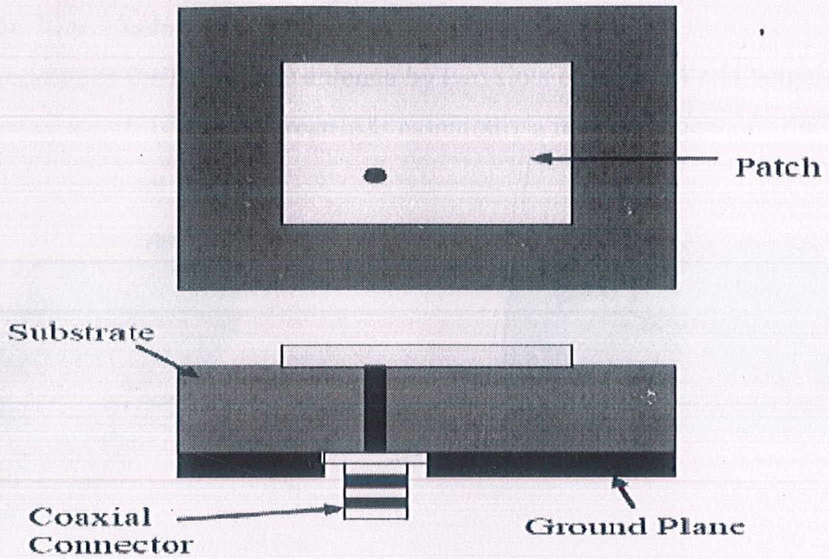


Figure 2.4 Probe fed Rectangular Microstrip Patch Antenna[1]

The main advantage of this type of feeding scheme is that the feed can be placed at any desired location inside the patch in order to match with its input impedance. This feed method is easy to fabricate and has low spurious radiation. However, a major disadvantage is that it provides narrow bandwidth and is difficult to model since a hole has to be drilled in the substrate and the connector protrudes outside the ground plane, thus not making it completely planar for thick substrates ($h > 0.02\lambda o$)[.1]. Also, for thicker substrates, the increased probe length makes the input impedance more inductive, leading to matching problems. It is seen above that for a thick dielectric substrate, which provides broad bandwidth, the Microstrip line feed and the coaxial feed suffer from numerous disadvantages. The non-contacting feed techniques which have been discussed below, solve these issues.

2.4 Methods of Analysis

The preferred models for the analysis of Microstrip patch antennas are the transmission line model, cavity model, and full wave model (which include primarily integral equations/Moment Method). The transmission line model is the simplest of all and it gives good physical insight but it is less accurate. The cavity model is more accurate and gives good physical insight but is complex in nature. The full wave models are extremely accurate, versatile and can treat single elements, finite and infinite arrays, stacked elements, arbitrary shaped elements and coupling. These give less insight as compared to the two models mentioned above and are far more complex in nature.

2.4.1 Transmission Line Model

This model represents the Microstrip antenna by two slots of width W and height h, separated by a transmission line of length L. The Microstrip is essentially a non-homogeneous line of two dielectrics, typically the substrate and air.

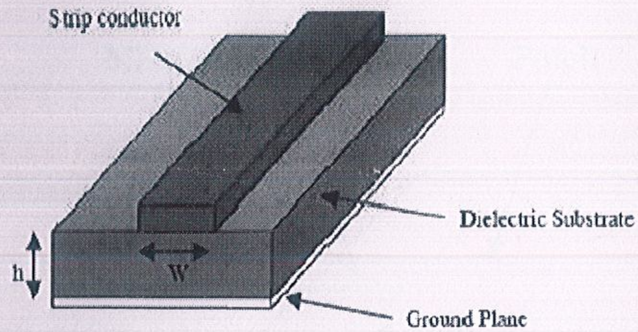


Figure 2.5 Microstrip Line [1]

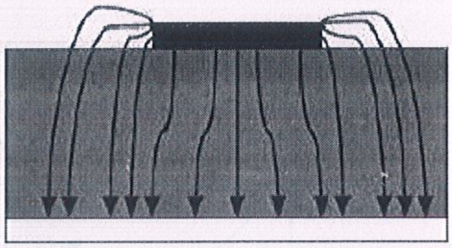


Figure 2.6 Electric Field Lines [1]

Hence, as seen from Figure 2.8, most of the electric field lines reside in the substrate and parts of some lines in air. As a result, this transmission line cannot support pure transverse-electric-magnetic (TEM) mode of transmission, since the phase velocities would be different in the air and the substrate. Instead, the dominant mode of propagation would be the quasi-TEM mode. Hence, an effective dielectric constant (ε_{reff}) must be obtained in order to account for the fringing and the wave propagation in the line. The value of ε_{reff} is slightly less then ε_r because the fringing fields around the periphery of the patch are not confined in the dielectric substrate but are also spread in the air as shown in Figure 3.8 above.

The expression for $\varepsilon reff$ is given by Balanis[1] as:

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

Where $\varepsilon reff$ = Effective dielectric constant

εr = Dielectric constant of substrate

h = Height of dielectric substrate

W = Width of the patch

Consider Figure 2.9 below, which shows a rectangular Microstrip patch antenna of length L, width W resting on a substrate of height h. The co-ordinate axis is selected such that the length is along the x direction, width is along the y direction and the height is along the z direction.

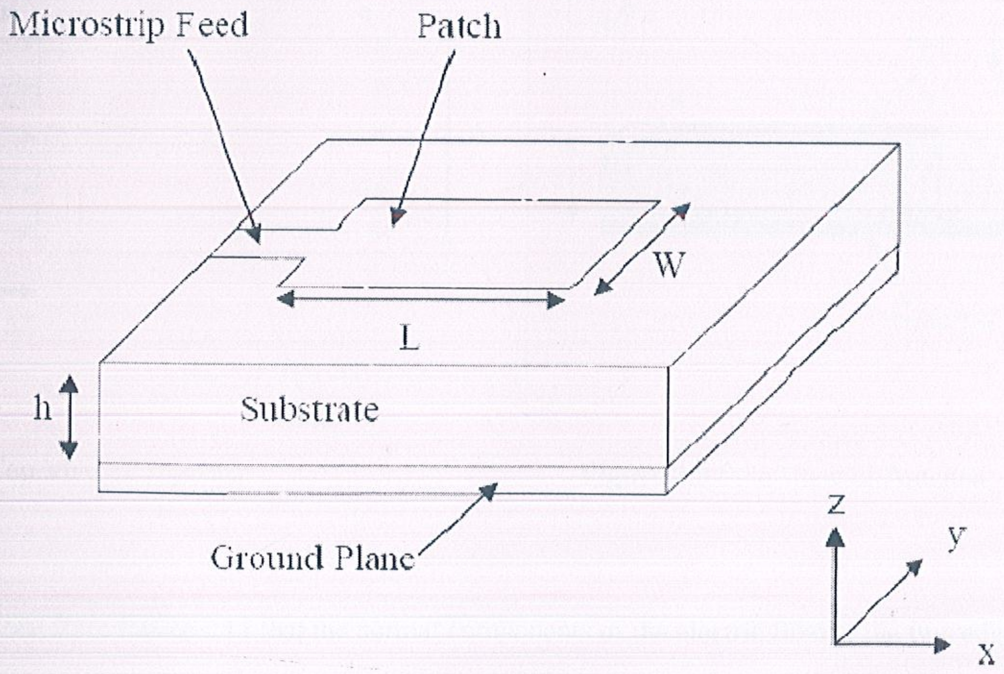


Figure 2.7 Microstrip Patch Antennas [1]

In order to operate in the fundamental *TM*10 mode, the length of the patch must be slightly less than λ/2 where λ is the wavelength in the dielectric medium and is equal to $\lambda o/\sqrt{\varepsilon reff}$ where λo is the free space wavelength. The *TM*10 mode implies that the field varies one λ/2 cycle along the length, and there is no variation along the width of the patch. In the Figure 2.10 shown below, the Microstrip patch antenna is represented by two slots, separated by a transmission line of length L and open circuited at both the ends. Along the width of the patch, the voltage is maximum and current is minimum due to the open ends. The fields at the edges can be resolved into normal and tangential components with respect to the ground plane.

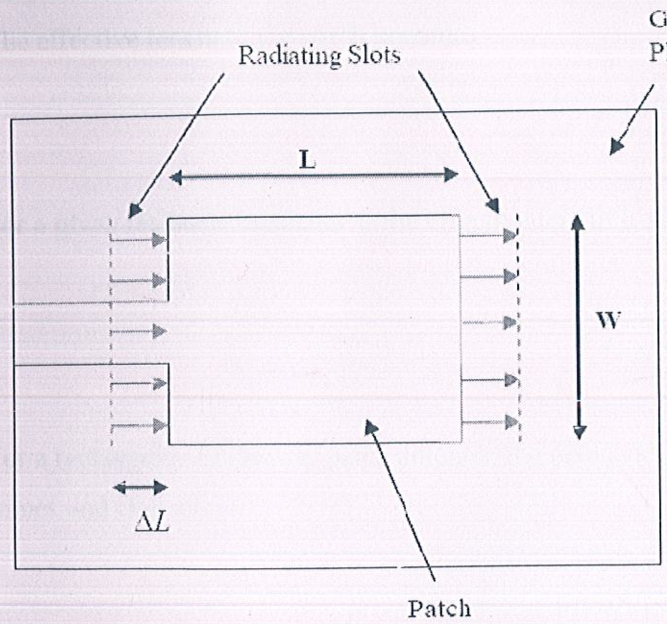


Figure 2.8 Top View of Antenna

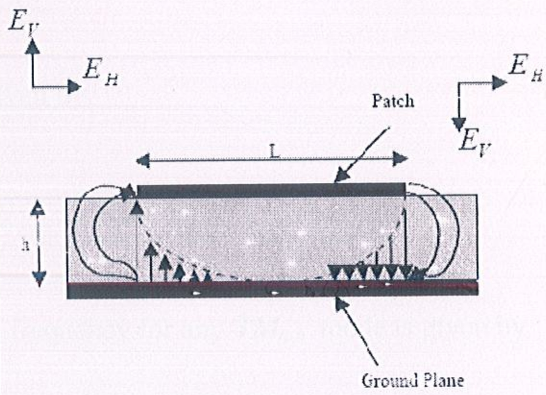


Figure 2.9 Side View of Antenna

It is seen from Figure 2.11 that the normal components of the electric field at the two edges along the width are in opposite directions and thus out of phase since the patch is λ/2 long and hence they cancel each other in the broadside direction. The tangential components (seen in Figure 2.11), which are in phase, means that the resulting fields combine to give maximum radiated field normal to the surface of the structure. Hence the edges along the width can be represented as two radiating slots, which are λ/2 apart and excited in phase and radiating in the half space above the ground plane.

The fringing fields along the width can be modeled as radiating slots and electrically the patch of the Microstrip antenna looks greater than its physical dimensions.

The dimensions of the patch along its length have now been extended on each end by a distance ΔL, which is given empirically by Hammerstad as [1]:

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

The effective length of the patch becomes

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

For a given resonant frequency f_0 the effective length is given by

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

For a rectangular Microstrip patch antenna, the resonance frequency for any TM_{mn} mode is given by James and Hall as:

$$f_o = \frac{c}{2\sqrt{\varepsilon_{reff}}} \left[\left(\frac{m}{L}\right)^2 + \left(\frac{n}{W}\right)^2\right]^{\frac{1}{2}}$$

Where m and n are modes along L and W respectively.

For efficient radiation, the width w is given by Bahl and Bhartia as

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

CHAPTER 3

Results and Simulation using MW CST 5.02

3.1 CASE 1- Designing a rectangular Microstrip antenna using a substrate (FR4) with dielectric constant of 4.3, at frequency 1.8 GHz. and varying height of substrate H.

Formulae Used -
Using the above formulae and height 4.5 mm,

Dimensions of Patch	Dimensions of Substrate	Dimensions of Strip
L= 38mm	Length= 2L	Length= 19mm
W= 51mm	Width= 2W	Width= 8.7mm

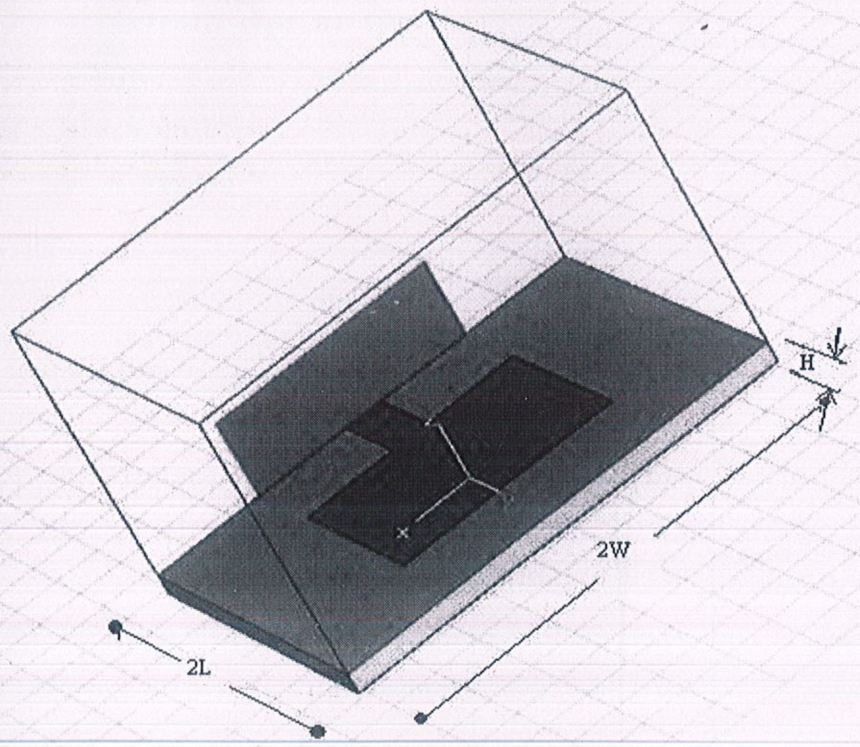
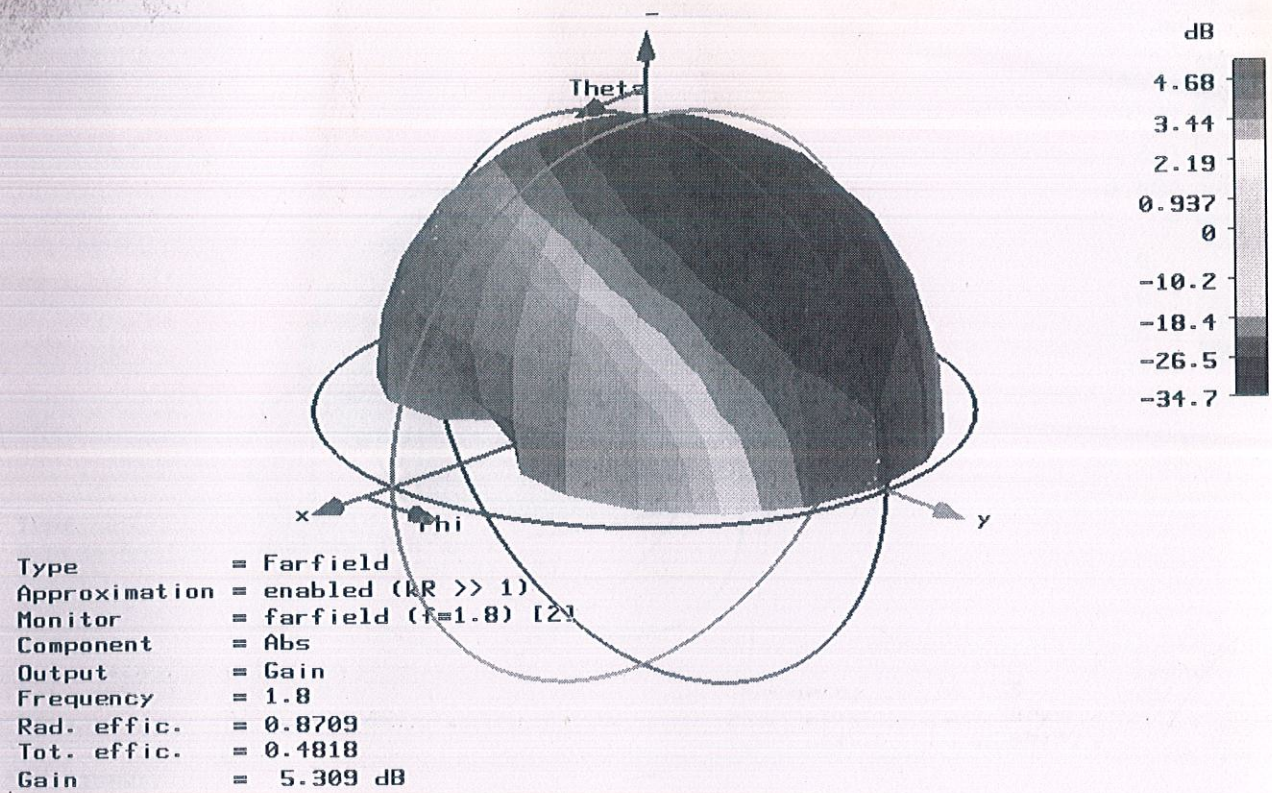
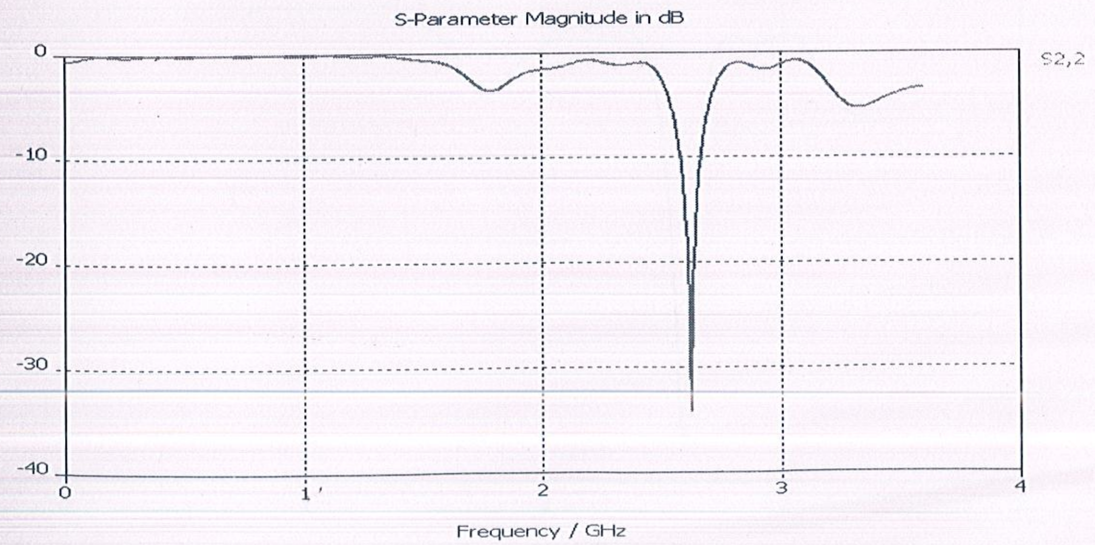


Figure 3.1- Microstrip Patch Antenna on CST MW software

Results - Gain and Efficiency

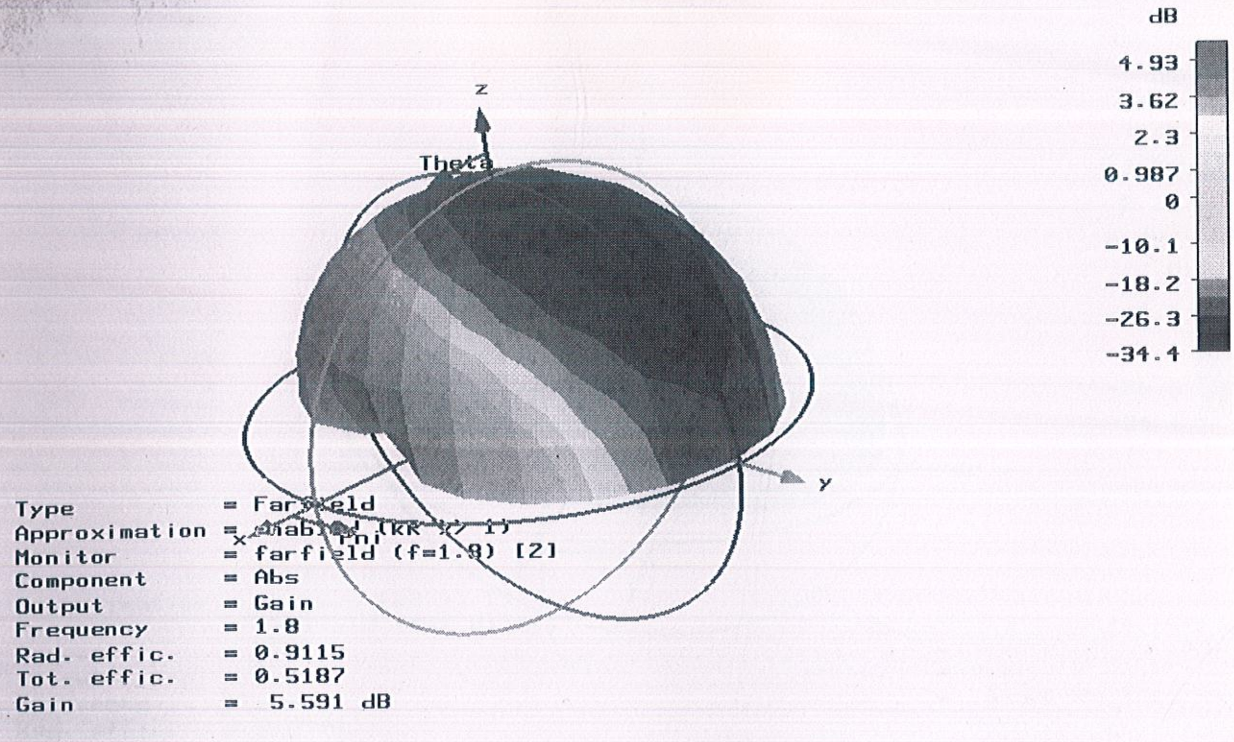


S-Parameter



3.2 CASE 2 – Keeping the above parameters constant and increasing the height to 5.5mm

Results - Gain and Efficiency



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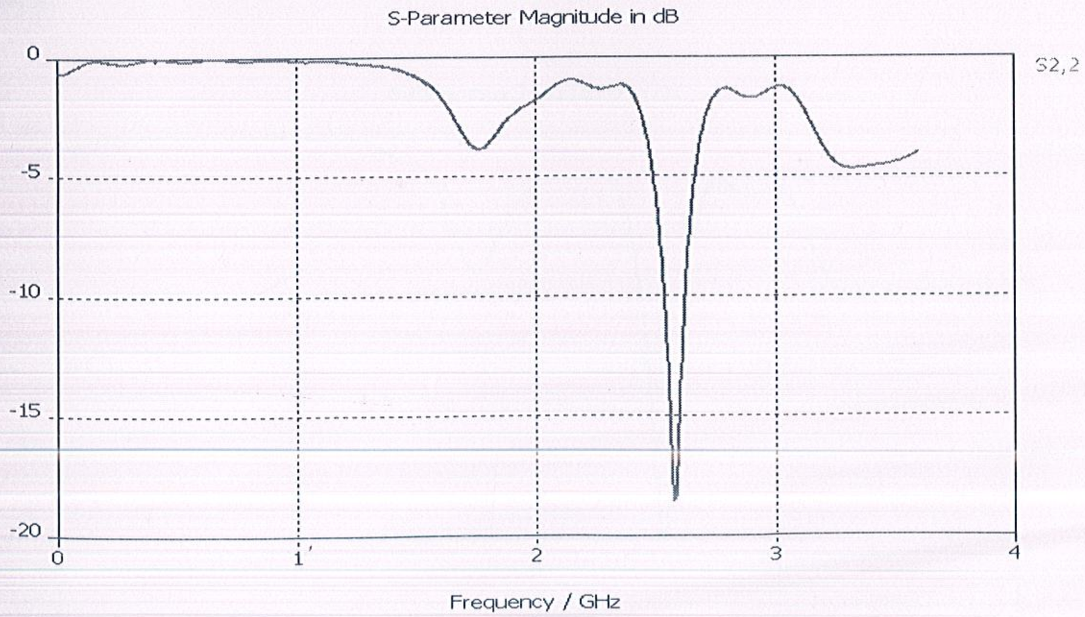
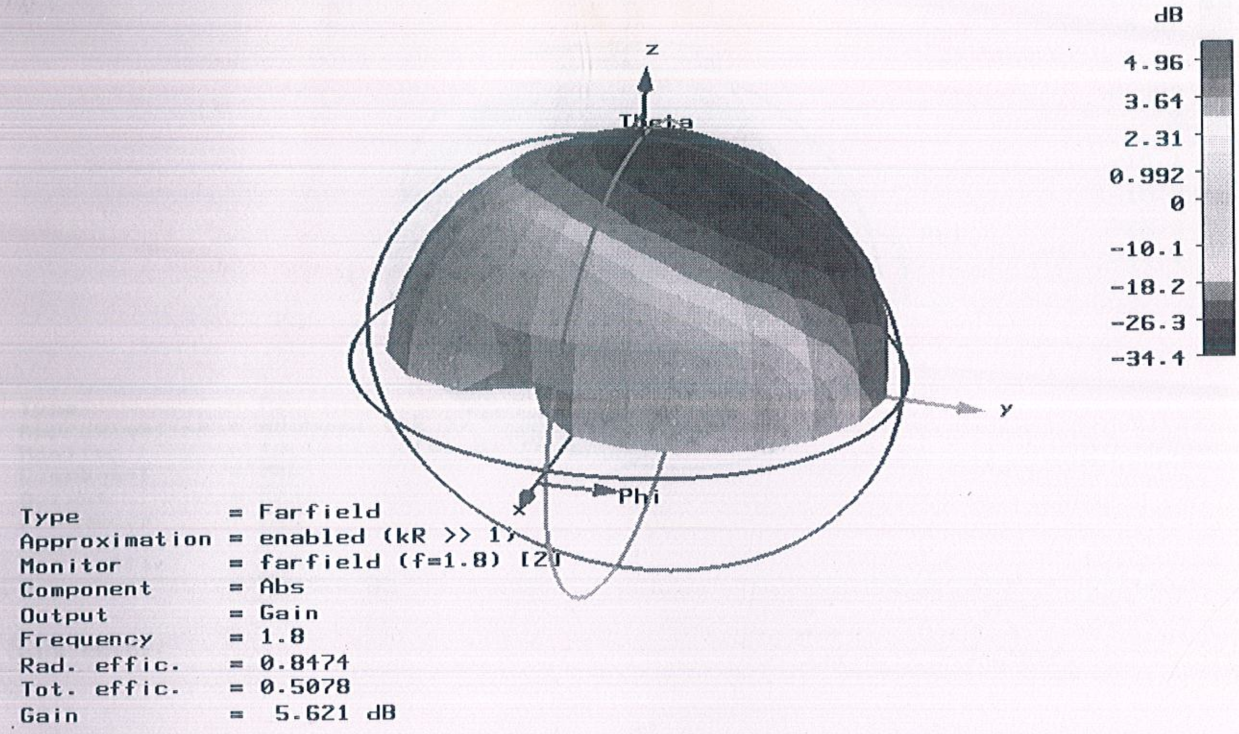
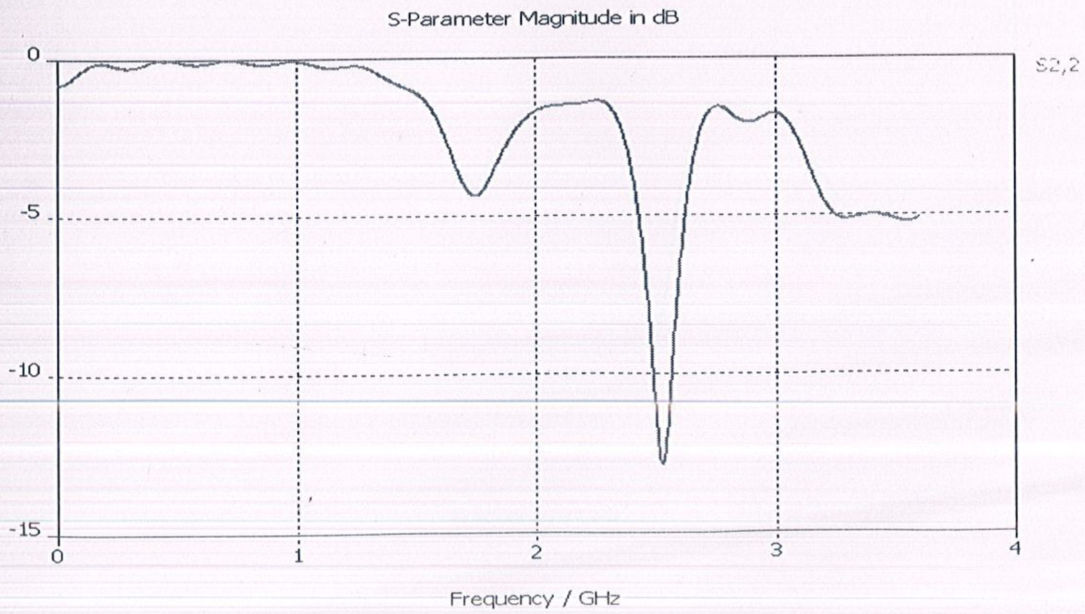


3.3 **CASE 3** – Keeping the above parameters constant and increasing the height to 6.5mm

Results - Gain and Efficiency

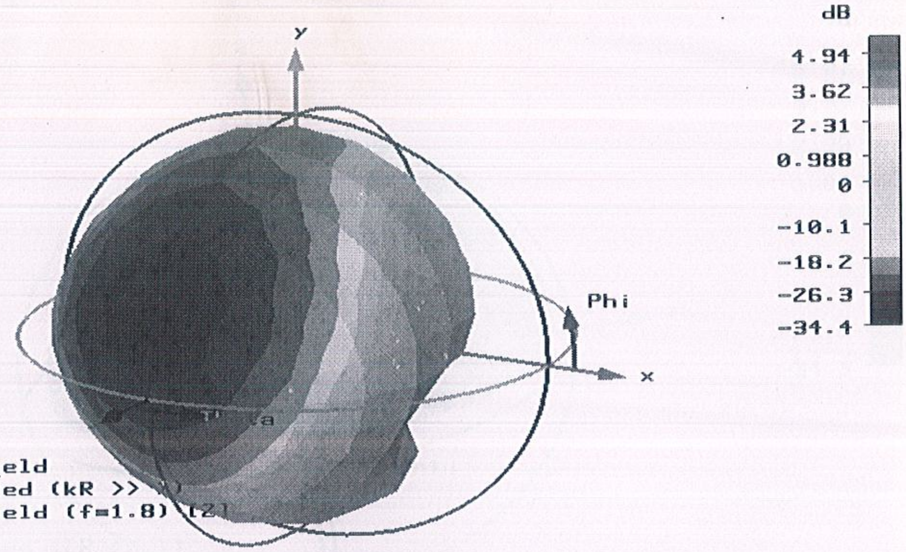


S-Parameter



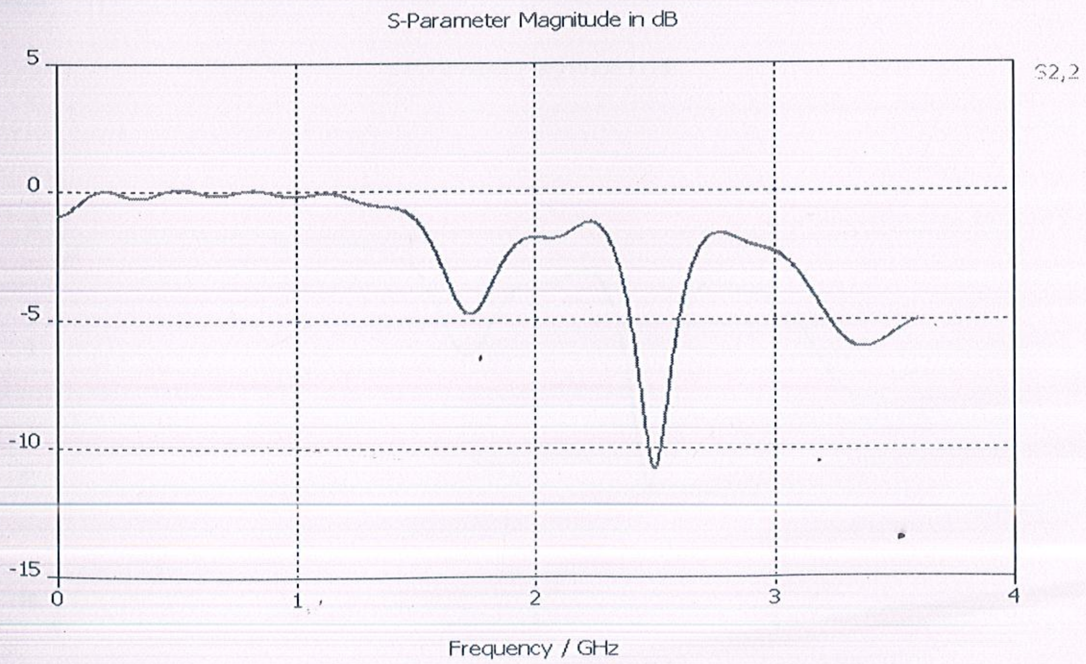
3.4 CASE 4 – Keeping the above parameters constant and increasing the height to 7mm

Results - Gain and Efficiency



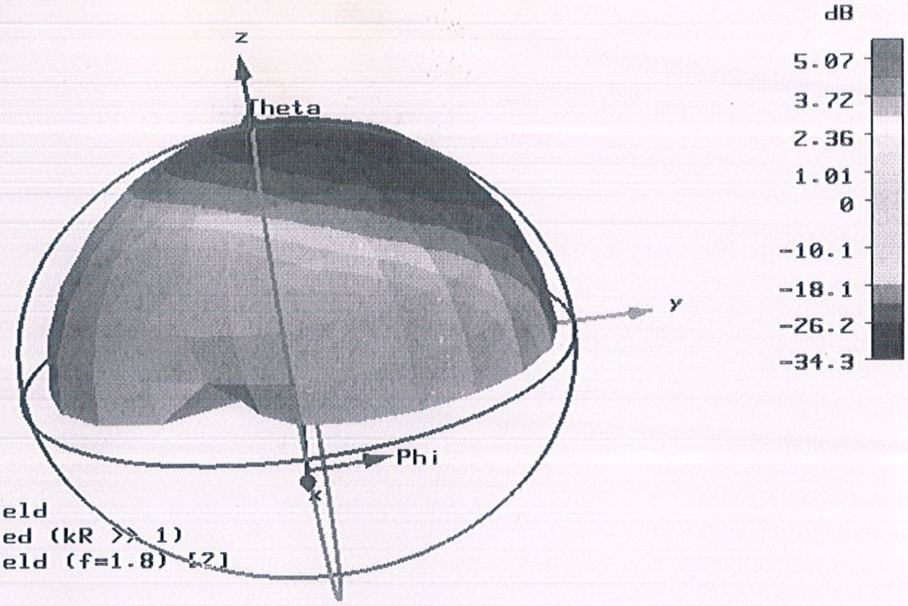
Type = Farfield
Approximation = enabled (kR >> 1)
Monitor = farfield (f=1.8) [2]
Component = Abs
Output = Gain
Frequency = 1.8
Rad. effic. = 0.8728
Tot. effic. = 0.5272
Gain = 5.600 dB

S-Parameter



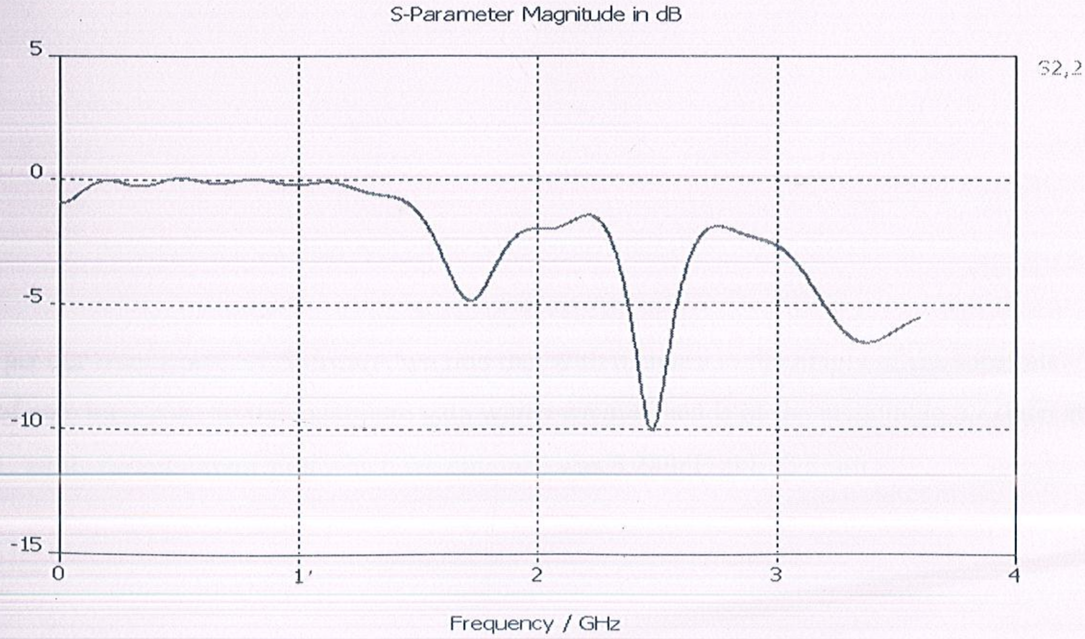
3.5 CASE 5– Keeping the above parameters constant and increasing the height to 7.5mm

Results - Gain and Efficiency

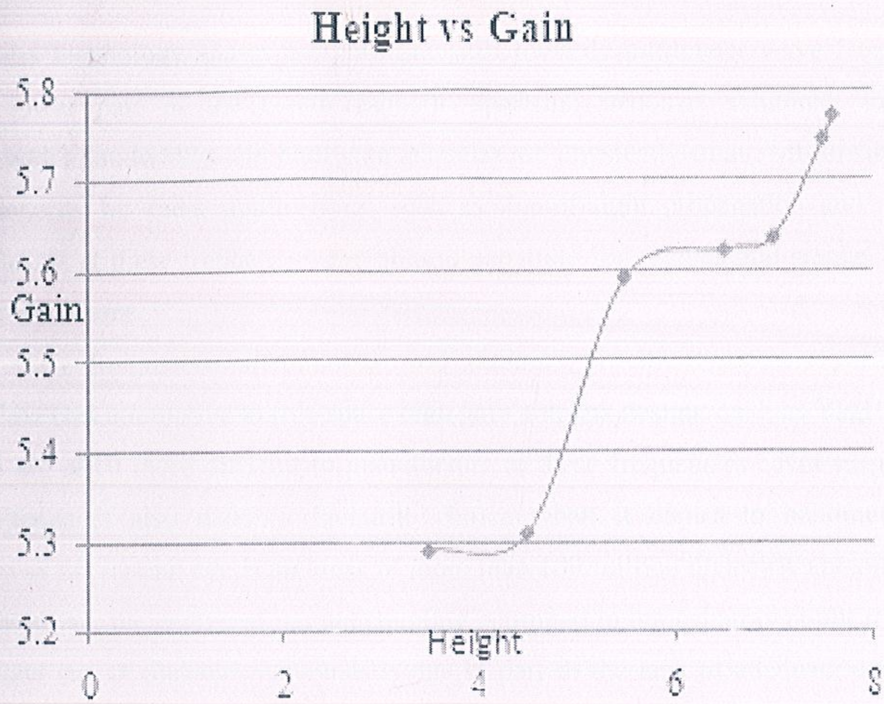



```
Type           = Farfield
Approximation  = enabled (kR >> 1)
Monitor        = farfield (f=1.8) [2]
Component      = Abs
Output         = Gain
Frequency      = 1.8
Rad. effic.    = 0.8837
Tot. effic.    = 0.5292
Gain           =  5.744 dB
```

S-Parameter



3.6 Conclusion



As per our results on CST Software, we find that with increase in the height of the substrate ,the value of gain increases. So the maximum gain which we obtained is of the magnitude 5.770dB at h= 7.6 mm , while the minimum gain which we obtained was 5.289dB at h=3.5mm .

CHAPTER 4

DIELECTRIC ROD ANTENNA

4.1 Introduction

Today's wireless technology shows a significant shift towards millimeter wave frequencies. Not only does the lower part of the electromagnetic spectrum becomes saturated, mm-wave frequencies allow for wider bandwidths and high-gain antennas are physically small. Millimeter-waves also offer a lot of benefits for radar applications, such as line-of-sight propagation and a higher imaging resolution. Beams at these frequencies are able to penetrate fog, clouds and smoke 20 to 50 times better than infra-red beams.

At millimeter-wave frequencies[5], dielectric rod antennas provide significant performance advantages and are a low cost alternative to free space high gain antenna designs such as Yagi-Uda and horn antennas, which are often more difficult to manufacture at these frequencies . Not surprisingly, the dielectric rod antenna is also nature's favourite choice when it comes to nanometer-wave applications: the retina of the human eye is an array of more than 100 million dielectric antennas (both rods and cones). Furthermore, the degree of mutual coupling is limited in typical array applications.
The relatively infrequent use of dielectric antennas is due in part to the lack of adequate design and analysis tools. Lack of analysis tools inhibits antenna development because designers must resort to cut-and-try methods. It is only recently that simulation of electromagnetic fields in arbitrarily shaped media has become fast and practical.

The aim of this report is to demonstrate the relative ease of obtaining high gain and broad-band performance from dielectric rod antennas that are at the same time easy and cheap to construct. The fundamental working principles of the dielectric rod antenna are explained, as well as their relation to other surface wave antennas; like there are the Yagi-Uda, antenna, the cigar antenna and the stacked patch antenna. A prototype of an X-band dielectric rod antenna has been designed and measured. The antenna was designed at X-band because waveguide and measuring equipment was available for this band. Finally, results and areas for improvement are also discussed.

4.1.1 Advantages of Dielectric Rod Antenna

- Easy to fabricate as compared to other antennas.
- This antenna provides good directivity and gain at millimeter wave frequencies.
- A low cost alternative to free space high gain antenna antennas at millimeter wave frequencies.
- It has low I^2R losses even at high frequencies .

4.2 Designing a Dielectic Rod Antenna

4.2.1 Radiation Mechanisms of the Dielectric Rod Antenna

The Dielectric Rod Antenna belongs to the family of surface wave antennas. The hybrid HE11 mode is the dominant surface wave mode and is used most often with dielectric rod antennas. The higher, transversal modes TE01 and TM01 produce a null in the end-fire direction or are below cut-off. The HE11 mode is a slow wave (i.e. bz > k1) when the losses in the rod material are small. In this case, increasing the rod diameter will result in an even slower HE11 surface wave of which the field is more confined to the rod. The dielectric or magnetic material could alternatively be an artificial one, e.g., a series of metal disks or rods (i.e. the cigar antenna and the long Yagi-Uda antenna, respectively). Design information for the long Yagi-Uda antenna will be employed for the design of the dielectric rod antenna. Both structures are shown in Figure 1.

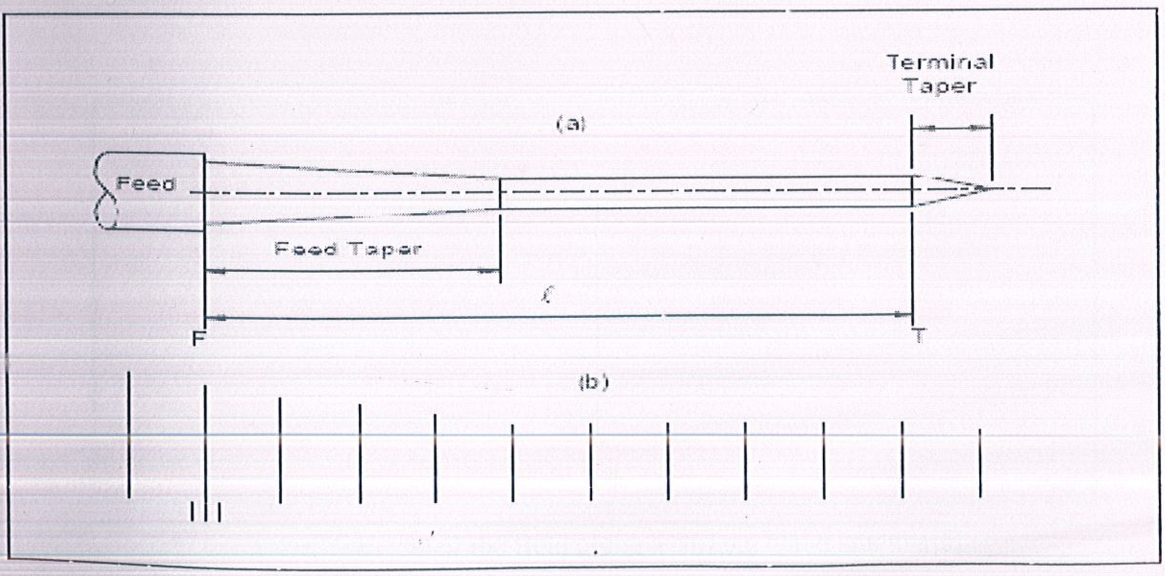


Figure 4.1 Two surface wave antenna structures: the dielectric/magnetic rod antenna (a) and the long Yagi-Uda antenna (b) [5]

Since a surface wave radiates only at discontinuities, the total pattern of this antenna (normally end-fire) is formed by interference between the feed and terminal patterns. The feed F (consisting of a circular or rectangular waveguide in Figure 1a and a monopole and a reflector in Figure 1b) couples a portion of the input power into a surface wave, which travels along the antenna structure to the termination T, where it radiates into space. The ratio of power in the surface wave to the total input power is called *the efficiency of excitation.* Normally, its value is between 65 and 75 percent. Power not coupled into the surface wave is directly radiated by the feed in a pattern resembling that radiated by the feed when no antenna structure is in front of it . The tapered regions in Figure 4.1 serve different purposes. *The feed taper* increases the efficiency of excitation and also affects the shape of the feed pattern. *A terminal taper* reduces the reflected surface wave to a negligible value. A reflected surface wave would spoil the radiation pattern and bandwidth of the antenna. *A body taper* (not shown) suppresses sidelobes and increases bandwidth.

4.2.2 Field Distribution along a Surface Wave Antenna

The field distribution along a surface wave antenna is depicted in Figure 2.The graph shows a hump near the feed. The size and extent of the hump are a function of feed and feed taper construction. The surface wave is well established at a distance l min from the feed where the radiated wave from the feed, propagating at the velocity of light, leads the surface wave by about 120° [5]

$$\ell_{min}\beta_z - \ell_{min}k_0 = \frac{\pi}{3} \cdot (1)$$

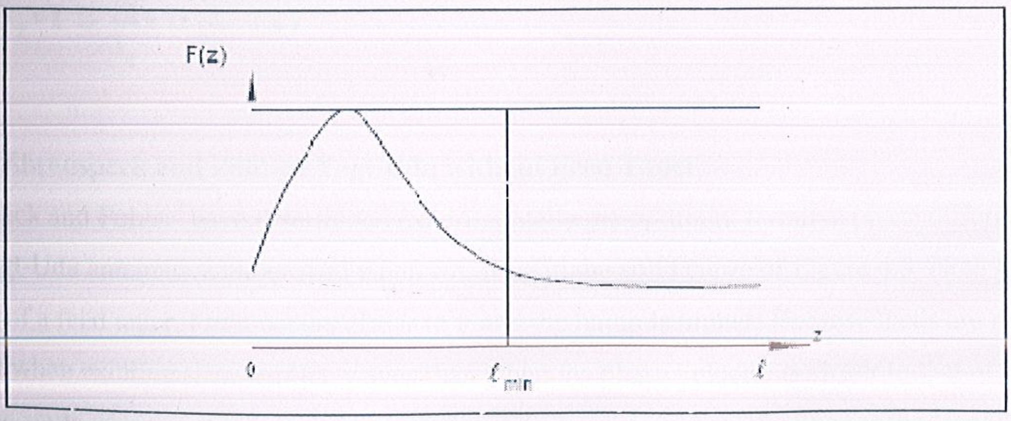


Figure 4.2: Amplitude of the field along a surface wave antenna[5]

The location of l min on an antenna designed for maximum gain is seen in Figure 2 to be about halfway between the feed and the termination. Since the surface wave is fully developed from this point on, the remainder of the antenna length is used solely to bring the feed and terminal radiation into the proper phase relation for maximum gain. The phase velocity along the antenna and the dimensions of the feed and terminal tapers in the maximum gain design of Figure 4.1a must now be specified.

4.2.3 The Hansen-Woodyard Condition: Flat Field Distribution

If the amplitude distribution in Figure 2 were flat, maximum gain would be obtained by meeting the Hansen-Woodyard condition (strictly valid for antenna lengths l >> l 0) [5], which requires the phase difference at T between the surface wave and the free space wave from the feed to be approximately 180°:

$$\ell\beta_z - \ell k_0 = \pi \Rightarrow \frac{\lambda_0}{\lambda_z} = 1 + \frac{\lambda_0}{2\ell}, \quad (2)$$

which is plotted as the upper dashed line in Figure 4.3.

4.2.4 100% Efficiency of Excitation

If the efficiency of excitation were 100%, there would be no radiation from the feed. Consequently, there would be no interference with the terminal radiation and the antenna needs to be just long enough so that the surface wave is fully established; that is l = l min in Figure 4.2. From equation (1) [5]:

$$\ell\beta_z - \ell k_0 = \pi \Rightarrow \frac{\lambda_0}{\lambda_z} = 1 + \frac{\lambda_0}{6\ell} \quad (3)$$

4.2.5 Ehrenspeck and Pöhler: Yagi-Uda without Feed Taper

Ehrenspeck and Pöhler have determined experimentally the optimum terminal phase difference for long Yagi-Uda antennas without feed taper, resulting in the solid curve of Figure 4.3. Note that in the absence of a feed taper, l min occurs closer to F and the hump is higher. Because feeds are more efficient when exciting slow surface waves than when the phase velocity is closer to that of light, the solid line starts near the 100% excitation efficiency line end ends near the line for the Hansen-Woodyard condition [5].

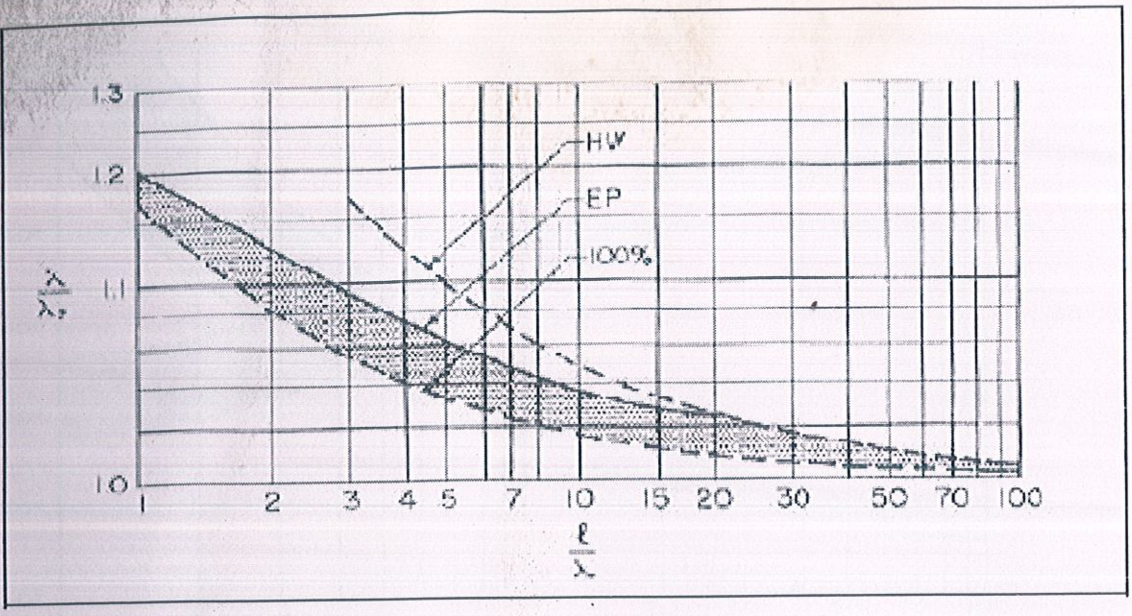


Figure 4.3: Relative phase velocity for maximum gain as a function of relativeantenna length (HW: Hansen-Woodyard condition; EP:Ehrenspeck and Pöhler experimental values; 100%: 100% efficiency of excitation) [5]

4.2.6 The Actual Design

In practice, the optimum terminal phase difference for a prescribed antenna length cannot easily be calculated because the size and extent of the hump in Figure 4.2 are a function of feed and feed taper construction. When a feed taper is present, the optimum 10/lz values must lie in the shaded region of Figure 4.3. Although this technique for maximizing the gain has been strictly verified only for long Yagi-Uda antennas, data available in literature on other surface wave antenna structures suggest that the optimum 10/lz values lie on or just below the solid curve in all instances. It follows from Figure 4.3 that for maximum excitation efficiency a feed taper should begin at F with 10/lz between 1.2 and 1.3. It is common engineering practice to have the feed taper extending over approximately 20% of the full antenna length.The terminal taper should be approximately half a (surface wave) wavelength long to match the surface wave to free space. Thus far, only the relative phase velocity has been specified as a function of relative antenna length. However, nothing has yet been said about what the actual antenna length should be. As can be seen from Figure 4.4, the gain and the beamwidth of a urface wave antenna are determined by the relative antenna length. Figure 4.4 is based on the values of maximum gain reported in literature.

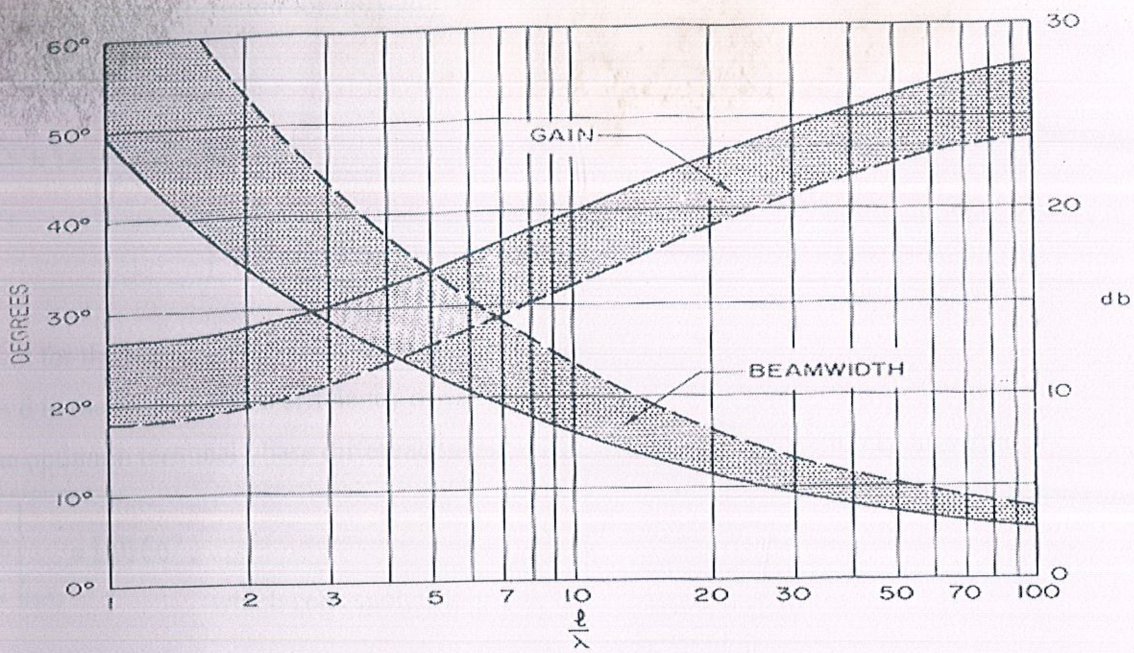


Figure 4.4: Gain and beamwidth of a surface wave antenna as a function of relative antenna length. Solid lines are optimum values; dashed lines are for low-sidelobe and broad-band designs [5]

The gain of a long (l >> l 0) uniformly illuminated (no hump in Figure 2) end-fire antenna whose phase velocity satisfies equation (2), was shown by Hansen and Woodyard to be approximately

$$G_{max} \approx \frac{7\ell}{\lambda_0}.$$

As Figure 4.4 shows, the gain is higher for shorter antennas. This is due to the higher efficiency of excitation and the presence of a hump in Figure 4.2. The antenna presented in this work is designed for a maximum gain of Gmax = 100 = 20dBi and an operating frequency of 10.4GHz (l0 = 28.8mm). As can be seen from Figure 4.4, this corresponds to an antenna length of $10\lambda_0$ or l = 288mm. Surface wave antennas longer than 20l0 are difficult to realize due to poor excitation efficiency at their feed. Also, the longer the antenna, the faster the surface wave and the more the surface wave field extends out of the dielectric. The length of the feed taper should be one fifth of the antenna length or 57.6mm.

It needs to be determined empirically if no information is available on the excitation efficiency of the feed. A general expression for the optimal terminal phase difference can be obtained from equations (2) and (3)

$$\frac{\lambda_0}{\lambda_z} = 1 + \frac{\lambda_0}{p\ell},$$

p = 2 for the Hansen-Woodyard condition and

p = 6 in the case of 100% efficiency of excitation.

The optimum terminal phase difference with 100% efficiency of excitation is, by virtue of

$$\left.\frac{\lambda_0}{\lambda_z}\right|_{100\%} = 1.01667,$$

which corresponds to p = 6.

The optimum terminal phase difference in absence of a feed taper is

$$\left.\frac{\lambda_0}{\lambda_z}\right|_{HP} = 1.02764,$$

which corresponds to p = 3.618.

For this design the terminal phase difference is chosen to equal the average of these two values or

$$\frac{\lambda_0}{\lambda_z} = 1.022,$$

which corresponds to p = 4.545.

The terminal taper length should be about (lz/2) » 15mm.

4.3 Dielectric Rod Antenna on CST

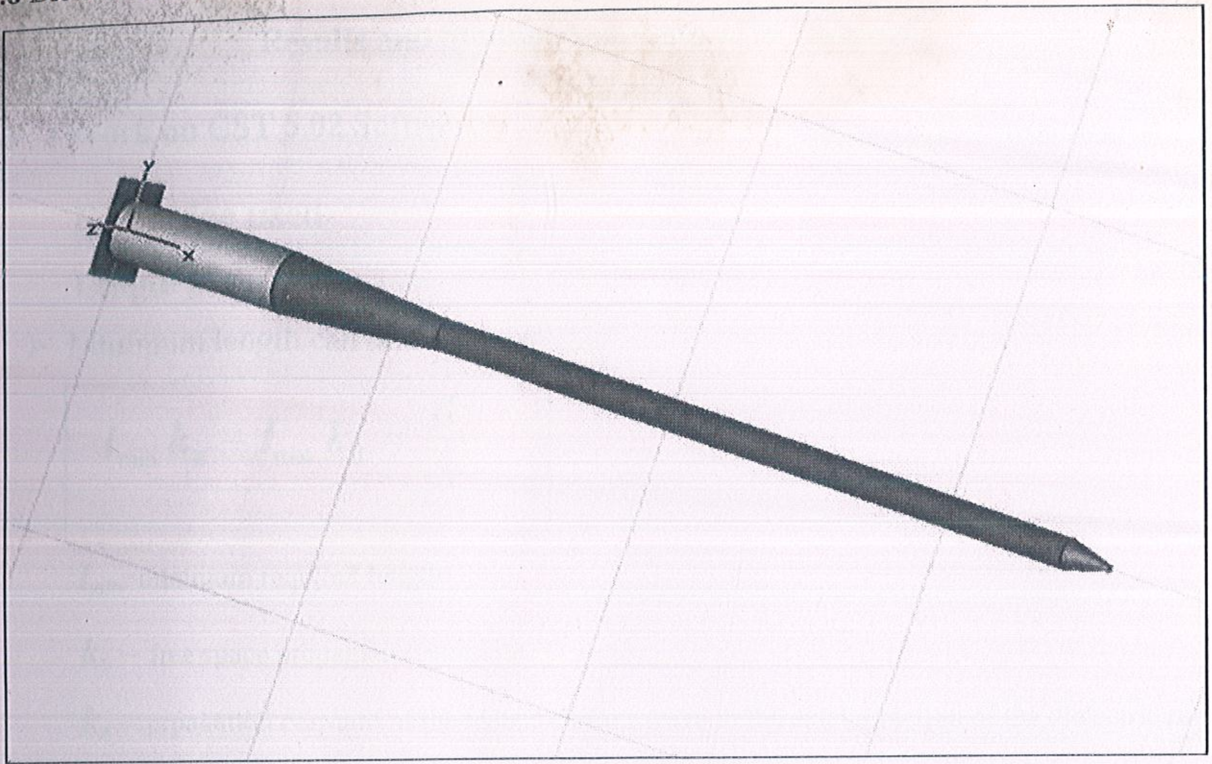


Figure 4.5

4.3.1 Dielectric Rod Antenna Dimensions

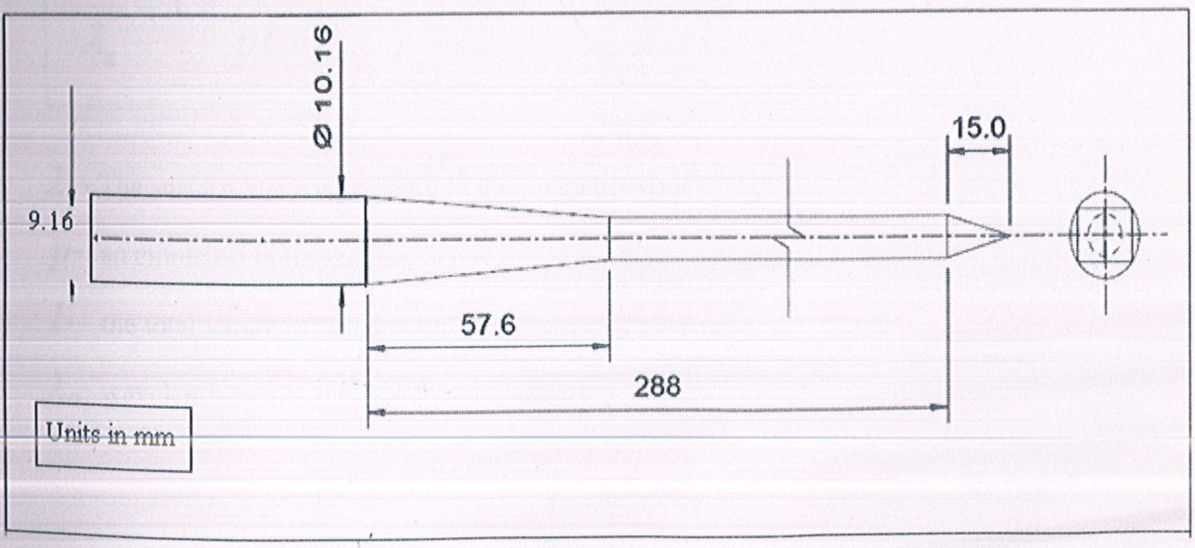


Figure 4.6

CHAPTER 5

Results and Simulations using MW CST 5.02

5.1 Work on CST 5.02 Software

Formulae used-

Length of the rod

- Minimum length can be defined as-

$$l_{\min} k_z - l_{\min} k_0 = \frac{\pi}{3}$$

l_{min}-minimum required length

k_o – free space propagation constant

k_z – prpagation constant of the hybrid surface wave in the axial direction of the dielectric rod

- The total rod length is calculated by-

$$\frac{\lambda_0}{\lambda_z} = 1 + \frac{\lambda_0}{pl}$$

λ_z- The surface wave wavelenth in the dielectric rod.

p- an empirical optimization factor.

l- the total length of rod antenna.

λ_o- wavelenth as per the frequency.

Dimensions-

Outer radius of waveguide	**10.16 mm**
Inner radius of waveguide	**9.16 mm**
Base radius of tapered region	**10.16 mm**
End radius of tapered region	**5.08 mm**
Radius of dielectric rod	**5.08 mm**
End radius of emitting end	**1 mm**

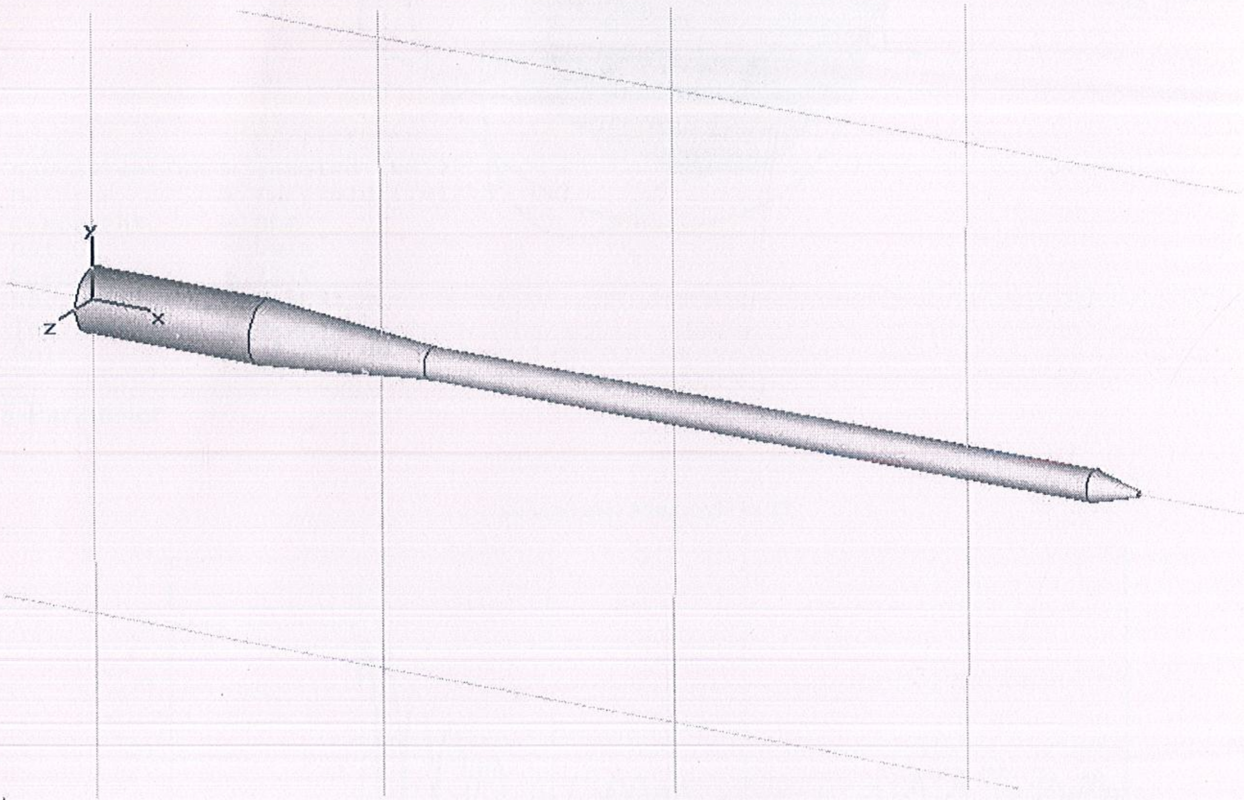
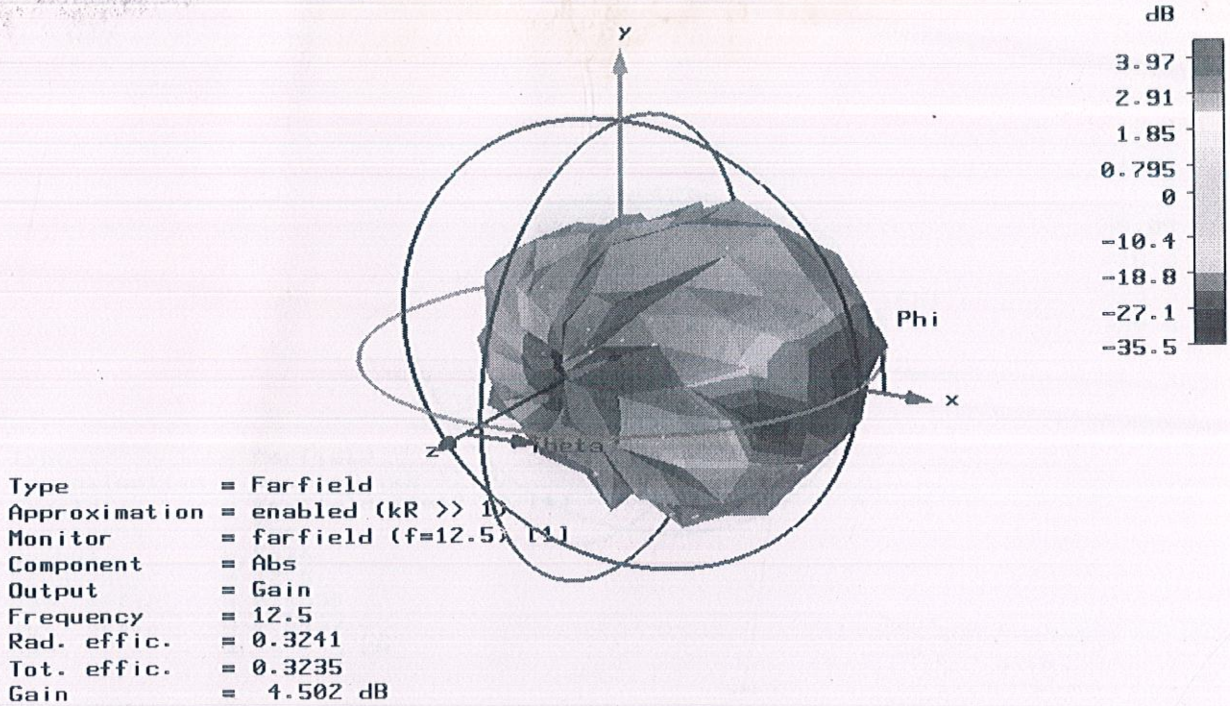


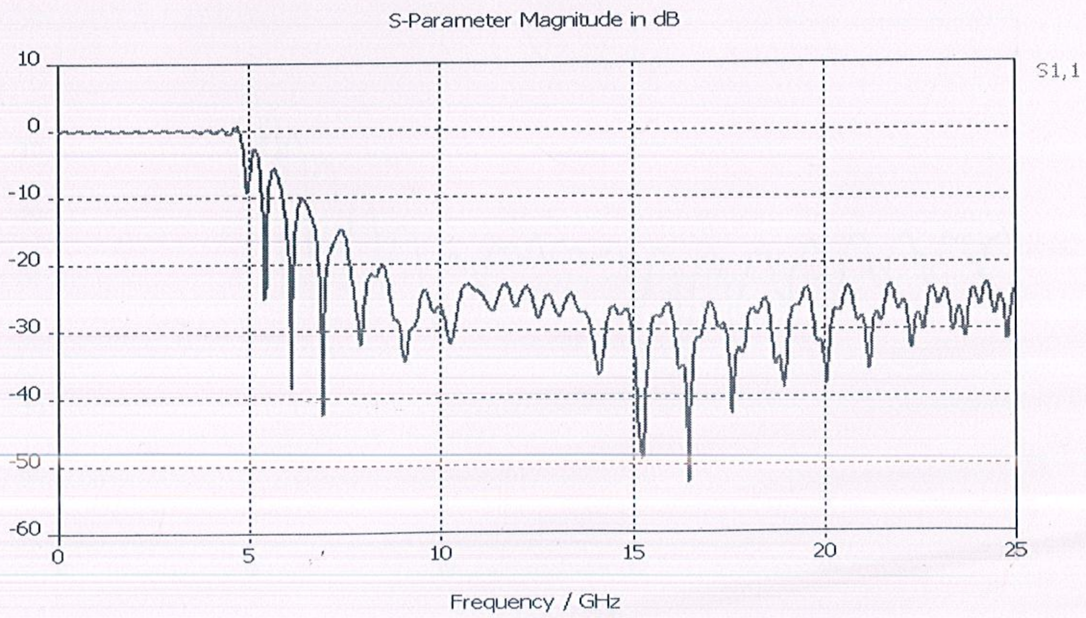
Figure 5.1 Design of Dielectric Rod on CST 5.02

5.2 CASE 1- Designing a Dielectric Rod Antenna using a dielectric with dielectric constant of 4 at frequency 12.5 GHz.

Results – Gain and Efficiency

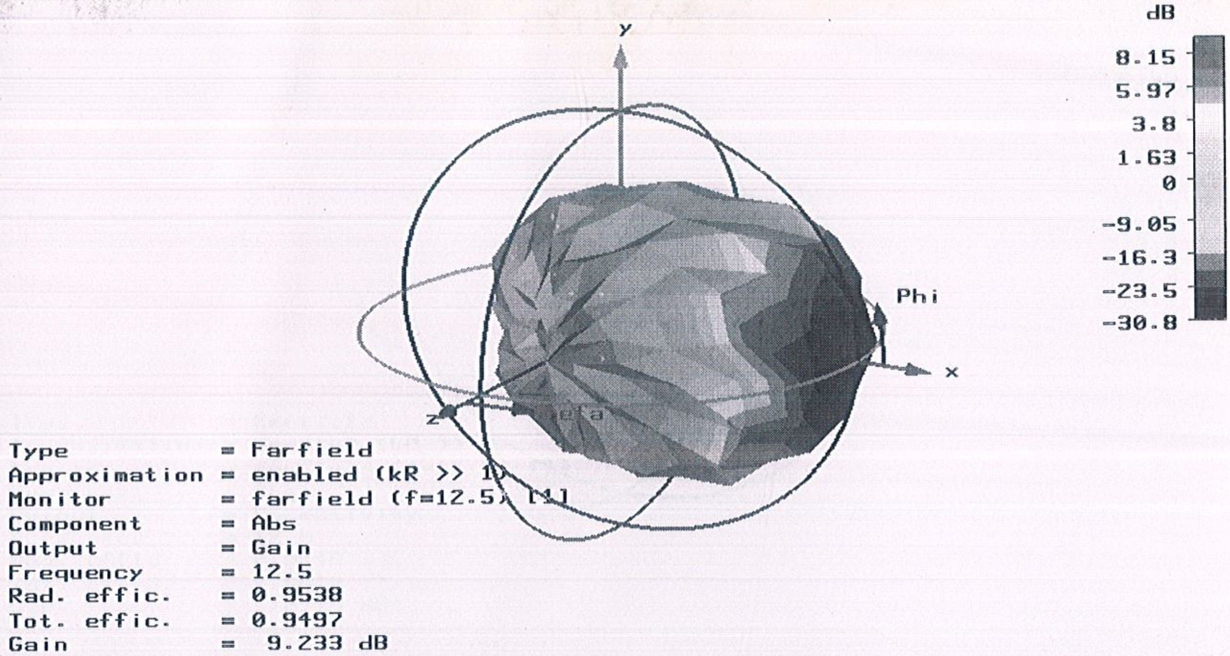


S-Parameter



5.3 CASE 2- Designing a Dielectric Rod Antenna using a dielectric with dielectric constant of 3.5 at frequency 12.5 GHz.

Results – Gain and Efficiency



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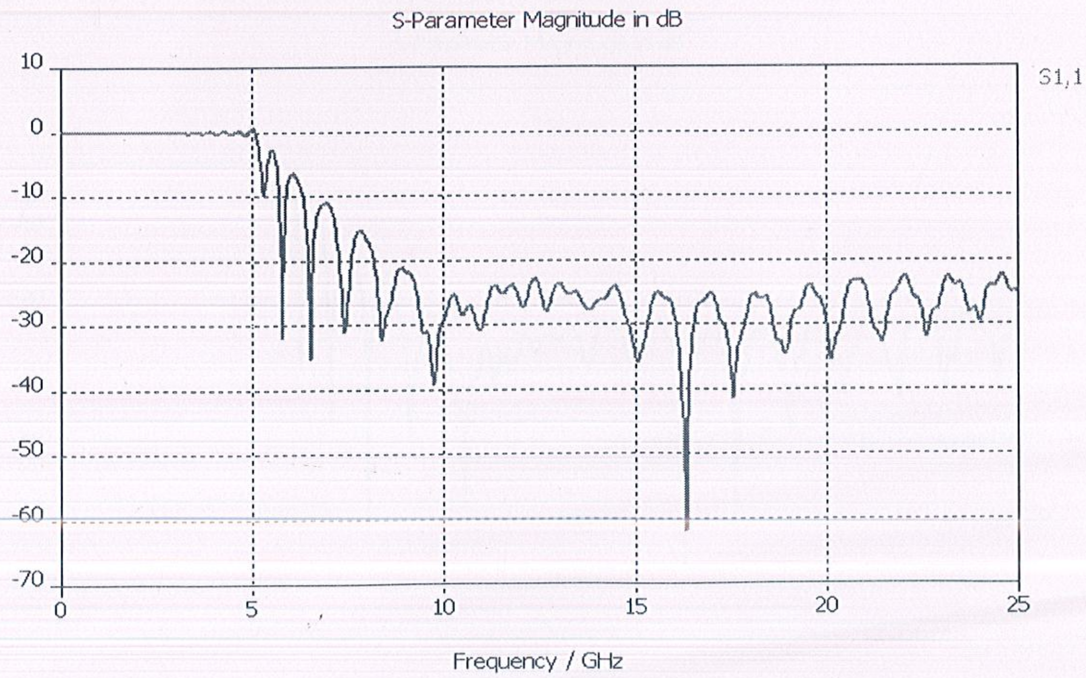
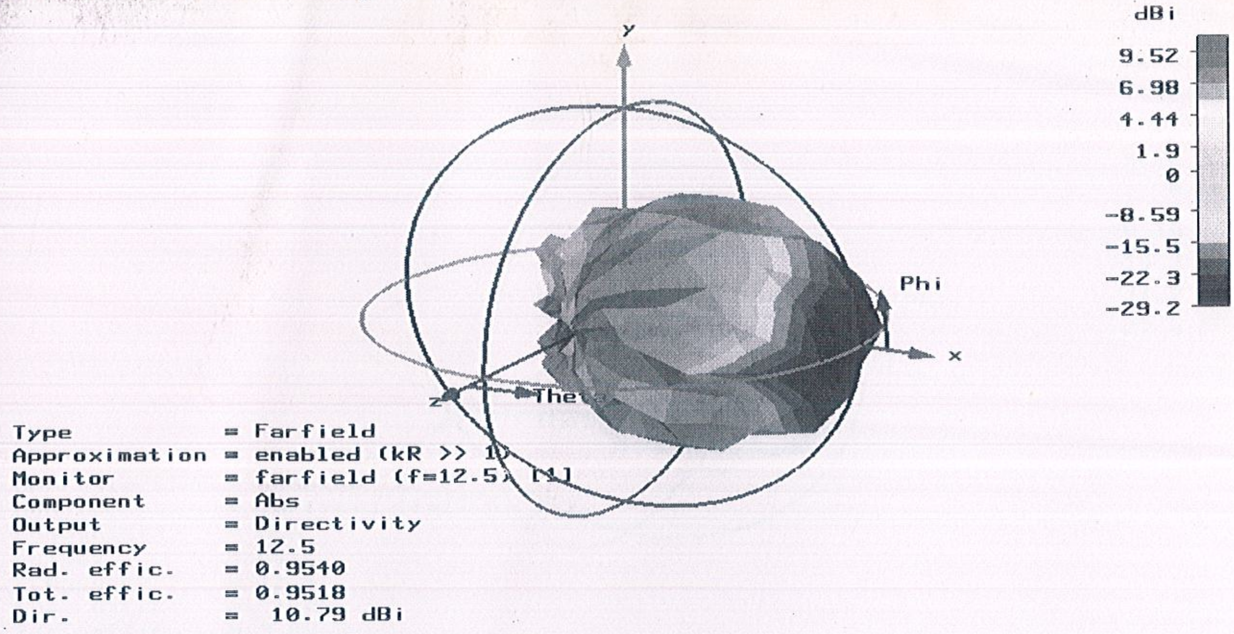


5.4 CASE 3- Designing a Dielectric Rod Antenna using a dielectric with dielectric constant of 3.0 at frequency 12.5 GHz.

Results – Gain and Efficiency



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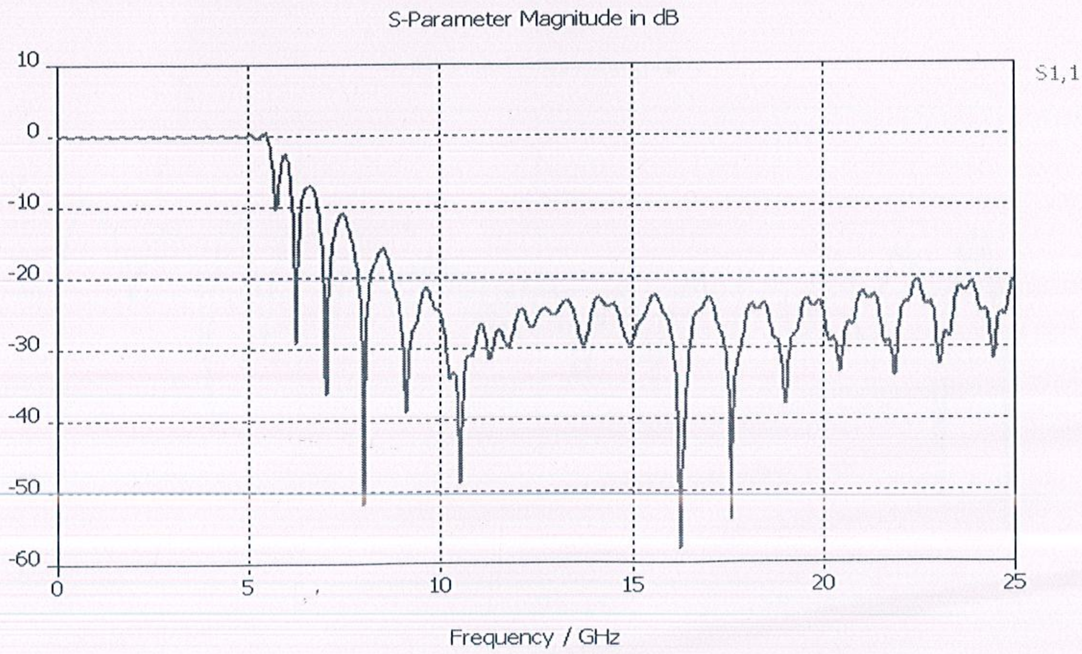
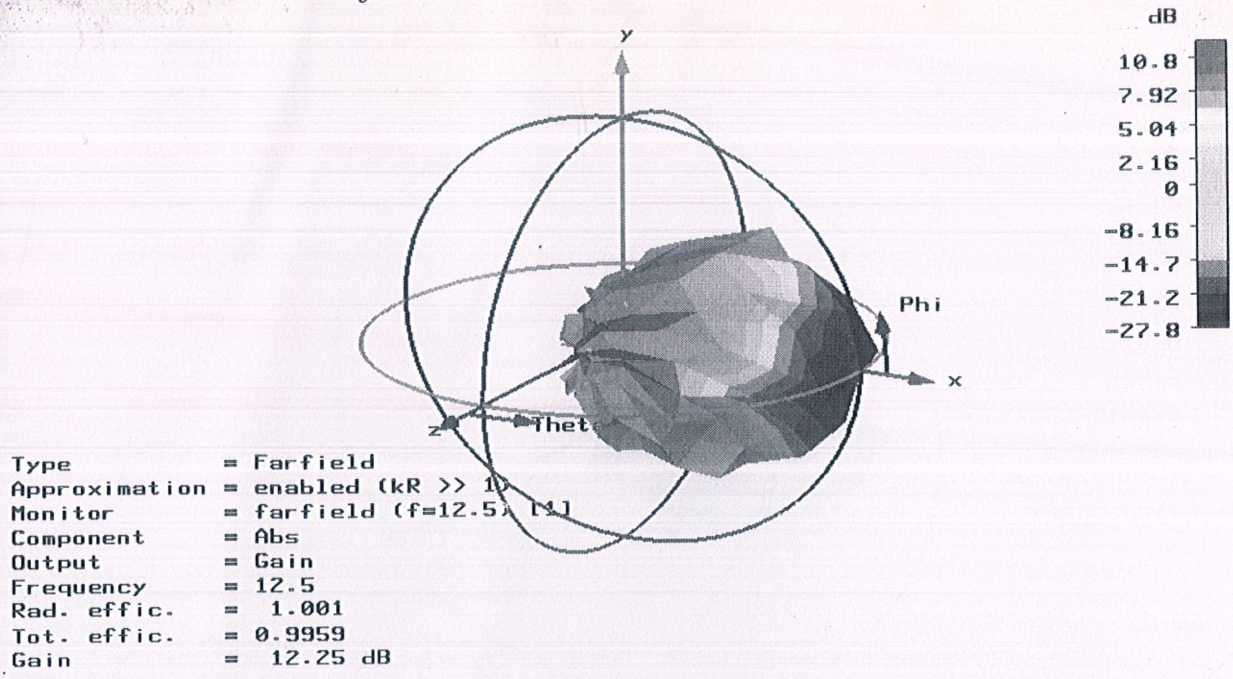
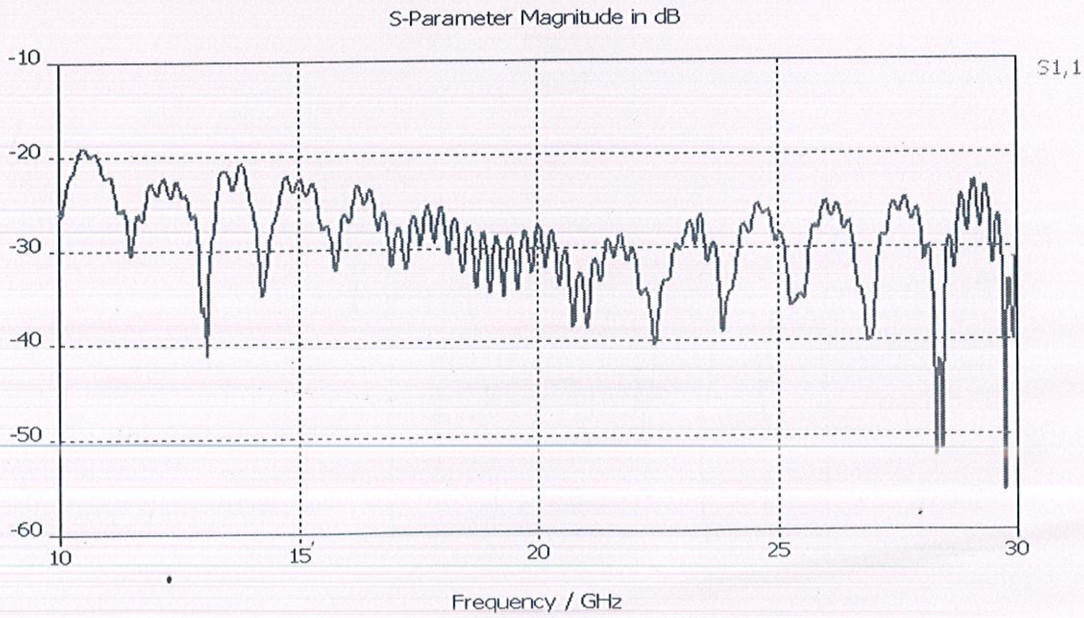


5.5 CASE 4- Designing a Dielectric Rod Antenna using a dielectric with dielectric constant of 2.5 at frequency 12.5 GHz.

Results – Gain and Efficiency

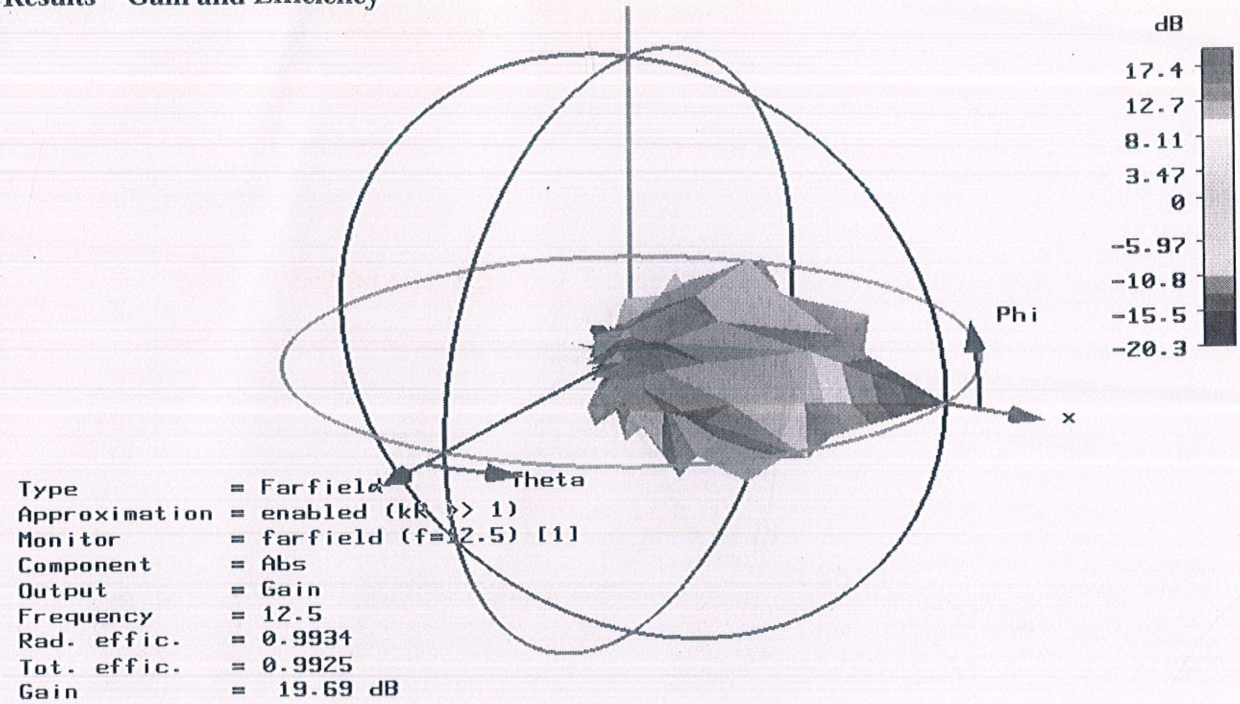


S-Parameter



5.6CASE 5- Designing a Dielectric Rod Antenna using a dielectric with dielectric constant of 2 at frequency 12.5 GHz.

Results – Gain and Efficiency



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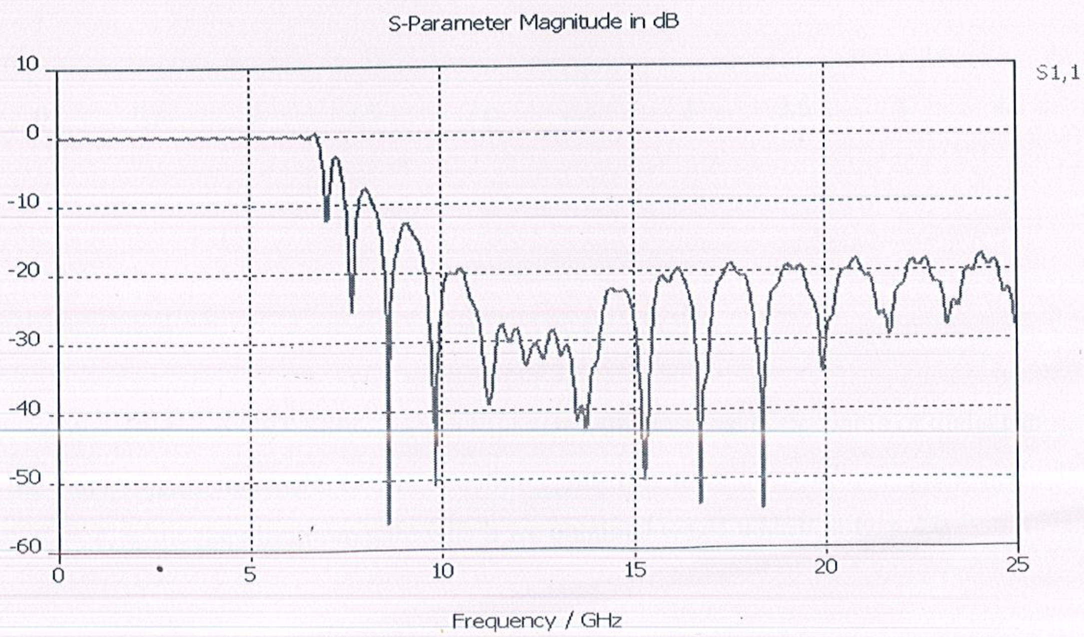
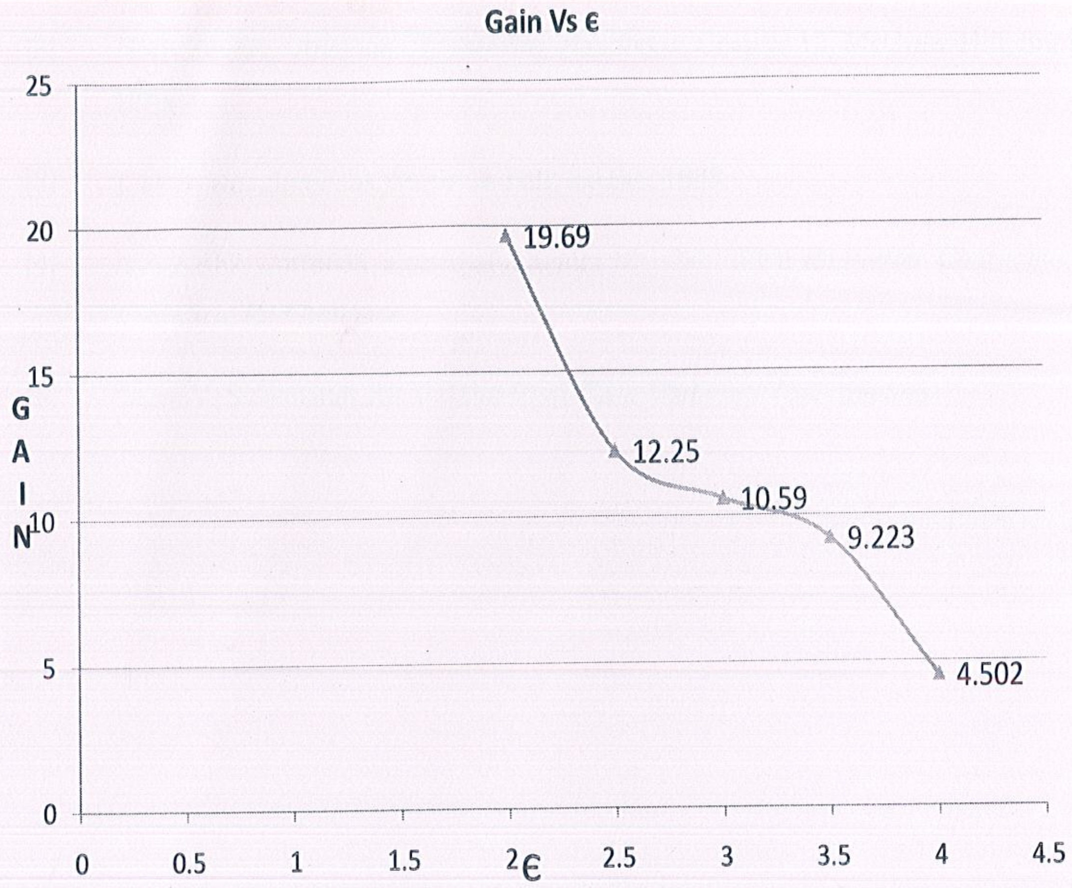


5.7 Conclusion



As per our results on CST Software, we find that with decrease in the value of dielectric constant, the value of gain increases. So the maximum gain which we obtained is of the magnitude 19.69db at $\epsilon = 2$, while the minimum gain which we obtained was 4.502dB at $\epsilon = 4.0$.

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