CHAPTER1

INTRODUCTION

INTRODUCTION

1.1 ANTENNA BASICS

Communication between humans was first by sound through voice. With the desire for slightly more distance communication came, devices such as drums, then, visual methods such as signal flags and smoke signals were used. These optical communication devices, of course, utilized the light portion of the electromagnetic spectrum. It has been only very recent in human history that the electromagnetic spectrum, outside the visible region, has been employed for communication, through the use of radio. One of humankind's greatest natural resources is the electromagnetic spectrum and the antenna has been instrumental in harnessing this resource.

Antennas are a very important component of communication systems. By definition, an antenna is a device used to transform an RF signal, travelling on a conductor, into an electromagnetic wave in free space. Antennas demonstrate a property known as *reciprocity*, which means that an antenna will maintain the same characteristics regardless if it is transmitting or receiving. Most antennas are resonant devices, which operate efficiently over a relatively narrow frequency band. An antenna must be tuned to the same frequency band of the radio system to which it is connected, otherwise the reception and the transmission will be impaired. When a signal is fed into an antenna, the antenna will emit radiation distributed in space in a certain way. A graphical representation of the relative distribution of the radiated power in space is called a *radiation pattern*.

1.1.1 Types of Antennas

Antenna classification of antennas can be based on:

a) Frequency and size

Antennas used for HF are different from the ones used for VHF, which in turn are different from antennas for microwave. The wavelength is different at different frequencies, so the antennas must be different in size to radiate signals at the correct wavelength. We are particularly interested in antennas working in the microwave range, especially in the 2.4 GHz and 5 GHz frequencies. At 2.4 GHz the wavelength is 12.5 cm, while at 5 Ghz it is 6 cm.

b) Directivity

Antennas can be omnidirectional, sectorial or directive. Omnidirectional antennas radiate the same pattern all around the antenna in a complete 360 degrees pattern. The most popular types of omnidirectional antennas are the Dipole-Type and the Ground Plane. Sectorial antennas radiate primarily in a specific area. The beam can be as wide as 180 degrees, or as narrow as 60 degrees. Directive antennas are antennas in which the beamwidth is much narrower than in sectorial antennas. They have the highest gain and are therefore used for long distance links. Types of directive antennas are the Yagi, the biquad, the horn, the helicoidal, the patch antenna, the Parabolic Dish and many others.

c) Physical construction

Antennas can be constructed in many different ways, ranging from simple wires to parabolic dishes, up to coffee cans. When considering antennas suitable for 2.4 GHz WLAN use, another classification can be used.

d) Application

We identify two application categories which are Base Station and Point-to-Point. Base Stations are used for multipoint access. Two choices are Omni antennas which radiate equally in all directions, or Sectorial antennas, which focus into a small area. In the Point-to-Point case, antennas are used to connect two single locations together. Directive antennas are the primary choice for this application. A brief list of common type of antennas for the 2.4 GHz frequency is resented now, with a short description.

- **1/4 Wavelength Ground Plane**

The 1⁄4 Wavelength Ground Plane antenna is very simple in its construction and is useful for communications when size, cost and ease of construction are important. This antenna is designed to transmit a vertically polarized signal. It consists of a 1⁄4 wave element as half-dipole and three or four 1⁄4 wavelength ground elements bent 30 to 45 degrees down. This set of elements, called *radials*, is known as a *ground plane*.

This is a simple and effective antenna that can capture a signal equally from all directions. To increase the gain, the signal can be flattened out to take away focus from directly above and below, and providing more focus on the horizon. The vertical beam width represents the degree of flatness in the focus. This is useful in a Point-to-Multipoint situation, if all the other antennas are also at the same height. The gain of this antenna is in the order of 2 - 4 dBi.

Figure 1.1.1(a) 1⁄4 Wavelength Ground Plane antenna

- **Yagi antenna**

A basic Yagi consists of a certain number of straight elements, each measuring approximately half wavelength. The driven or active element of a Yagi is the equivalent of a center-fed, half-wave dipole antenna. Parallel to the driven element, and approximately 0.2 to 0.5 wavelength on either side of it, are straight rods or wires called reflectors and directors, or passive elements altogether. A reflector is placed behind the driven element and is slightly longer than half wavelength; a director is placed in front of the driven element and is slightly shorter than half wavelength. A typical Yagi has one reflector and one or more directors. The more directors a Yagi has, the greater the gain. As more directors are added to a Yagi, however, it becomes longer. Following is the photo of a Yagi antenna with 6 directors and one reflector.

Figure 1.1.1(b) Yagi antenna

- **Horn**

The horn antenna derives its name from the characteristic flared appearance. The flared portion can be square, rectangular, cylindrical or conical. The direction of maximum radiation corresponds with the axis of the horn. It is easily fed with a waveguide, but can be fed with a coaxial cable and a proper transition. Horn antennas are commonly used as the active element in a dish antenna. The horn is pointed toward the center of the dish reflector. The use of a horn, rather than a dipole antenna or any other type of antenna, at the focal point of the dish minimizes loss of energy around the edges of the dish reflector. At 2.4 GHz, a simple horn antenna made with a tin can has a gain in the order of 10 - 15 dBi.

Figure 1.1.1(c) Horn antenna

- **Parabolic Dish**

Antennas based on parabolic reflectors are the most common type of directive antennas when a high gain is required. The main advantage is that they can be made to have gain and directivity as large as required. The main disadvantage is that big dishes are difficult to mount and are likely to have a large wind age. The basic property of a perfect parabolic reflector is that it converts a spherical wave irradiating from a point source placed at the focus into a plane wave. Conversely, all the energy received by the dish from a distant source is reflected to a single point at the focus of the dish.

Figure 1.1.1(d) parabolic dish

- **BiQuad**

The BiQuad antenna is simple to build and offers good directivity and gain for Point-to-Point communications. It consists of a two squares of the same size of 1⁄4 wavelength as a radiating element and of a metallic plate or grid as reflector. This antenna has a beamwidth of about 70 degrees and a gain in the order of 10-12 dBi. It can be used as stand-alone antenna or as feeder for a Parabolic Dish. The polarization is such that looking at the antenna from the front, if the squares are placed side by side the polarization is vertical. Many other types of antennas exist and new ones are created following the advances in technology.

- ***Sector or Sectorial antennas***: they are widely used in cellular telephony infrastructure and are usually built adding a reflective plate to one or more phased dipoles. Their horizontal beamwidth can be as wide as 180 degrees, or as narrow as 60 degrees, while the vertical is usually much narrower. Composite antennas can be built with many Sectors to cover a wider horizontal range (*multisectorial antenna*).
- ***Panel or Patch antennas***: they are solid flat panels used for indoor coverage, with a gain up to 20 dB.

1.1.2 Antenna Glossary

Input Impedance

For an efficient transfer of energy, the impedance of the radio, of the antenna and of the transmission cable connecting them must be the same. Transceivers and their transmission lines are typically designed for 50Ω impedance. If the antenna has an impedance different from 50 Ω, then there is a mismatch and an impedance matching circuit is required.

Return loss

The return loss is another way of expressing mismatch. It is a logarithmic ratio measured in dB that compares the power reflected by the antenna to the power that is fed into the antenna from the transmission line. The relationship between SWR and return loss is

Return Loss (in dB) =20log10 [SWR/SWR-1]

Bandwidth

The bandwidth of an antenna refers to the range of frequencies over which the antenna can operate correctly. The antenna's bandwidth is the number of Hz for which the antenna will exhibit an SWR less than 2:1. The bandwidth can also be described in terms of percentage of the center frequency of the band.

$$BW = 100 \times [(FH - FL)/FC]$$

where FH is the highest frequency in the band, FL is the lowest frequency in the band, and FC is the center frequency in the band.

Directivity and Gain

Directivity is the ability of an antenna to focus energy in a particular direction when transmitting, or to receive energy better from a particular direction when receiving.

Gain is not a quantity which can be defined in terms of a physical quantity such as the Watt or the Ohm, but it is a dimensionless ratio.

Gain is given in reference to a standard antenna.

Radiation Pattern

The radiation or antenna pattern describes the relative strength of the radiated field in various directions from the antenna, at a constant distance. The radiation pattern is a reception pattern as well, since it also describes the receiving properties of the antenna. The radiation pattern is three-dimensional, but usually the measured radiation patterns are a two dimensional slice of the three-dimensional pattern, in the horizontal or vertical planes. These pattern measurements are presented in either a *rectangular* or a *polar* format.

Beamwidth

An antenna's beamwidth is usually understood to mean the half-power beamwidth. The peak radiation intensity is found and then the points on either side of the peak which represent half the power of the peak intensity are located. The angular distance between the half power points is defined as the beamwidth. Half the power expressed in decibels is —3dB, so the half power beamwidth is sometimes referred to as the 3dB beamwidth. Both horizontal and vertical beamwidths are usually considered.

Sidelobes

No antenna is able to radiate all the energy in one preferred direction. Some is inevitably radiated in other directions. The peaks are referred to as sidelobes, commonly specified in *dB down from the main lobe*.

Nulls

In an antenna radiation pattern, a *null* is a zone in which the effective radiated power is at a minimum. A null often has a narrow directivity angle field, and is what is most commonly of interest. Ordinarily, it is the radiated power that is of interest, and so antenna patterns are usually measured in the far-field region.

Polarization

Polarization is defined as the orientation of the electric field of an electromagnetic wave. Polarization is in general described by an ellipse. Two special cases of elliptical polarization are linear polarization and circular polarization.

1.2 MICROSTRIP ANTENNA

1.2.1 Aim and Objectives

Microstrip patch antenna used to send onboard parameters of article to the ground while under operating conditions. The aim of the thesis is to design and fabricate an inset-fed rectangular Microstrip Patch Antenna and study the effect of antenna dimensions Length (L) , Width (W) and substrate parameters relative Dielectric constant (εr), substrate thickness (t) on the Radiation parameters of Bandwidth and Beam-width.

Overview of Microstrip Antennae

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[1] 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 Advantages and disadvantages:

Microstrip antennas have several advantages compared to conventional microwave antennas, and therefore many applications cover the broad frequency range from 100MHz to 100GHz.Some of the principal advantages of microstrip antennas compared to conventional antennas are:

- Light wieght,low volume and thin profile configuration,which can be made conformal.
- Low fabrication cost,reily amenable to mass prodution.
- Linear and circular polarization antennas can be easily made.
- Can be easily integrated with microwave integrated circuits.
- No cavity backing is required.
- Feed lines and matching networks can be fabricated simultaneously with the antenna structure.

However, microstrip antennas also have some limitations compared to conventional microwave antennas:

- Narrow bandwidth and associated tolerance problems.
- Somewhat lower gain(-6dB).
- Large ohmic loss in the feed structure of arrays.
- Most microstrip antennas radiate into half space.
- Complex feed structures required for high performance arrays.
- Polarization purity is difficult to achieve.
- Low power handling capability(~100W)
- Excitation of surface waves.
- Reduced gain and efficiency as well as unacceptably high levels of cross-polarization and mutual coupling within an array environment at high frequencies.

1.2.3 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. 1.2.3(a)).This source radiates electromagnetic waves. Depending on the direction toward which waves are transmitted, they fall within three distinct categories, each of which exhibits different behaviours.

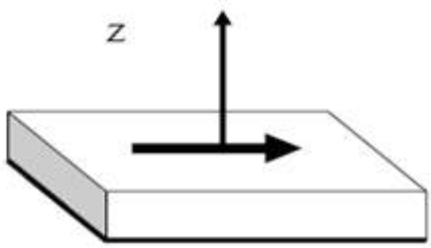


Figure 1.2.3(a) Grounded dielectric substrate

- **Surface Waves**

The waves transmitted slightly downward, having elevation angles θ between π/2and π -arcsin (1/√*εr*), meet the ground plane, which reflects them, and then meet the dielectric-to-air boundary, which also reflects them (total reflection condition). The magnitude of the field amplitudes builds up for some particular incidence angles that leads to the excitation of a discrete set of surface wave modes; which are similar to the modes in metallic waveguide.

The fields remain mostly trapped within the dielectric, decaying exponentially above the interface (fig1.2.3(b)). The vector α, pointing upward, indicates the direction of largest attenuation. The wave propagates horizontally along β, with little absorption in good quality dielectric. With two directions of α and β orthogonal to each other, the wave is a non-uniform plane wave. Surface waves spread out in cylindrical fashion around the excitation point, with field amplitudes decreasing with distance (r), say1/*r*, more slowly than space waves. The same guiding mechanism provides propagation within optical fibers. Surface waves take up some part of the signal's energy, which does not reach the intended user. The signal's amplitude is thus reduced, contributing to an apparent attenuation or a decrease in antenna efficiency. Additionally, surface waves also introduce spurious coupling between different circuit or antenna elements. This effect severely degrades the performance of microstrip filters because the parasitic interaction reduces the isolation in the stop bands.

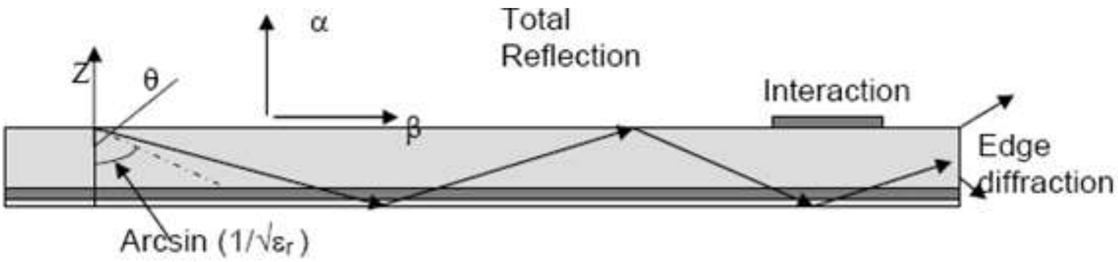


Figure 1.2.3(b) Surface waves

In large periodic phased arrays, the effect of surface wave coupling becomes particularly obnoxious, and the array can neither transmit nor receive when it is pointed at some particular directions (blind spots). This is due to a resonance phenomenon, when the surface waves excite in synchronism the Floquet modes of the periodic structure. Surface waves reaching the outer boundaries of an open microstrip structure are reflected and diffracted by the edges. The diffracted waves provide an additional contribution to radiation, degrading the antenna pattern by raising the side lobe and the cross polarization levels. Surface wave effects are mostly negative, for circuits and for antennas, so their excitation should be suppressed if possible.

- **Leaky Waves**

Waves directed more sharply downward, with θ angles between π - arcsin ($1/\sqrt{\varepsilon r}$) and π,are also reflected by the ground plane but only partially by the dielectric-to-air boundary. They progressively leak from the substrate into the air ,hence their name laky waves, and eventually contribute to radiation. The leaky waves are also non-uniform plane waves for which the attenuation direction α points downward, which may appear to be rather odd; the amplitude of the waves increases as one moves away from the dielectric surface. This apparent paradox is easily understood by looking at the figure 1.2.3(c); actually, the field amplitude increases as one move away from the substrate because the wave radiates from a point where the signal amplitude is larger. Since the structure is finite, this apparent divergent behavior can only exist locally, and the wave vanishes abruptly as one crosses the trajectory of the first ray in the figure.

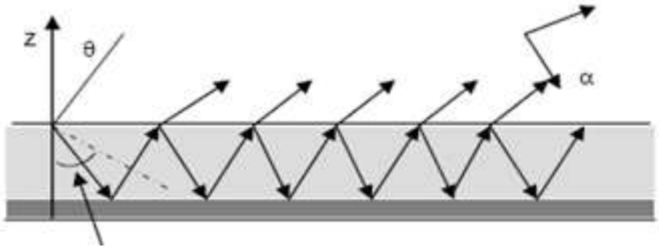


Figure 1.2.3(c) Leaky waves

In more complex structures made with several layers of different dielectrics, leaky waves can be used to increase the apparent antenna size and thus provide a larger gain. This occurs for favorable stacking arrangements and at a particular frequency. Conversely, leaky waves are not excited in some other multilayer structures.

- **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.

1.2.4 Antenna Characteristics

There are several important antenna characteristics that should be considered when choosing an antenna for your application as follows

- Antenna radiation patterns
- Power Gain
- Directivity
- Polarization

1.3 LITERATURE SURVEY AND MOTIVATION

1.3.1 Literature Survey

After a brief introduction to microstrip antenna, we present a systematic survey on microstrip antenna and motivation for present study in this chapter .Narrow bandwidth has been a problem of microstrip antenna. Many works have been conducted to increase the bandwidth of microstrip antenna. For small size bandwidth, multilayered substrate has been fabricated using MEMS Process.

Usually microstrip antennas built on dielectric substrates and their characteristics studies at frequencies in the GHz range. The bandwidth reported is about 1% in all such cases. But the author here has found out by theoretical analysis that at lower frequency ranges by building microstrip antennas on ferri magentic substrates which possess both dielectric and magnetic properties would yield larger bandwidth and smaller size at particular frequency.

Common techniques for reducing the size of a microstrip antenna are to employ a substrate with high dielectric constant and to incorporate a shorting pin in a microstrip patch. Recently, two techniques to enhance the bandwidth has been reported, they are, one use of an annular ring coupled to a shorted circular patch, while the second is to employ a low resistance chip is to employ a low resistance chip instead of the shorting pin.

1.3.2 Motivation

1. From the literature survey it is obvious that there are number of experimental and theoretical studies of various microstrip antennas. Number of investigators have designed and studied various types of microstrip antennas. In most of their studies the substrate materials considered in non-magnetic material. There are very few reports in the literature about the substrate material s having magnetic properties. Also there are no reports considering the effects of and on the radiation properties of any antenna. It is well known fact that the bandwidth of microstrip antenna becomes narrower as the size of the antenna reduces. It is difficult to achieve an impedance bandwidth of more than 3% for small microsstrip antennas.

From the literature, we come to know that many researchers have dedicated their efforts to create new design or variation to the original antenna so that wide bandwidth or multiple frequency operation can be realized in single elements. This work is another attempt to increase the bandwidth and the multiple frequency operation by introducing magnetic properties (μr and $\tan\delta\varepsilon$) in the substrate of the microstrip antenna. From our literature survey ours is the prominent group in introducing $\tan\delta\varepsilon$ in substrate for increasing the bandwidth. Also, in order to understand and learn the electromagnetic simulation tool like FEKO EM [2] we have taken up this work. In this present work we are systematically studying microstrip antenna properties and we are motivated to carry out the following studies:

2. Designing of microstrip antenna by using CAD FEKO.
3. Study their radiation properties using FEKO.
4. Optimization of this design.
5. Introducing of magnetic properties (μr and $\tan\delta\varepsilon$) in the substrate of microstrip antenna designed.
6. A systematic study of radiation properties of microstrip antenna under the influence of substrate μr and $\tan\delta\varepsilon$.
7. Optimization of μr and $\tan\delta\varepsilon$ for required bandwidth.

CHAPTER 2

MICROSTRIP PATCH ANTENNA

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 hoto lithographic technology are seen as an engineering breakthrough[3,4].

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(a). 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.

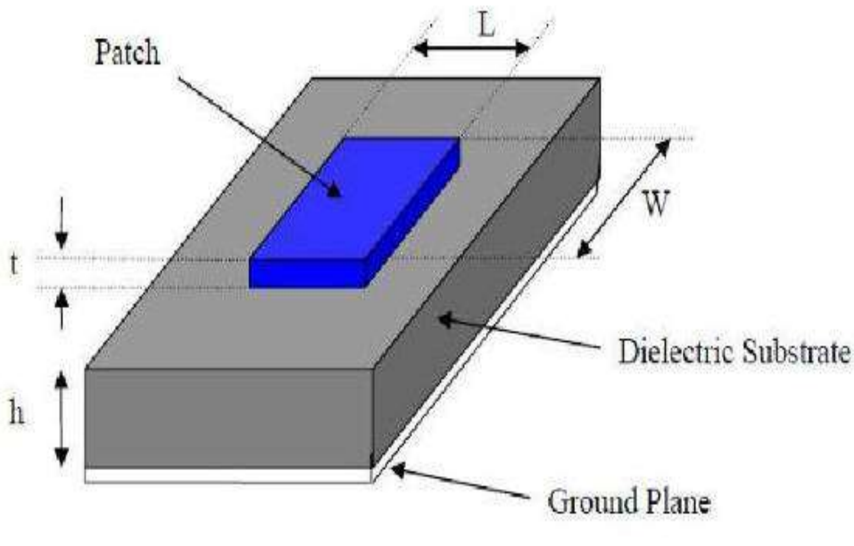


Figure 2.1 (a) Microstrip Patch Antenna

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 2.1(b). 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 $t \ll \lambda o$ (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 $2.2 \leq \varepsilon r \leq 12$.

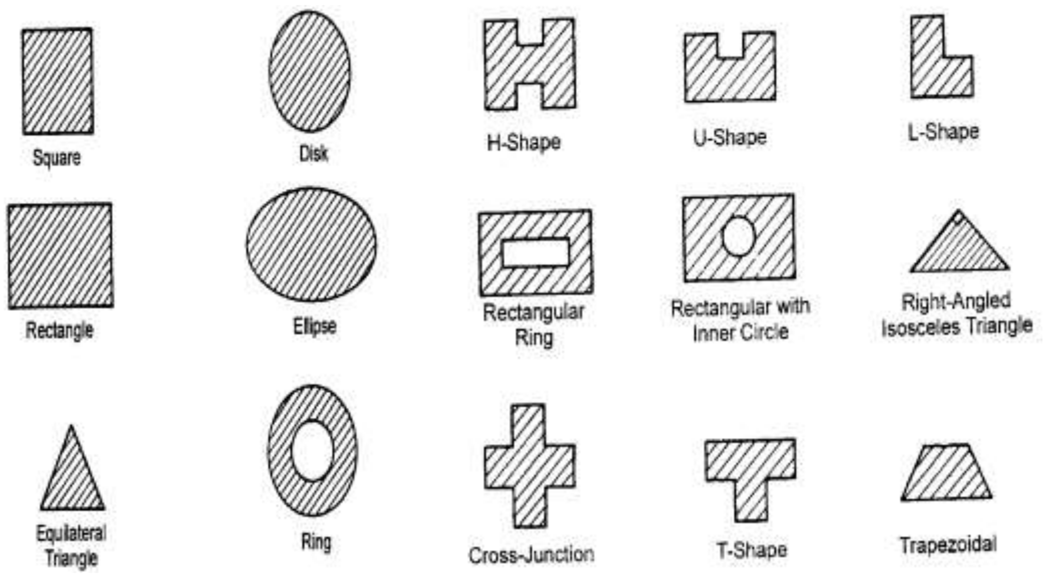


Figure 2.1(b) Common Shapes of microstrip patch elements

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.

Comparison of Various Types of Flat Profile Printed Antennas

Characteristics	Microstrip Patch Antennas	Microstrip Slot Antennas	Printed Dipole Antennas
Profile	Thin	Thin	Thin
Fabrication	Very easy	Easy	Easy
Polarization	Both linear and circular	Both linear and circular	Linear
Dual-frequency operation	Possible	Possible	Possible
Shape flexibility	Any shape	Mostly rectangular and circular shapes	Rectangular and triangular
Spurious radiation	Exists	Exists	Exists
Bandwidth	2–50%	5–30%	~30%

Table 2.1 Comparison of various types of flat profile printed antennas

Properties of a Basic Microstrip Patch

A microstrip or patch antenna is a low profile antenna that has a number of advantages[5] over other antennas it is lightweight, inexpensive, and easy to integrate with accompanying electronics. While the antenna can be 3D in structure (wrapped around an object, for example), the elements are usually flat; hence their other name, planar antennas. Note that a planar antenna is not always a patch antenna.

2.2 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).

I. 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 2.2(a). 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.

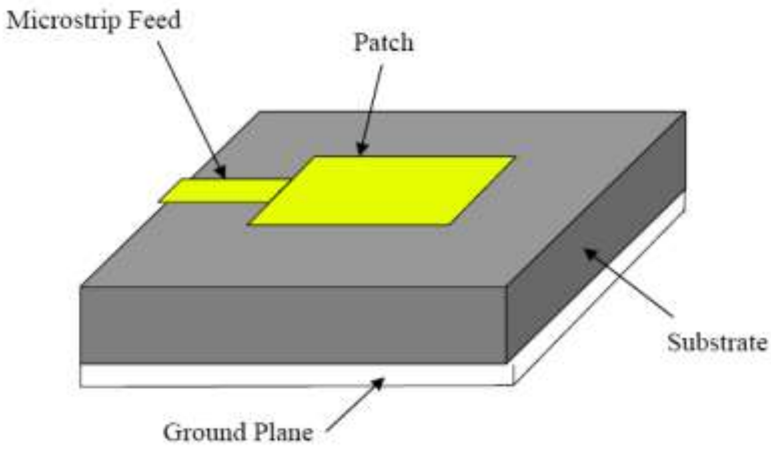


Figure 2.2(a) Microstrip Line Feed

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.

II. Coaxial Feed

The Coaxial feed or probe feed is a very common technique [6] used for feeding Microstrip patch antennas. As seen from Figure 2.2(b), 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.

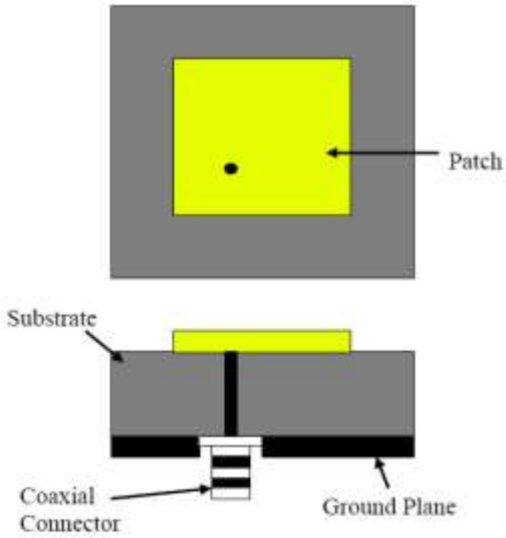


Figure 2.2(b) Probe fed Rectangular Microstrip Patch Antenna

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 ($h > 0.02\lambda o$). Also, for thicker substrates[7], 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.

III. Aperture Coupled Feed

In this type of feed technique, the radiating patch and the microstrip feed line are separated by the ground plane as shown in Figure 2.2(c). Coupling between the patch and the feed line is made through a slot or an aperture in the ground plane.

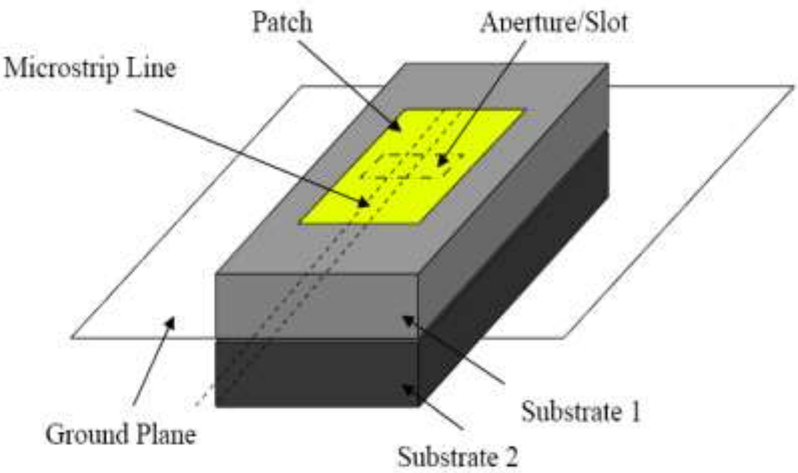


Figure 2.2(c) Aperture-coupled feed

The coupling aperture is usually centred under the patch, leading to lower cross polarization due to symmetry of the configuration. The amount of coupling from the feed line to the patch is determined by the shape, size and location of the aperture. Since the ground plane separates the patch and the feed line, spurious radiation is minimized. Generally, a high dielectric material is used for bottom substrate and a thick, low dielectric constant material is used for the top substrate to optimize radiation from the patch. The major disadvantage of this feed technique is that it is difficult to fabricate due to multiple layers, which also increases the antenna thickness. This feeding scheme also provides narrow bandwidth.

IV. Proximity Coupled Feed

This type of feed technique is also called as the electromagnetic coupling scheme.
As shown in figure 2.2(d), two dielectric substrates are used such that the feed line is between the two substrates and the radiating patch is on top of the upper substrate. The main advantage of this feed technique is that it eliminates spurious feed radiation and provides very high bandwidth (as high as 13%), due to overall increase in the thickness of the microstrip patch antenna. This scheme also provides choices between two different dielectric media, one for the patch and one for the feed line to optimize the individual performances.

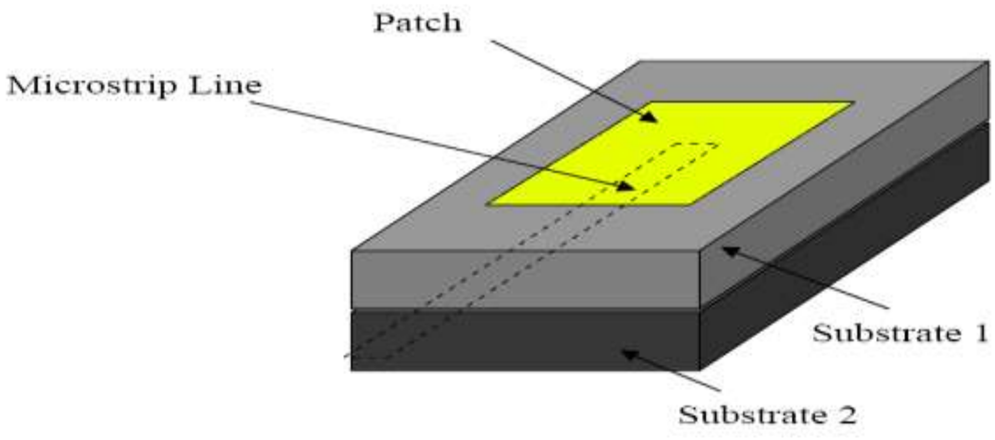


Figure 2.2(d) Proximity-coupled Feed

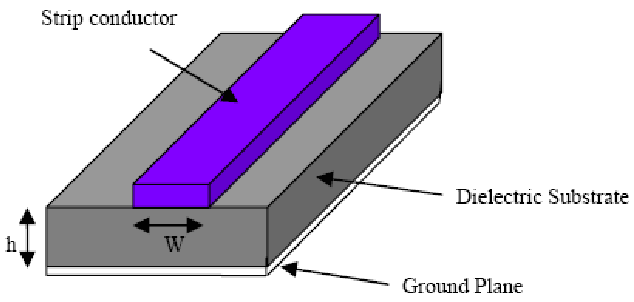
Matching can be achieved by controlling the length of the feed line and the width to-line ratio of the patch. The major disadvantage of this feed scheme is that it is difficult to fabricate because of the two dielectric layers which need proper alignment. Also, there is an increase in the overall thickness of the antenna.

2.3 Methods of Analysis

The preferred models for the analysis of Microstrip patch antennas are the transmission line model, cavity model, and full wave model[8] (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.

2.3.1 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.



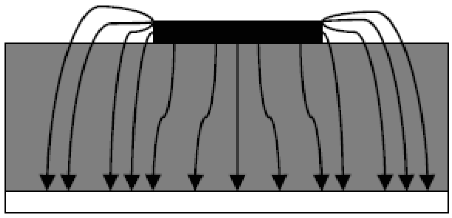


Figure 2.3.1(a) Microstrip Line **Figure 2.3.1(b) Electric Field Lines**

Hence, as seen from Figure 2.3.1(b), 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 ($\varepsilon reff$) must be obtained in order to account for the fringing and the wave propagation in the line. The value of $\varepsilon reff$ is slightly less then εr 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 above. The expression for $\varepsilon reff$ is given by Balanis[9] as:

$$\varepsilon reff = \frac{\varepsilon r+1}{2} + \frac{\varepsilon r-1}{2}\sqrt{[1+\frac{12h}{W}]}$$

Where,

$\varepsilon reff$ = Effective dielectric constant

εr = Dielectric constant of substrate

h = Height of dielectric substrate

W = Width of the patch

Consider Figure 2.3.1(c) 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.

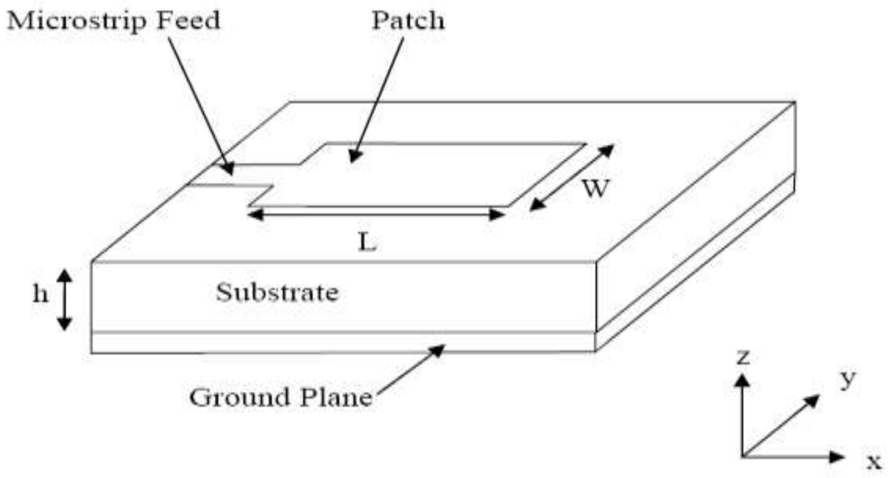


Figure 2.3.1(c) Microstrip Patch Antennas

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 λ*o*/√ε*reff* where λ*o* 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 2.3.1(d) 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.

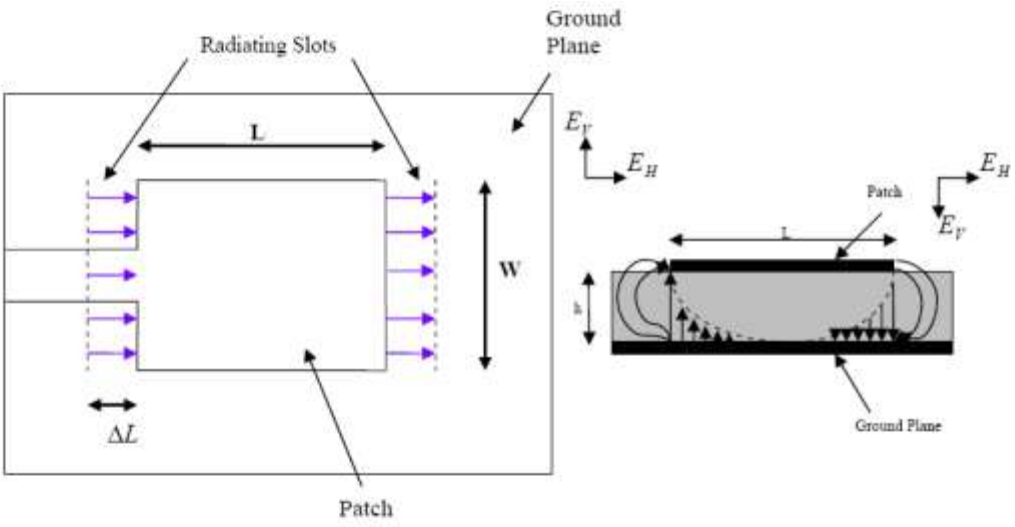


Figure 2.3.1(d)

Top View of Antenna **Side View of Antenna**

It is seen from Figure 2.3.1(d) 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 2.3.1(e)), 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 given empirically by Hammerstad [10] as:

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

The effective length of the patch L_{eff} now becomes:

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

For a given resonance frequency f_o,the effective length is given as:

$$L_{eff}= \frac{c}{2fo\sqrt{\varepsilon reff}}$$

For a rectangular microstrip patch antenna ,the resonance frequency for any TM_{mn} mode is given by James and Hall [11] as:

$$f_o=\frac{c}{2\sqrt{\varepsilon reff}}\,[(\frac{m}{L})^2 + (\frac{n}{W})^2]^{1/2}$$

where m and n are modes along L and W respectively

For efficient radition ,the width W is given by Bahland Bhartia [12] as:

$$W=\frac{c}{2fo\sqrt{(\varepsilon r+1)/2}}$$

2.3.2 Cavity Model

Although the transmission line model discussed in the previous section is easy to use, it has some inherent disadvantages. Specifically, it is useful for patches of rectangular design and it ignores field variations along the radiating edges. These disadvantages can be overcome by using the cavity model. A brief overview of this model is given below.

In this model, the interior region of the dielectric substrate is modelled as a cavity bounded by electric walls on the top and bottom. The basis for this assumption is the following observations for thin substrates ($h << \lambda$).

• Since the substrate is thin, the fields in the interior region do not vary much in the *z* direction, i.e. normal to the patch.

• The electric field is *z* directed only, and the magnetic field has only the transverse components H_x and H_y in the region bounded by the patch metallization and the ground plane. This observation provides for the electric walls at the top and the bottom.

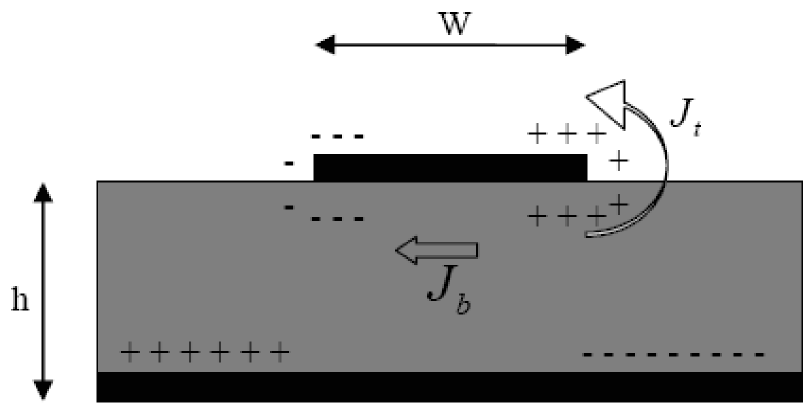


Figure2.3.2 Charge distribution and current density creation on the microstrip patch

Consider Figure shown above, when the microstrip patch is provided power, a charge distribution is seen on the upper and lower surfaces of the patch and at the bottom of the ground plane. This charge distribution is controlled by two mechanisms-an attractive mechanism and a repulsive mechanism as discussed by Richards. The attractive mechanism is between the opposite charges on the bottom side of the patch and the ground plane, which helps in keeping the charge concentration intact at the bottom of the patch. The repulsive mechanism is between the like charges on the bottom surface of the patch, which causes pushing of some charges from the bottom, to the top of the patch. As a result of this charge movement, currents flow at the top and bottom surface of the patch. The cavity model assumes that the height to width ratio (i.e. height of substrate and width of the patch) is very small and as a result of this the attractive mechanism dominates and causes most of the charge concentration and the current to be below the patch surface. Much less current would flow on the top surface of the patch and as the height to width ratio further decreases, the current on the top surface of the patch would be almost equal to zero, which would not allow the creation of any tangential magnetic field components to the patch edges. Hence, the four sidewalls could be modeled as perfectly magnetic conducting surfaces. This implies that the magnetic fields and the electric field distribution beneath the patch would not be disturbed. However, in practice, a finite width to height ratio would be there and this would not make the tangential magnetic fields to be completely zero, but they being very small, the side walls could be approximated to be perfectly magnetic conducting.

Since the walls of the cavity, as well as the material within it are lossless, the cavity would not radiate and its input impedance would be purely reactive. Hence, in order to account for radiation and a loss mechanism, one must introduce a radiation resistance R_R and a loss resistance R_L. A lossy cavity would now represent an antenna and the loss is taken into account by the effective loss tangent δ_{eff} which is given as:

$$\delta eff = 1/Q_T$$

Q_T is the total antenna quality factor and has been expressed in the form:

$$\frac{1}{QT} = \frac{1}{Qd} + \frac{1}{Qc} + \frac{1}{Qr}$$

- Qd represents the quality factor of the dielectric and is given as :

$$Qd = \frac{\omega r WT}{Pd} = \frac{1}{tan\delta}$$

Where,

ωr is the angular resonant frequency

WT is the total energy stored in the patch at resonance

Pd is the dielectric loss

Tanδ is the loss tangent of dielectric

- Qc represents the quality factor of the conductor and is given as :

$$Qc = \frac{\omega r WT}{Pc} = \frac{h}{\Delta}$$

Where,

Pc is the conductor loss

$\mathit{\Delta}$ is the skin depth of the conductor

H is the height of the substrate

- Qr represents the quality factor for radiation and is given as :

$$Qr = \frac{\omega rWT}{Pr}$$

Where, Pr is the power radiated from the patch

Therefore from the above equations we get,

$$\Delta eff = \tan\delta + \frac{\mathit{\Delta}}{h} + \frac{Pr}{\omega rWT}$$

Thus, the above equation describes the total effective loss tangent for the microstrip patch antenna.

CHAPTER 3

METHODOLOGY

METHODOLOGY

3.1 FEKO-SOFTWARE SUITE

3.1.1 Introduction to the FEKO Suite

The name FEKO[13] is an abbreviation derived from the German phrase ***FE****ldberechnung bei* ***K****¨orpern mit beliebiger* ***O****berfl¨ache*. *(Field computations involving bodies of arbitrary shape.)* As the name suggests, FEKO can be used for various types of electromagnetic field analyses involving objects of arbitrary shapes.

3.1.2 FEKO Overview

FEKO is a software Suite intended for the analysis of a wide range of electromagnetic problems. Applications include EMC analysis, antenna design, microstrip antennas and circuits, dielectric media, scattering analysis and many more. The kernel provides a comprehensive set of powerful computational methods and has been extended for the analysis of thin dielectric sheets, multiple homogeneous dielectric bodies and planar stratified media. Figure 3.1.2 illustrates some of the numerical analysis techniques available in FEKO and the types of problems for which they are intended.

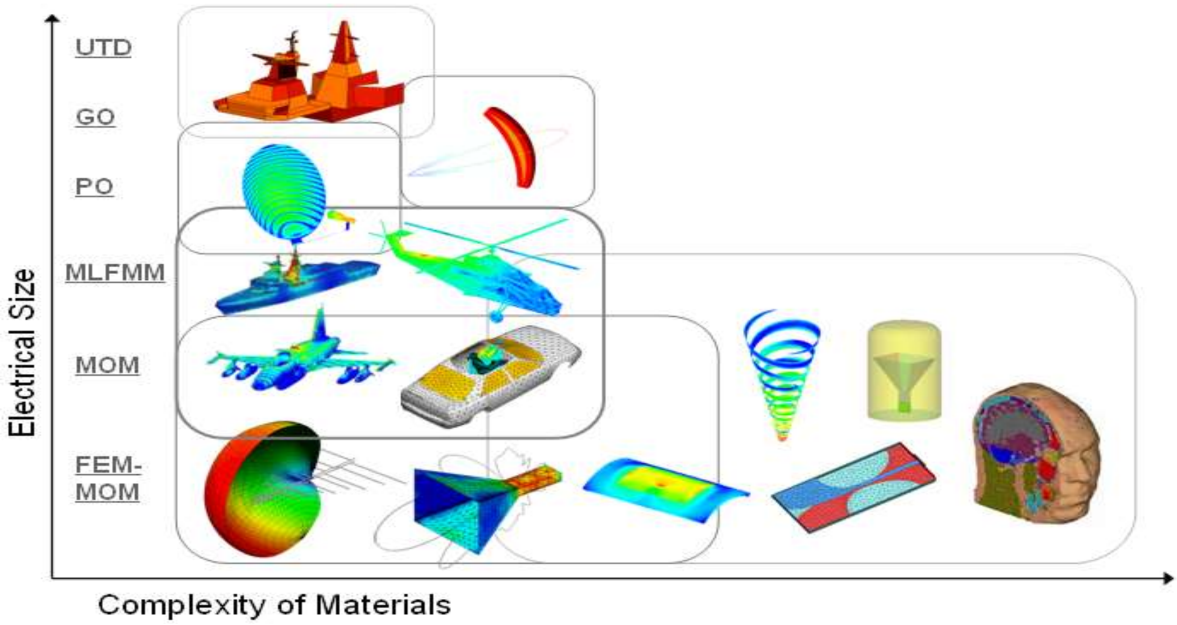


Figure 3.1.2 Numerical analysis methods available in FEKO

3.1.3 FEKO solution engine

The Method of Moments (MoM) technique forms the basis of the FEKO solver. Other techniques such as the Multilevel Fast Multipole Method (MLFMM), the Finite Element Method (FEM) Uniform Theory of Defraction (UTD), Geometrical optics (ray launching) and Physical Optics (PO) have been implemented to allow the solving of electrically large problems and inhomogeneous dielectric bodies of arbitrary shape. Special approximations and acceleration techniques are available for problems of specific types. FEKO provides for parallel processing usage on a range of workstations, servers and clusters. The performance for each platform, operating system and deployment method has been optimised for the delivery of accurate and timely results.

3.1.4 Method of Moments

The core of the program FEKO is based on the *Method of Moments* (MoM). The MoM is a full wave solution of Maxwell's integral equations in the frequency domain. An advantage of the MoM is that it is a "source method" meaning that only the structure in question is discretised, not free space as with "field methods". Boundary conditions do not have to be set and memory requirements scale proportional to the geometry in question and the required solution frequency. The following special extensions have been included in FEKO's MoM formulation to enable the modelling of magnetic and dielectric media.

- **Surface Equivalence Principle (SEP):** The SEP introduces equivalent electric and magnetic currents on the surface of a closed dielectric body. The surface of such bodies can be arbitrarily shaped and is discretized using triangles.

- **Volume Equivalence Principle (VEP):** The VEP allows the creation of dielectric
  bodies from cuboids. More basis functions are typically required than for the SEP, but neighbouring cuboids may have differing electric and magnetic properties.

- **Planar Green's Functions for Multilayered Media:** Multilayered dielectric media may be modelled with Greens functions, e.g. substrates for microstrip architecture. The special Greens function formulation implements 2D infinite planes with finite thickness to handle each layer of the dielectric. Conducting surfaces and wires inside the dielectric layers have to be discretized, but not the dielectric layers themselves. Metallic surfaces and wires can be arbitrarily oriented in the media and are allowed to cross multiple layers. (Calculations using Greens functions are accelerated by using interpolation tables.)

- **Thin Dielectric Sheets:** Multiple layers of thin dielectric and anisotropic sheets can be analysed as a single layer in FEKO. Typical applications are the analysis of random covered antennas and windscreens of automobiles.

- **Dielectrically Coated Wires:** FEKO implements two methods for the modelling of dielectric and magnetic coatings on wires:

- **MLFMM** The MLFMM is an alternative formulation of the technology behind the MoM and is applicable to much larger structures than the MoM, making full-wave current-based solutions of electrically large structures a possibility. This fact implies that it can be applied to most large models that were previously treated with the MoM without having to change the mesh. The agreement between the MoM and MLFMM is that basis functions model the interaction between all triangles. The MLFMM differs from the MoM in that it groups basis functions and computes the interaction between groups of basis functions, rather than between individual basis functions. FEKO employs a boxing algorithm that encloses the entire computational space in a single box at the highest level, dividing this box in three dimensions into a maximum of eight child cubes and repeating the process iteratively until the side length of each child cube is approximately a quarter wavelength at the lowest level. Only populated cubes are stored at each level, forming an efficient tree-like data structure. In the MoM framework the MLFMM is implemented through a process of aggregation, translation and disaggregation of the different levels.

3.1.5 FEKO Suite components

The user interface consists of the components CADFEKO, EDITFEKO, POSTFEKO and SECFEKO.

• CADFEKO is used to create and mesh the geometry, and to specify the solution settings and calculation requirements in a graphical environment.

• EDITFEKO is used to construct advanced models (both the geometry and solution requirements) using a high level scripting language which includes repetitive FOR loops and conditional IF–ELSE statements.

• POSTFEKO reads results form binary output files (*.bof) and can display the results on 2D graphs or in combination with the geometry in 3D views. POSTFEKO is also used to visualise optimisation results during and after optimisation, as well as the meshed geometry of the FEKO model, with excitations, field requests points etc. before the actual FEKO run.

• QUEUEFEKO facilitates the creation of packages which can be transported to remote cluster machines where the package is placed in an execution queue (such as PBS).

• FEKO UPDATE is a command line tool that can be used to check if updates are available from a master (internet) or local repository. The FEKO GUI update tool is an interactive application that allows the user to set preferences regarding the automatic download of updates.

• SECFEKO GUI is the FEKO licence manager.

• SECFEKO is the FEKO licence manager and shows all the licences in the specified secfeko.dat file (for node locked licences) or connects to the floating licence servers and retrieves licence information.

Other components that form part of the FEKO Suite do not provide a graphical interface, but are concerned with the analysis and solution of the electromagnetic problem as defined in the GUI components. These components are launched indirectly from the GUI components, but may also be launched from a command line. The solution components are fully supported by a large range of platforms.

• PREFEKO processes the model and prepares the input file (*.fek) for the FEKO solution kernel.

• FEKO is the actual solver code. The ASCII (*.out) and binary (*.bof) output files generated by FEKO contain all the solution information.

• OPTFEKO is a tool that is used for the optimisation of a FEKO model according to specific requirements. OPTFEKO calls the FEKO solver as required during optimisation.

• TIMEFEKO provides a Fourier-transform based time-domain analysis mechanism for FEKO. TIMEFEKO calls the FEKO solver as required during the solution process.

• ADAPTFEKO is used in the generation of continuous adaptively sampled results. ADAPTFEKO is called as required by the FEKO kernel when continuously sampled results are required.

• CADFEKO BATCH is a command line tool that can be used to modify variable values in a CADFEKO model file from a command-line interface without launching the CADFEKO GUI.

Platforms

The FEKO kernel components are available on PC's and a wide variety of workstations.The GUI components CADFEKO, EDITFEKO, and POSTFEKO are available on PC's running MS Windows or Linux. All pre- and post processing must thus be performed on a PC, while the actual computationally intensive field calculations can be performed on a workstation, parallel cluster or on the PC itself as required. FEKO includes a remote launching facility to make such a remote execution easy to use from within the GUI running on the PC.

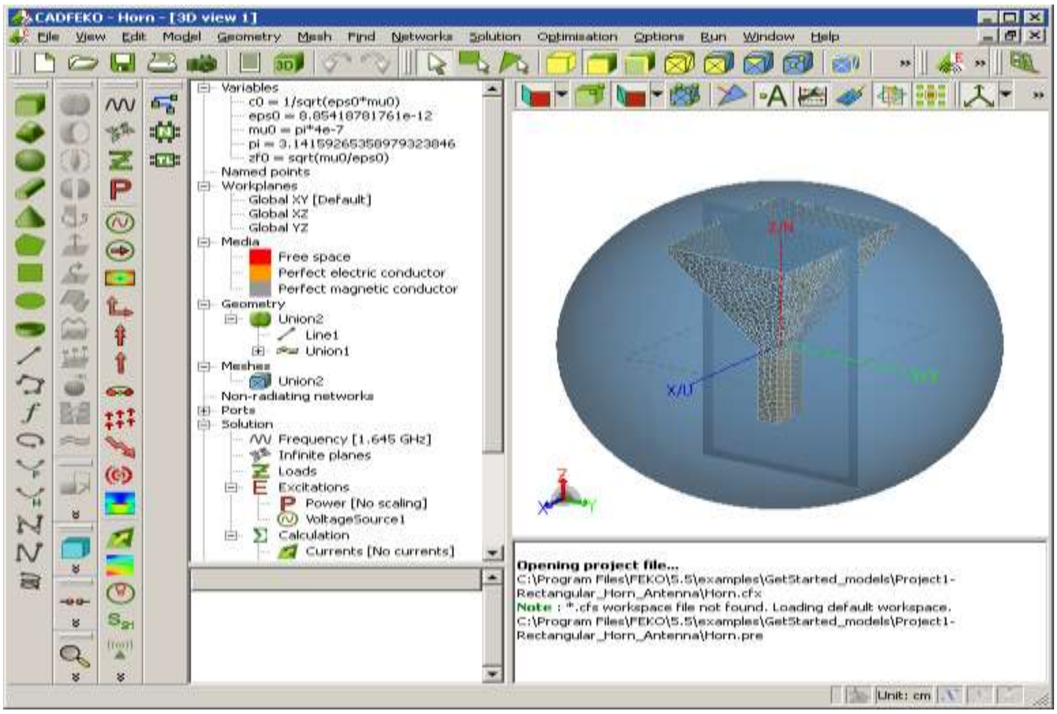


Figure 3.1.5 CADFEKO platform

3.1.6 General modelling guidelines

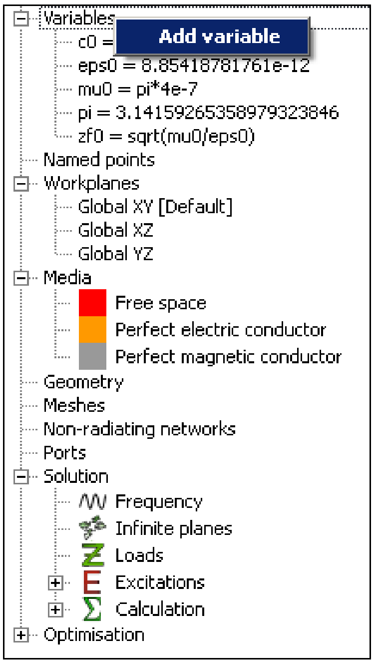
Program flow

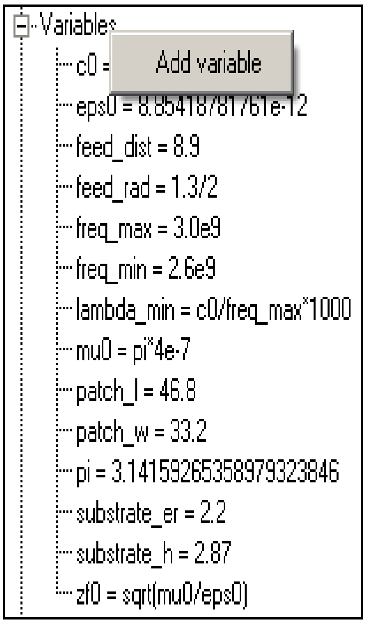
Models are generally constructed in CADFEKO. The model information is saved to the *.cfx file and the workspace layout to the *.cfs file. Next the user runs PREFEKO — launched from the CADFEKO *Run* menu — which processes the *.cfm and *.pre files (created automatically by CADFEKO during the save operation) and generates the *.fek file. The *.fek file is the input to the solution kernel, FEKO. (When running FEKO from the CADFEKO *Run* menu, PREFEKO is executed automatically if the user has not yet done so.) The FEKO output is stored in the binary *.bof file from which the results can be viewed in POSTFEKO. The results are also stored in the *.out file.

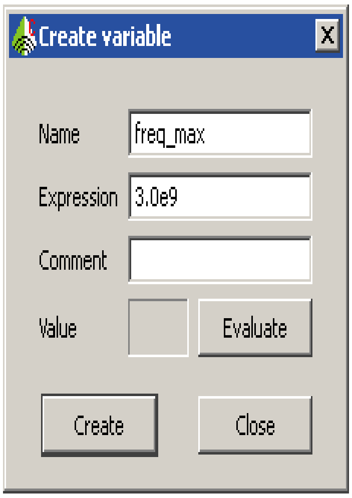
Where an optimisation has been defined in CADFEKO, the relevant optimisation information is written to the *.opt file and optimisation-specific visualisation quantities are saved to a special POSTFEKO graph file (*.pfg). The user may launch the optimiser (OPTFEKO) from the CADFEKO *Run* menu. The optimiser will automatically launch the other FEKO Suite components as required during the optimisation process. During the optimisation process, general iteration-specific results as well as optimisation process-specific information can be viewed in POSTFEKO. Once the optimisation process has completed, the optimum model as well as a full set of results are available for viewing in POSTFEKO.

3.1.7 Design Steps

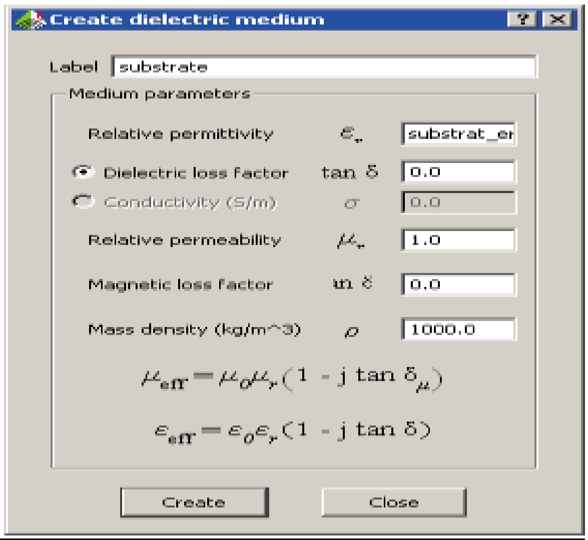
STEP1- ADDITION OF VARIABLES



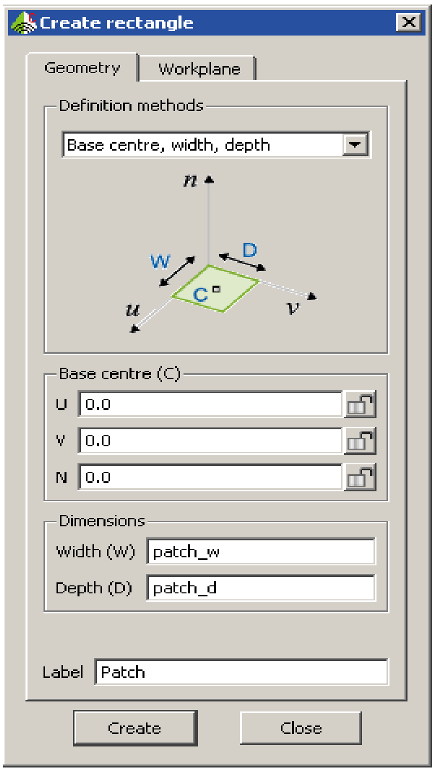




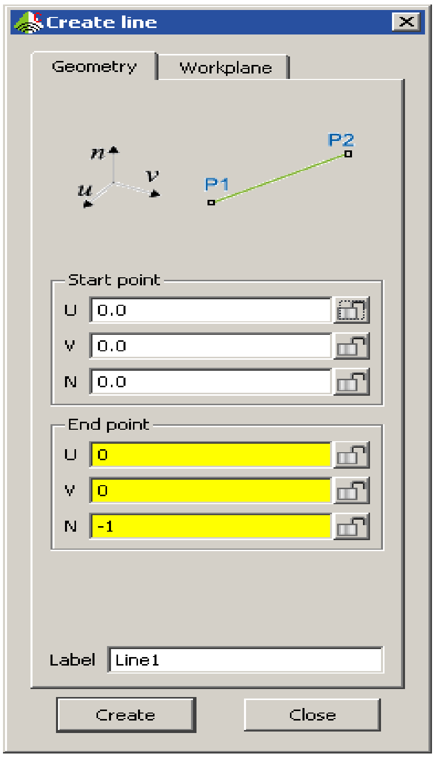
STEP2- CREATION OF DIELECTRIC MEDIUM



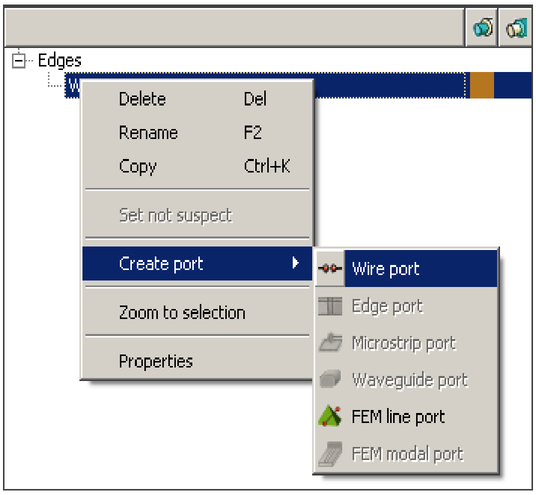
STEP3- CREATION OF RECTANGULAR PATCH

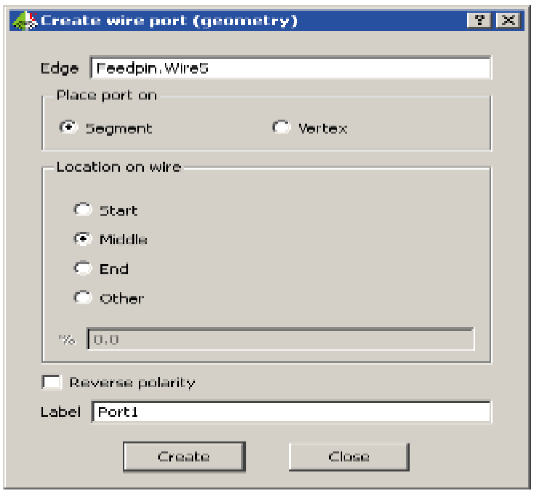


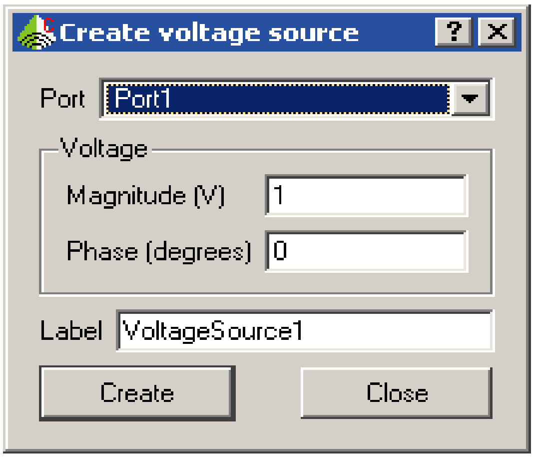
STEP4- FEED l INE

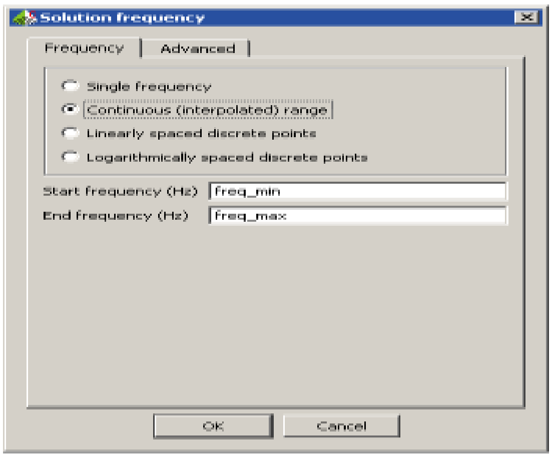


STEP 5- ADDITION OF PORTS AND VOLTAGE SOURCES

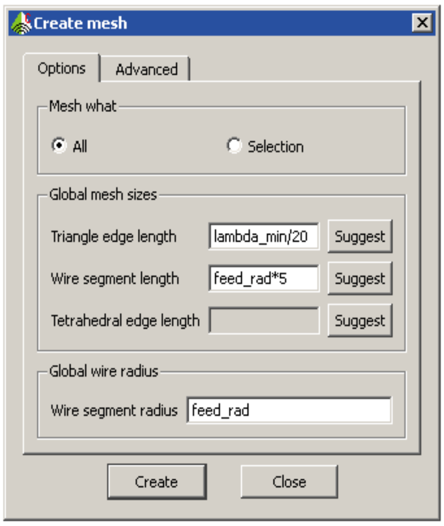




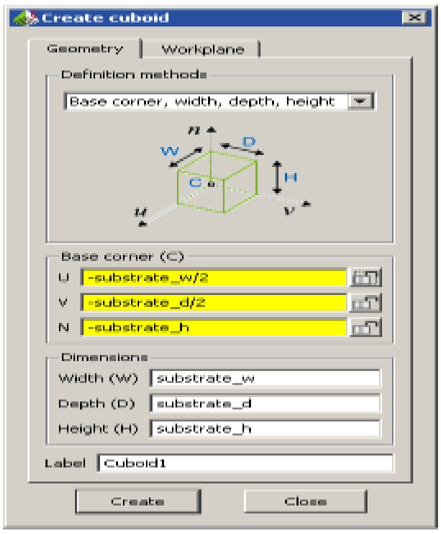




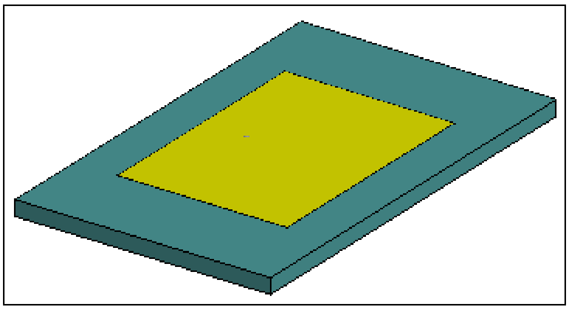
STEP 6-CREATION OF MESH

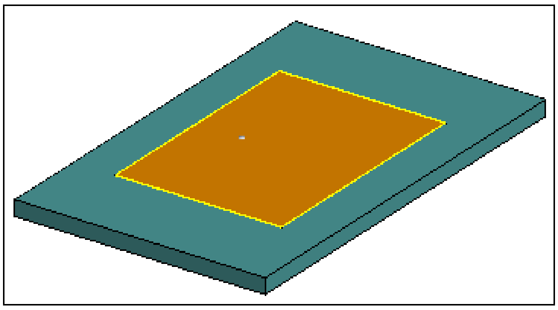


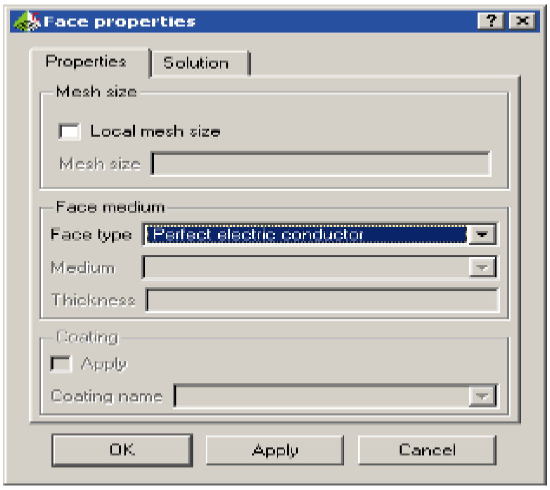
STEP 7-CREATION OF CUBOID

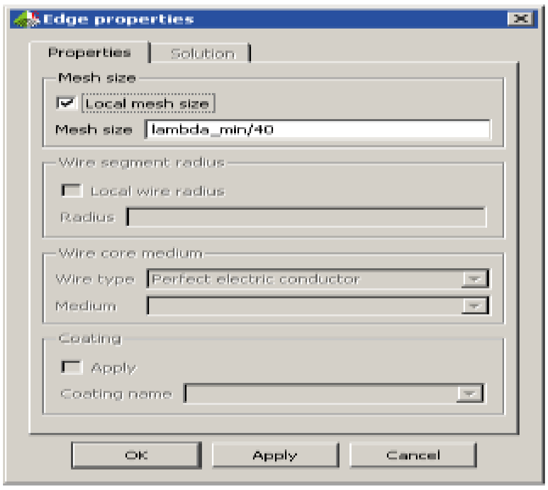


STEP8-SELECTION OF EDGES AND FACES

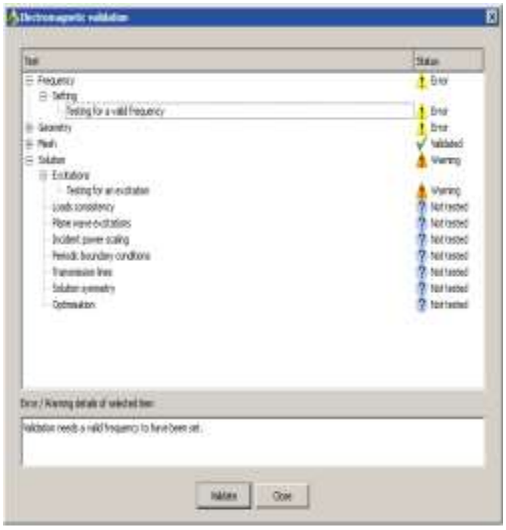




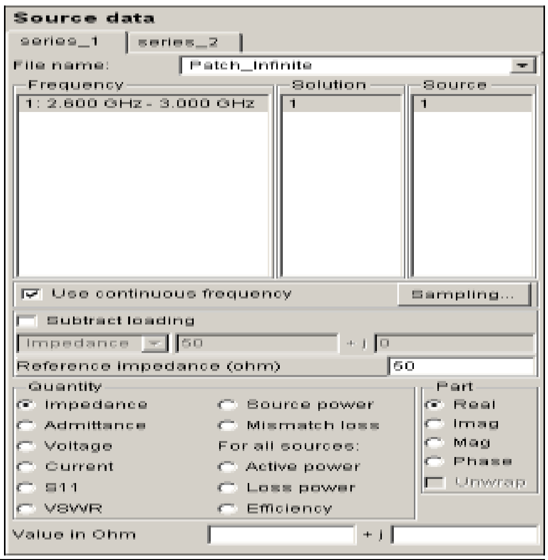


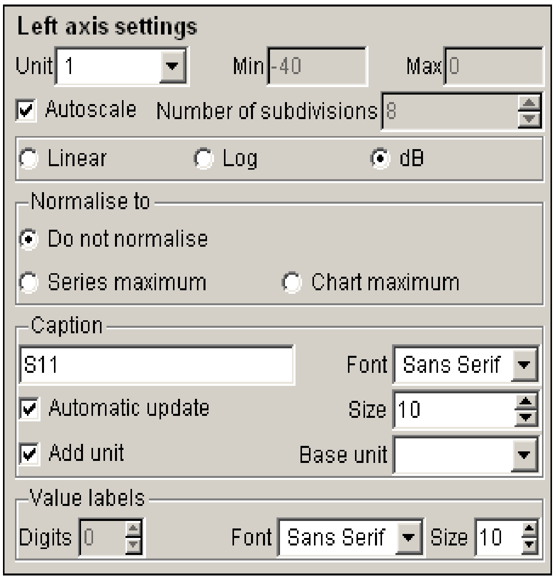


STEP 9- EM VALIDATION AND RUN

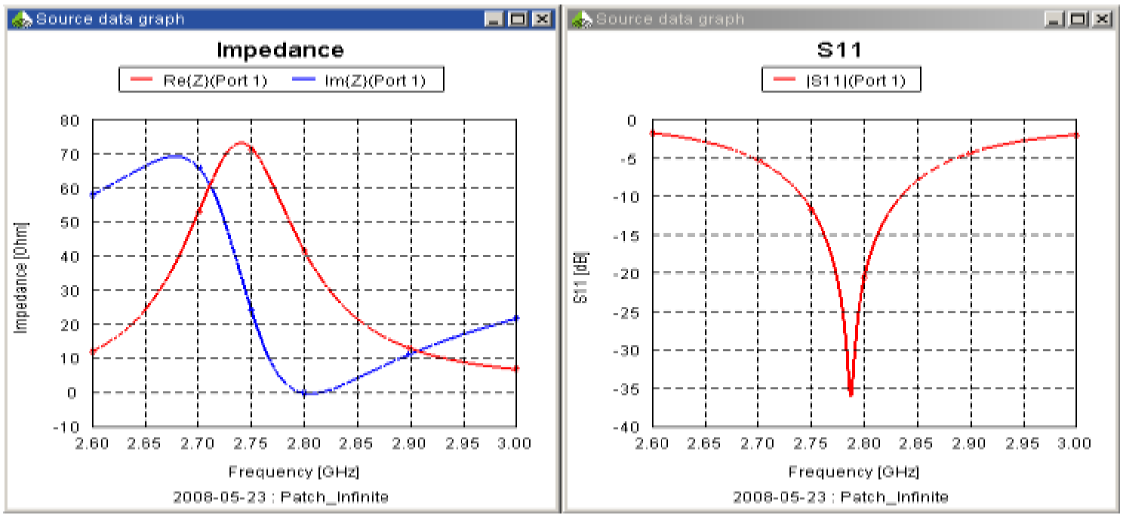


STEP 10- POST FEKO SIMULAITON





SAMPLE GRAPHS



3.2 DESIGN

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. This model represents the microstrip antenna by 2 slots of width W and height h, separated by a transmission line of length L. Since the electric field lines reside in the substrate and parts of some line in air, the transmission line can't support pure TEM (transverse-electric-magnetic) mode of transmission, because the phase velocities would be different in air and in substrate. Instead the dominant mode of propagation is quasi-TEM. So we need to obtain ε_{reff} to account for the fringing and the wave propagation in the line. The value of ε_{reff} is less than ε_r because of the fringing fields around the periphery of the patch are not confined in the substrate.

$$\varepsilon reff = \frac{\varepsilon r+1}{2} + \frac{\varepsilon r-1}{2}\sqrt{[1+\frac{12h}{W}]}$$

The above expression is given by BALANIS[9]

Since we want to operate in the fundamental TM_{10} mode L must be less than λ/2 where λ= λo/√εreff. This implies that the field varies 1 λ/2 cycles along the length and no variation along the width. The ΔL slots separated by length L and which is open circuited at both ends, so along the width the voltage is maxima and current is minimum due to the open ends. The fields at the edges get resolved between normal and tangential components with respect to ground plane. It is seen that the normal components at the edges are in opposite direction so its gets cancelled out. The tangential components are in phase, so then they combine to give maximum radiation field therefore the edges along the width is represented by two radiating slots which is λ/2 apart. The length L has been extended by ΔL on both sides, which is given by

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

The above equations were given by HAMMERSTAD[10]

The real length for the patch can be calculated by L= $L_{eff} - 2\Delta L$

Where

$$L_{eff} = \frac{c}{2fo\sqrt{\varepsilon reff}}$$

For the effective radiation the width W is given by Bahl and Bhartia[12]

$$W = \frac{c}{2fo\sqrt{(\varepsilon r+1)/2}}$$

The transmission line model is applicable to infinite ground planes only. However, for practical considerations, it is essential to have a finite ground plane. It has been shown by[13] that similar results for finite and infinite ground plane can be obtained if the size of the ground plane is greater than the patch dimensions by approximately six times the substrate thickness all around the periphery. Hence, for his design, the ground plane dimensions would be given as:

Lg= 6h+ L

Wg=6h+W

3.3 PREPARATION

STEP 1-CREATION OF MOULDS:

- We first take a glass plate on which we prepare the moulds of size ($7.2cm*7.5cm*.2mm=10.8cm^3$)
- The glass is cleaned with a soft cloth to remove the areas of dirt.
- On the glass plate, boundaries are created using smaller pieces of glass of the required thickness and dimensions.
- The boundaries are fixed, using a chemical substance called araldite .This takes some time to dry.
- We clean the entire surface with PVA solution.
- We then apply wax to the entire area so that it will be easy to remove the substrate and fill the edges with.
- We prepare two rectangular mould of volume $10.8cm^3$ and a sample of module volume of $2.25cm^3$

Figure 3.3(a) Cleaned glass surface **Figure 3.3(b) Application of wax**

STEP 2-TO OBTAIN THE SOUTION:

- Polymer used:- STYRENE(25cc)
- Using, Mass=volume*density we calculate the different amounts of Barrium ferrite that needs to be added, for the required concentration (5%, 10%, 15%, 20%, and 25%) of the solution.
- In addition, we also add about 2% of accelerator (**Cobalt Naphthalate**) & catalyst(**Methyl Ethyl Ketone Peroxide**) for a faster, uniform reaction.

- Samples are created using each of the solutions, which are then studied, to obtain their parameters.

Figure 3.3(c) Glass moulds

Figure 3.3(d) Styrene solution

STEP 3- PREPARATION OF SUBSTRATE FROM SOLUTION:

- Add 25cc of styrene to a beaker and calculated amount of barium ferrite.
- Stir the solution for 20-30min, till it gets mixed up uniformly.
- Add a magnetic bead for uniform mixing.
- We next add 2% of catalyst and hardener to enhance the reaction.
- Further stir the solution for 20-30 min till it starts to get thick.
- The solution is then ready to be poured on the moulds.

Figure 3.3(e) Pouring solution into moulds

Figure 3.3(f) Drying of the solution

ESTIMATION

Mass =volume * density

Volume =21.3 cm^3

Density =0.909 g/cm^3 therefore, **Mass**=19.36 gm

for 21.3 cc **styrene**,

0% of **barium ferrite ($BaFe_{12}O_{19}$)** = 0 gm

5% of **barium ferrite ($BaFe_{12}O_{19}$)** = 0.968 gm

10% of **barium ferrite ($BaFe_{12}O_{19}$)** = 1.936 gm

15% of **barium ferrite ($BaFe_{12}O_{19}$)** = 2.904 gm

20% of **barium ferrite ($BaFe_{12}O_{19}$)** = 4.53 gm

25% of **barium ferrite ($BaFe_{12}O_{19}$)** = 5.6625 gm

CHAPTER 4

RESULTS AND DISCUSSIONS

RESULTS AND DISCUSSION

		s11		s21			sample reading			
samples	peak	magnitude (dB)	phase(degrees)	magnitude(dB)	phase	transmission line length	transmission line w	substrate length	substrate width	substrate thickness
pure sample	1.6GHz	-30	-93	-1.2	98	7.5cm	2cm	7.5cm	1.45cm	2.44mm
5% magnetic	1.16GHz	-28.1	-86.7	-0.7	94	7.6cm	2cm	7.6cm	2cm	2.43mm
10% magnetic	1.16GHz	-30	-96	-1.6	95					
	2.6GHz	-27	-1	-1.6	-177	7.5cm	0.2cm	7.5cm	1.45cm	2.39mm
15% magnetic	1.146GHz	-18	-103	-2.2	68					
	2.268GHz	-32	-36	-0.8	-164	7.5cm	0.2cm	7.5cm	1.85cm	2.34mm
20% magnetic	1.169GHz	-28	-93	-1.4	92					
	2.6GHz	-20	-11	-1.9	176	7.5cm	0.2cm	7.5cm	1.8cm	2.25mm
25% magnetic	1.158GHz	-29	-89	-0.4	153	7.3cm	0.2cm	7.3cm	1.4cm	2.22mm

Table4- S_{11}& S_{21} Parameters with magnitude and phase for a given transmission line

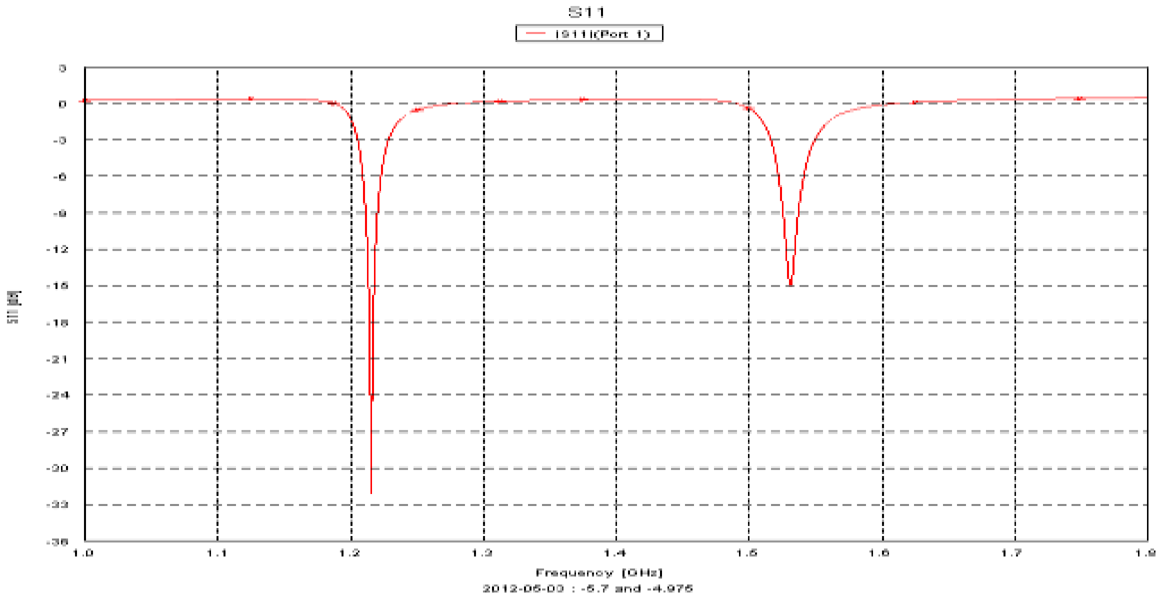
4.1 MATLAB CODE

```
clear all;
close all;

 s11m = input('Enter magnitude of S11');  %'s11=20log(1/mod(s11)'
 s11m=s11m/20;
 s11m=10^s11m;
 s11m=1/s11m;
 s11p = input('Enter phase of S11');
 s11p = (s11p*pi)/180;
 [s11r,s11i] = pol2cart(s11p,s11m);
 s11=s11r+s11i*i;
 disp('s11=');disp(s11);

 % Found s11

 s12m = input('Enter magnitude of S12');  %'s11=20log(1/mod(s11)'
 s12m=s11m/20;
 s12m=10^s12m;
```

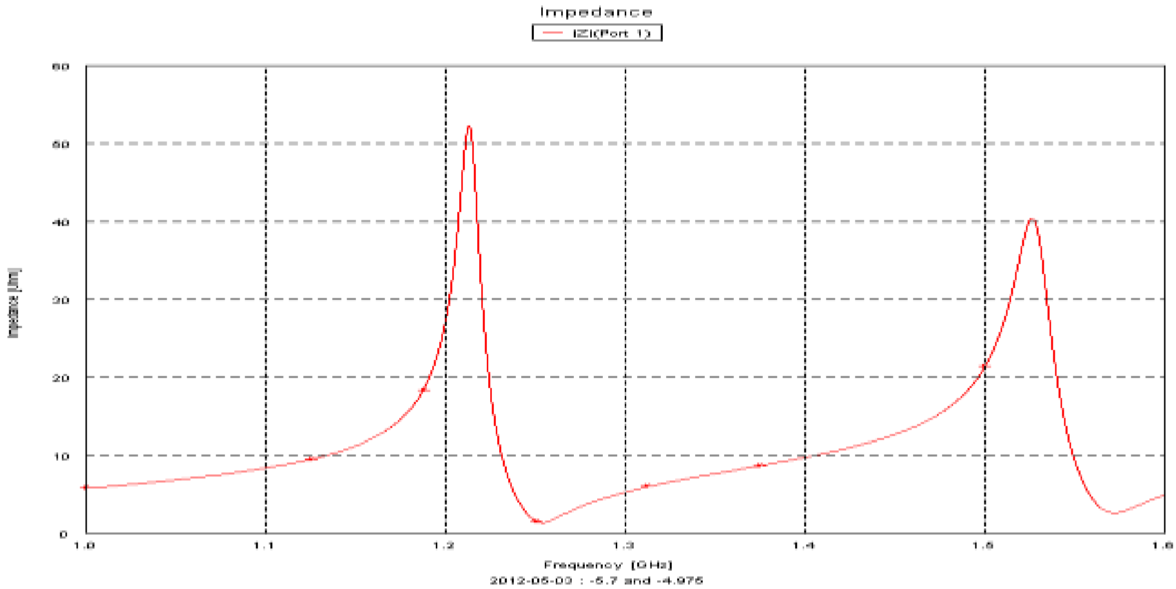
```
s12m=1/s12m;
s12p = input('Enter phase of S12');
s12p = (s12p*pi)/180;
[s12r,s12i] = pol2cart(s12p,s12m);
s12=s12r+s12i*i;
disp('s12=');disp(s12);

% Found s12

zl = (50*(1+s11))/(1-s11);
 h=input('Enter height of the dielectric medium');
t=input('Enter thickness of the patch');
w=input('Enter width of the dielectric medium');
er=((60/zl)*log((1.9*(2*h + t))/(0.8*w + t)))^2;

disp('er=');disp(er);

X = (s11^2 - s12^2 + 1)/ (2 * s11);

g1 = X + sqrt( X*X -1);

g2 = X - sqrt(X*X - 1);

if(abs(g1) < 1)
    gamma = g1;

else
    gamma = g2;

end

T = (s11 + s12 - gamma) / (1-((s11 + s12) * gamma));

L = input('Enter length of the transmission line');

kasq = (-1)*((log(1/T)/(2*pi*L))^2);

fr = input('Enter measured frequency');

lamo = (3*10^8)/fr;
 lamc= 0.09;

term1 = lamo^2/er;
term2 = (1/lamc^2) + kasq;

ur = term1*term2;
 disp('ur=');disp(ur);
```

4.2 SIMULATION STUDIES

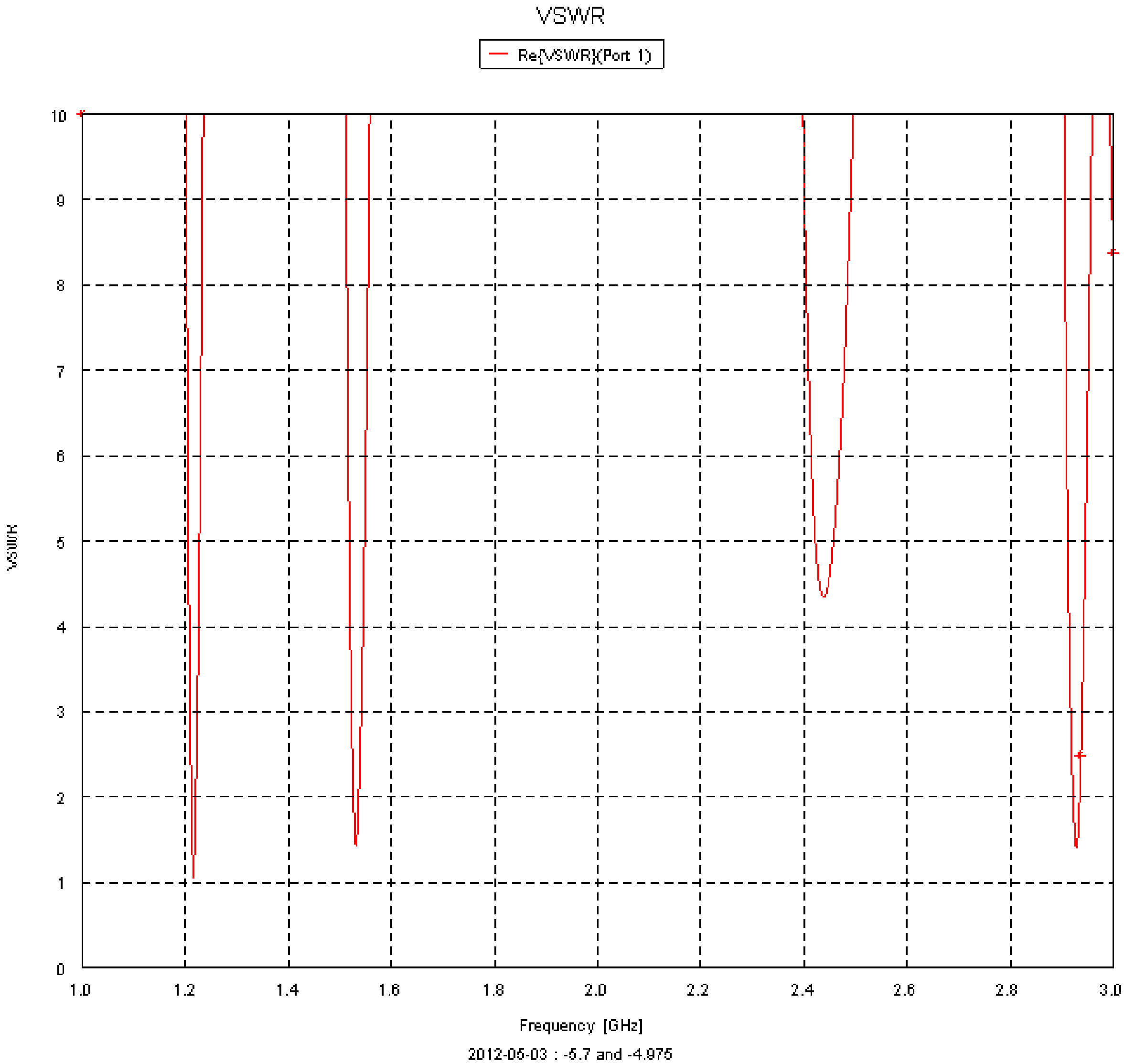
4.2.1 PURE SAMPLE



Graph 4.2.1(a) Return loss for Pure Polystyrene



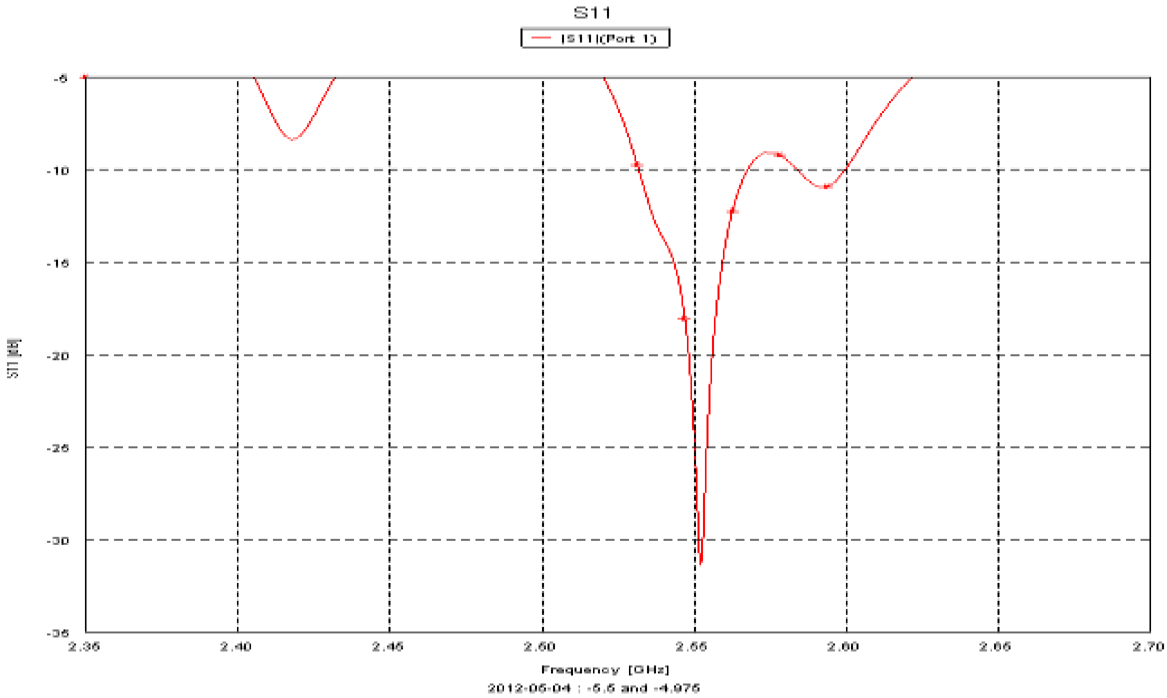
Graph 4.2.1(b) Impedance V/S Frequency for Pure Polystyrene



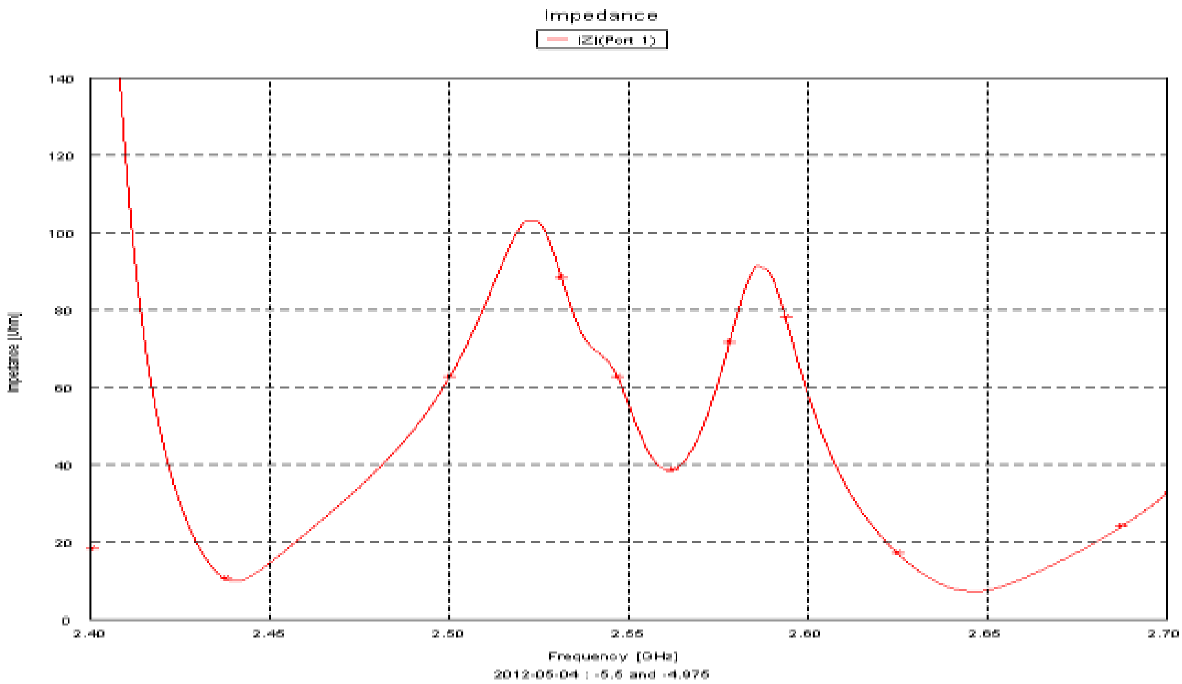
Graph 4.2.1(c) Vswr V/S Frequency (Impedance Bandwidth) for Pure Polystyrene

From graph 4.2.1(a) we see the variation of S11 v/s frequency which will provide us with the return loss measurement, having a value of -32.15 dB, which is very close to the desired value of -30dB. Also, from graph 4.2.1(b) we see that it is a variation of impedance v/s frequency having a value of 52Ω and it provides a very good coupling as it is very close to the ideal value of 50Ω. This provides for a good matching and hence it can be observed the resulting bandwidth as shown in graph 4.2.1(c) consists of multiple resonating frequencies at f1=1.22GHz, f2=1.53GHz and f3=2.92GHz with the corresponding VSWR values of 1.112, 1.42 and 1.38 respectively. The total resulting impedance bandwidth is 33.3MHz corresponding to 1.665% utilization.

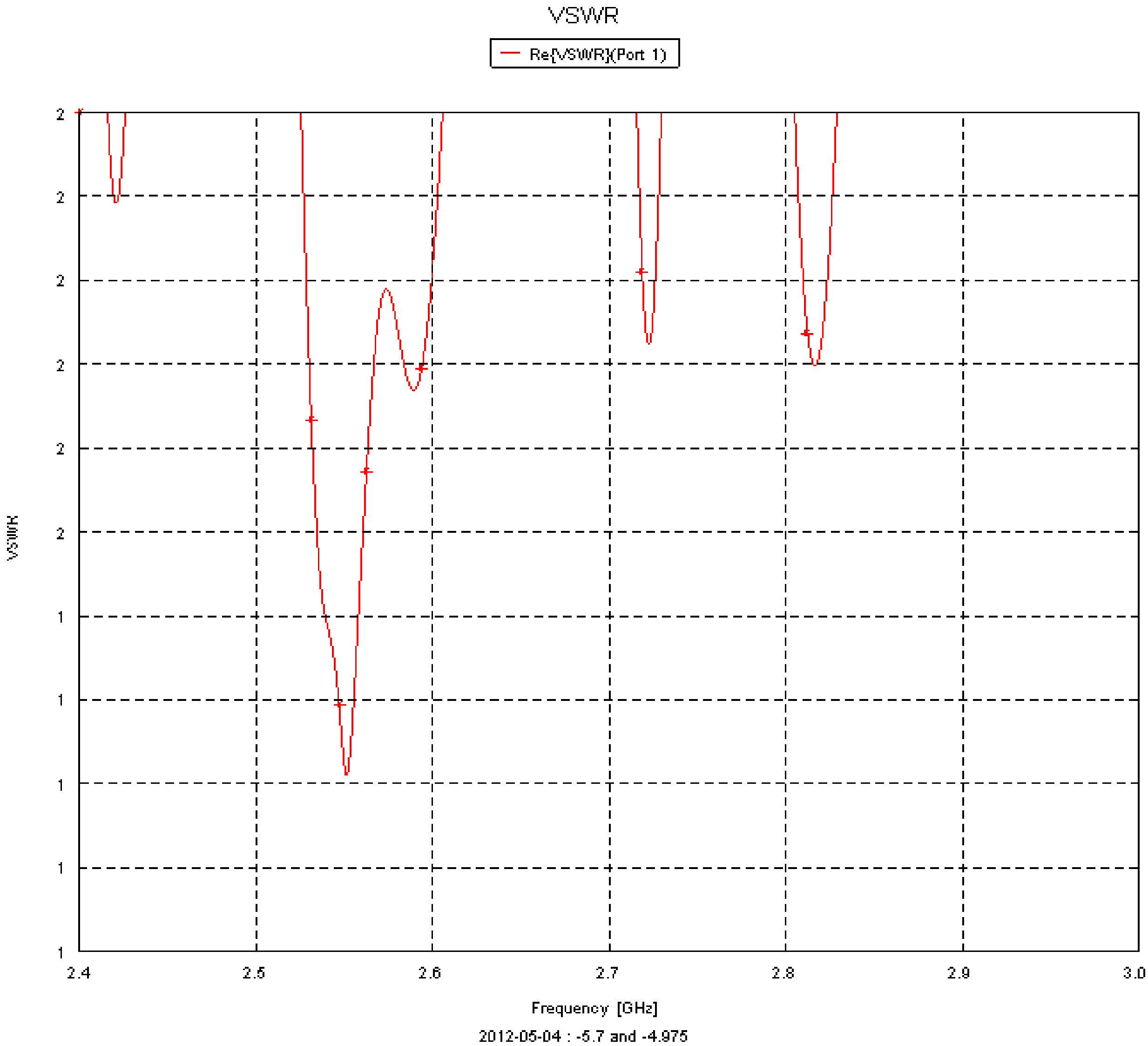
4.2.2 5%



Graph 4.2.2(a) Return loss for 5% of Barium ferrite substrate



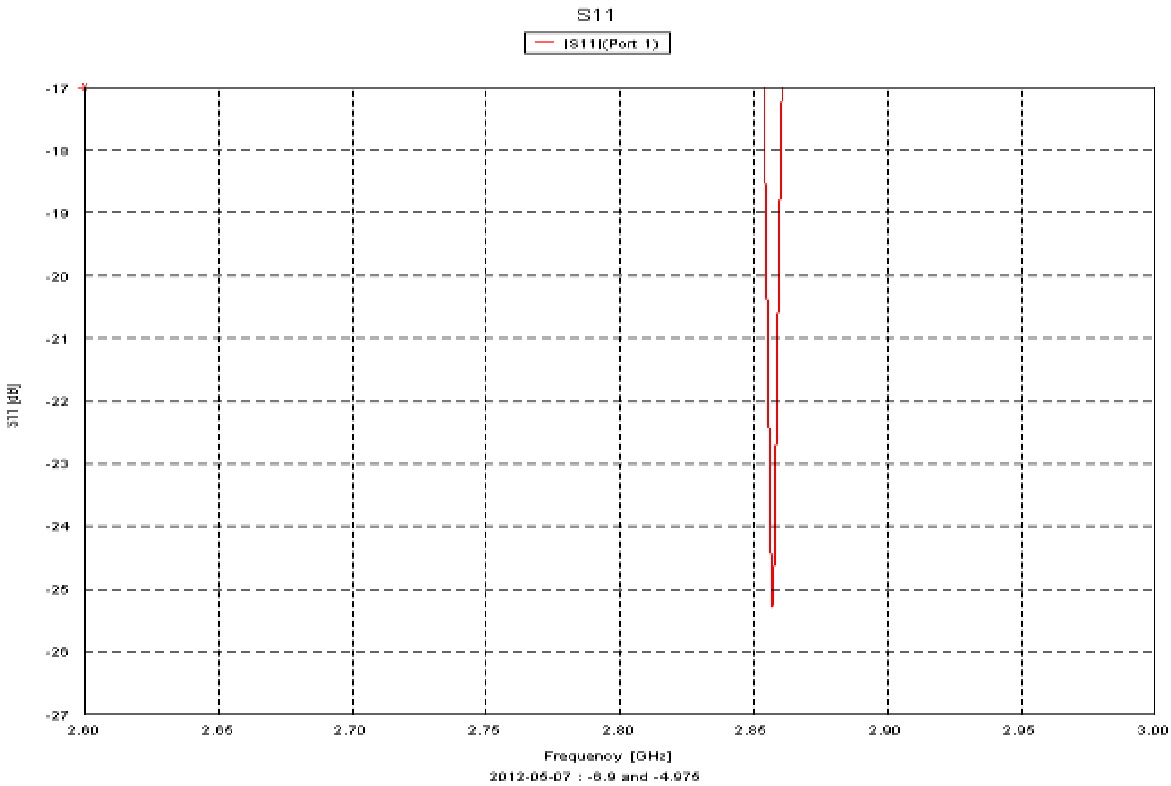
Graph 4.2.2(b) Impedance V/s Frequency for 5% of Barium ferrite substrate



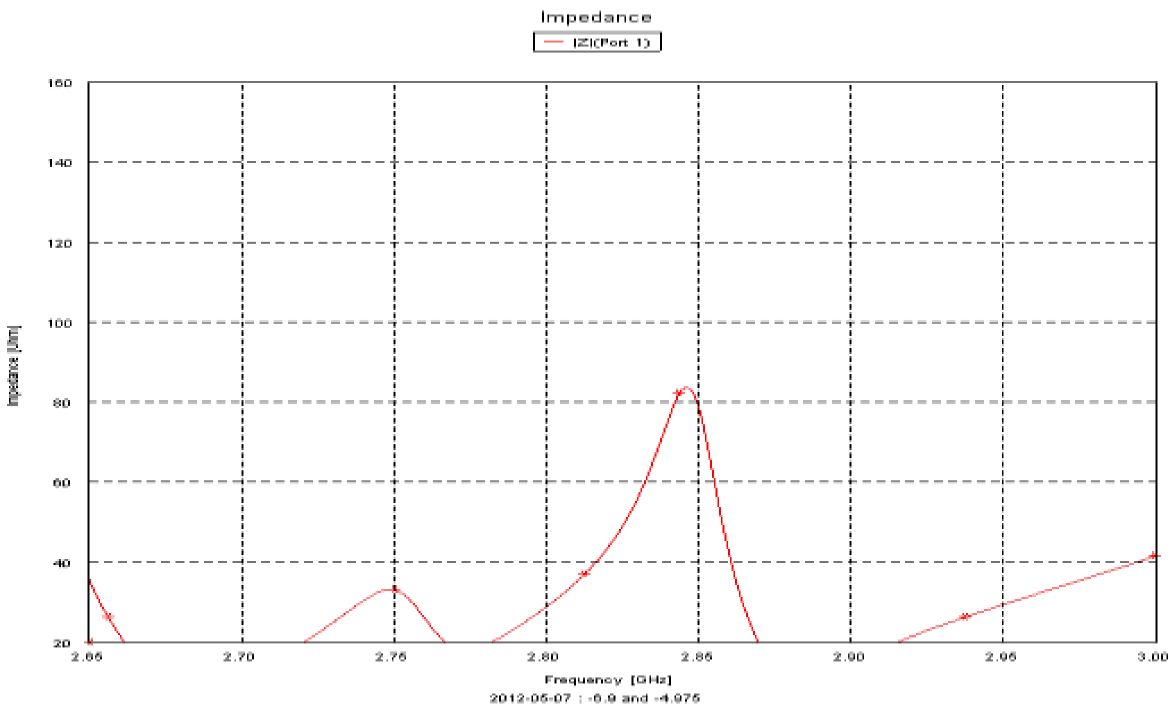
Graph 4.2.2(c) VSWR v/s Frequency (Impedance Bandwidth) for 5% Barium ferrite

From graph 4.2.2(a) we see the variation of S11 v/s frequency which will provide us with the return loss measurement, having a value of -31.2 dB, which is very close to the desired value of -30dB. Also, from graph 4.2.2(b) we see that it is a variation of impedance v/s frequency having a value of 88Ω .It can be observed the resulting bandwidth as shown in graph 4.2.1(c) consists of multiple resonating frequencies at f1=1.92GHz, f2=2.55GHz, f3=2.585GHz and f4=2.8184GHz with the corresponding VSWR values of 1.2, 1.42, 1.86 and 1.98 respectively. The total resulting impedance bandwidth is 89.05 MHz corresponding to 4.4525 % utilization.

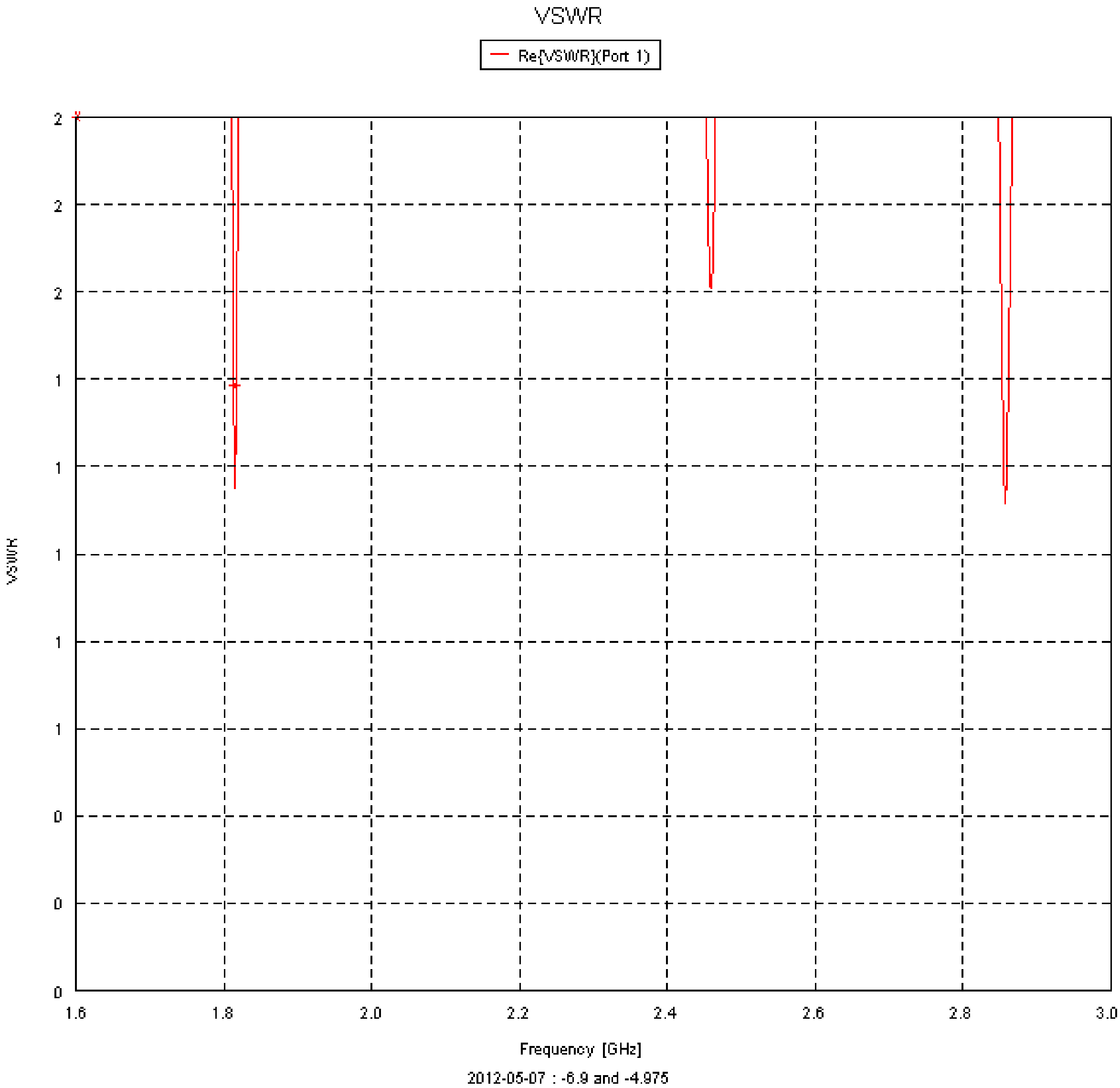
4.2.3 10%



Graph 4.2.3(a) Return loss for 10% Barium Ferrite



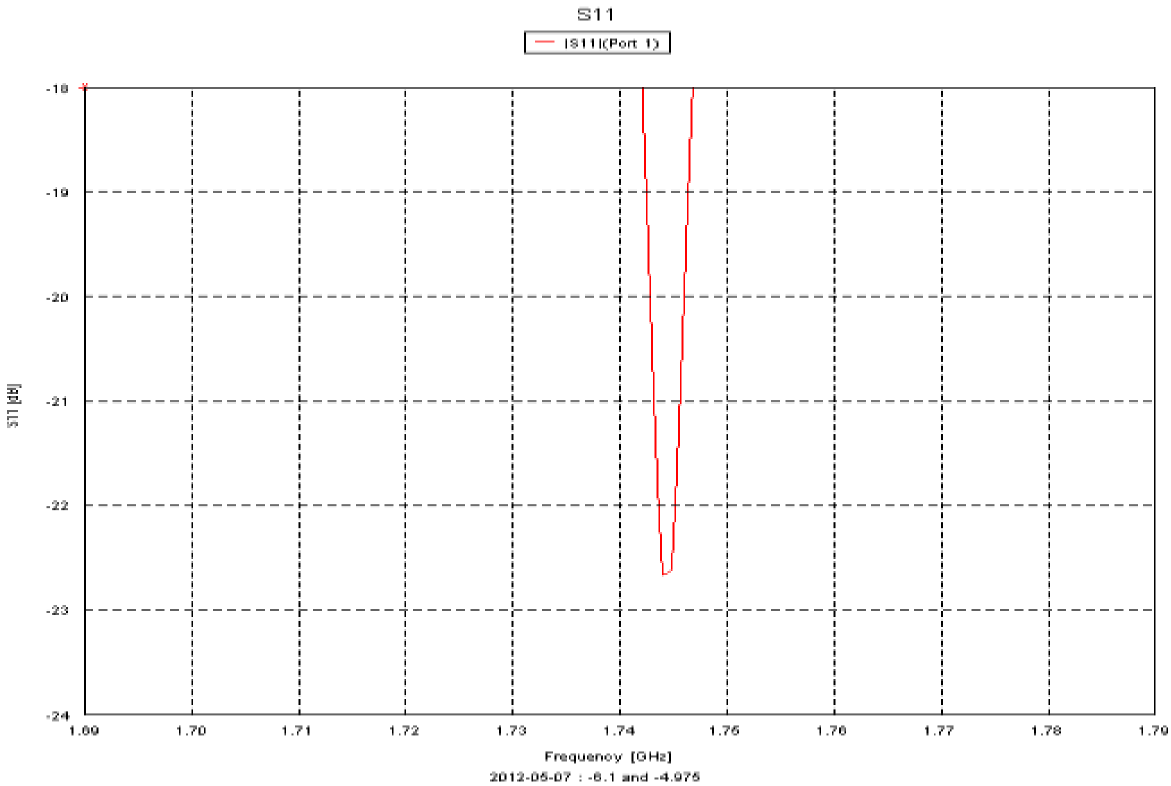
Graph 4.2.3(b) Impedance V/S Frequency for 15% Barium Ferrite



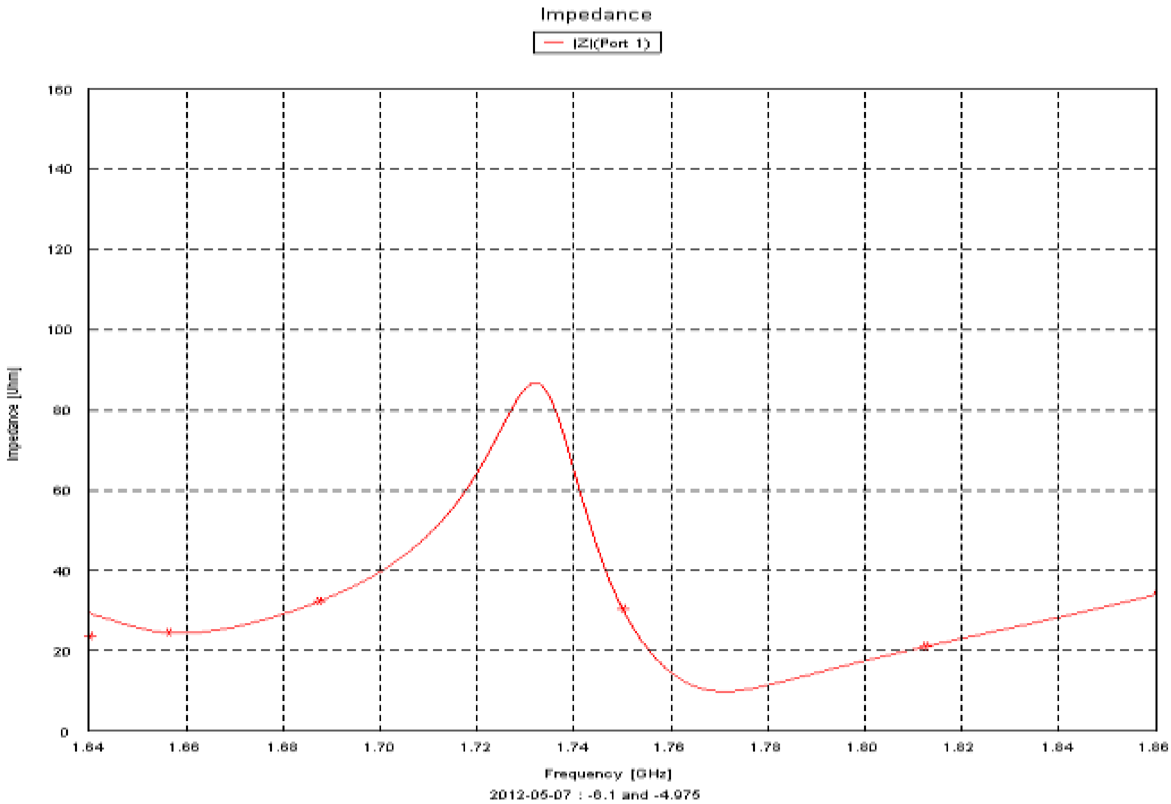
Graph 4.2.3(c) VSWR v/s Frequency (Impedance Bandwidth) for 10% Barium Ferrite

From graph 4.2.3(a) we see the variation of S11 v/s frequency which will provide us with the return loss measurement, having a value of -25.2 dB. Also, from graph 4.2.3(b) we see that it is a variation of impedance v/s frequency having a value of 83.57Ω .It can be observed the resulting bandwidth as shown in graph 4.2.3(c) consists of multiple resonating frequencies at f1=1.814GHz, f2=2.459GHz and f3=2.8569GHz,with the corresponding VSWR values of 1.152, 1.61 and 1.247 respectively. The total resulting impedance bandwidth is 38.1 MHz corresponding to 1.905 % utilization.

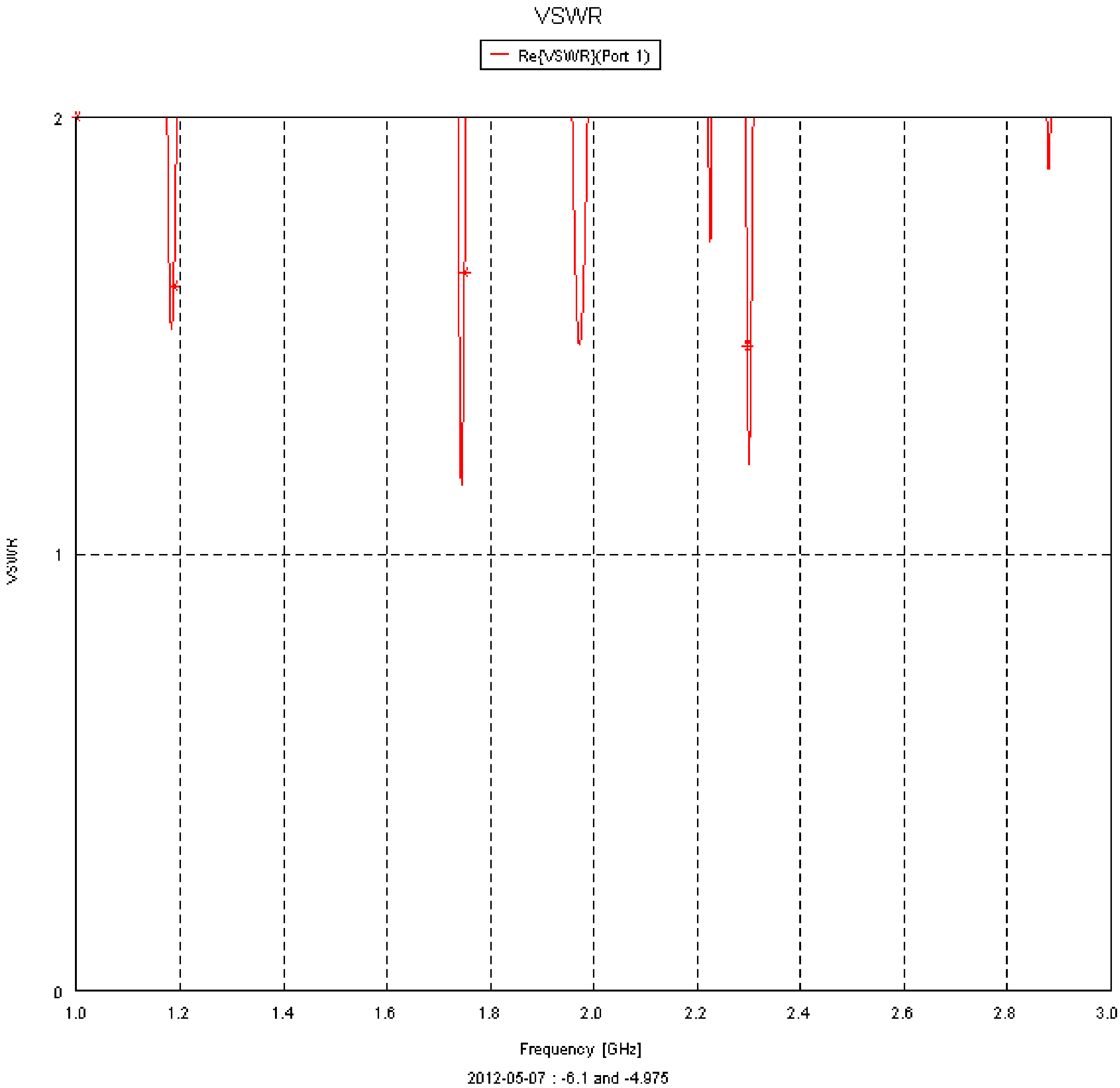
4.2.4 15%



Graph 4.2.4(a) Return loss for 15% Barium Ferrite



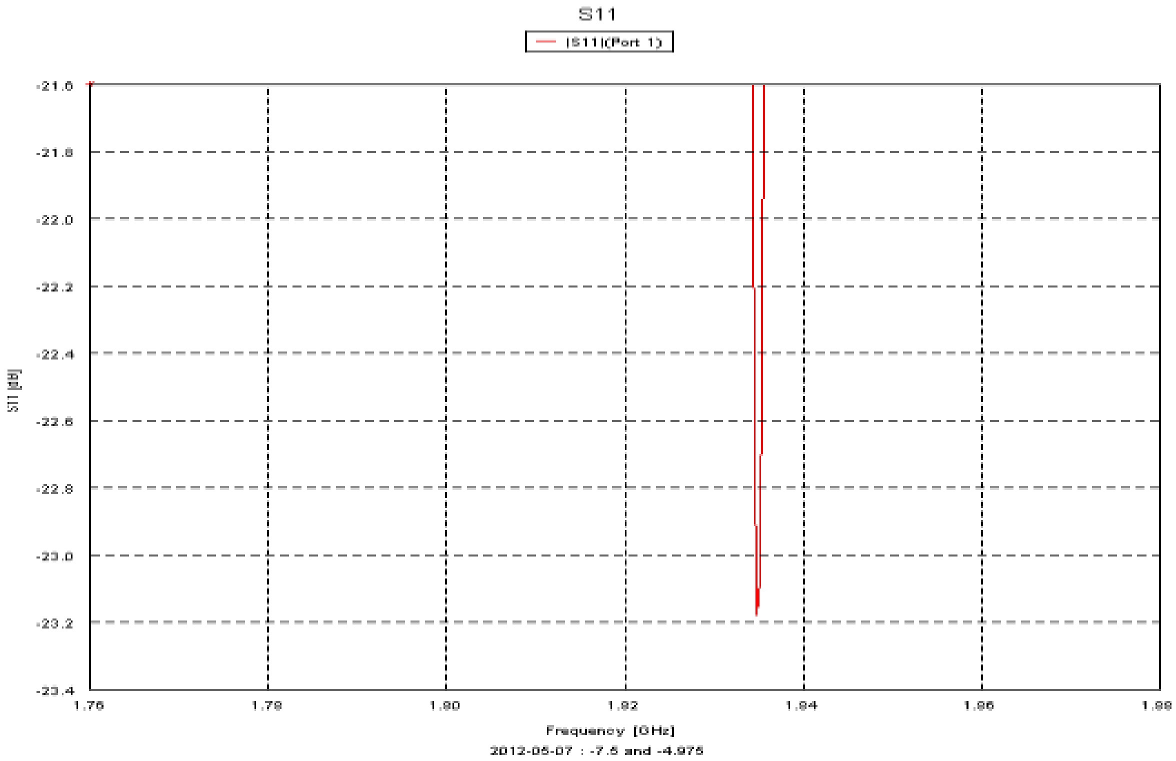
Graph 4.2.3(b) Impedance V/s Frequency for 15% Barium Ferrite



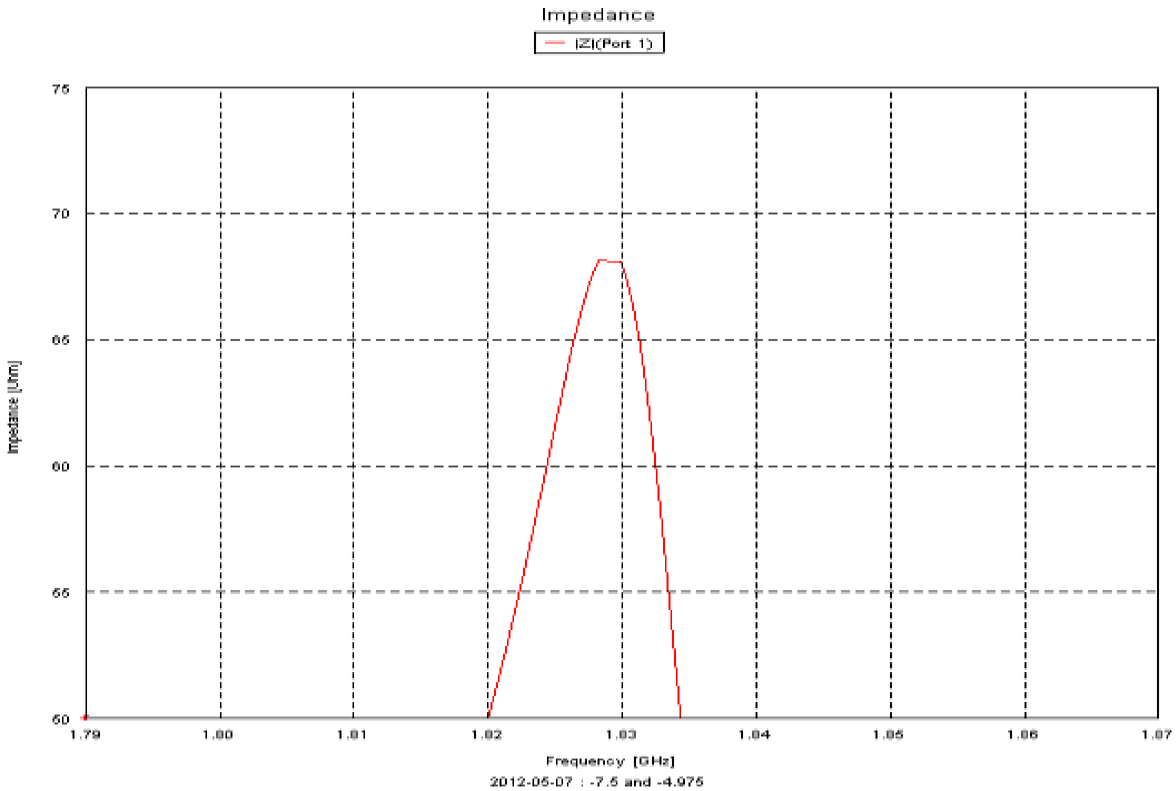
Graph 4.2.3(c) VSWR v/s Frequency (Impedance Bandwidth) for 15% Barium Ferrite

From graph 4.2.3(a) we see the variation of S11 v/s frequency which will provide us with the return loss measurement, having a value of -22.65 dB,. Also, from graph 4.2.3(b) we see that it is a variation of impedance v/s frequency having a value of 86.41Ω .It can be observed the resulting bandwidth as shown in graph 4.2.1(c) consists of multiple resonating frequencies at f1=1.1831GHz, f2=1.742GHz , f3=1.9723GHz, f4=2.2252GHz, f5=2.29GHz and f6=2.88GHz ,with the corresponding VSWR values of 1.514, 1.159,1.474,1.707,1.20 and 1.88 respectively. The total resulting impedance bandwidth is **128MHz** corresponding to **6.4 %** utilization.

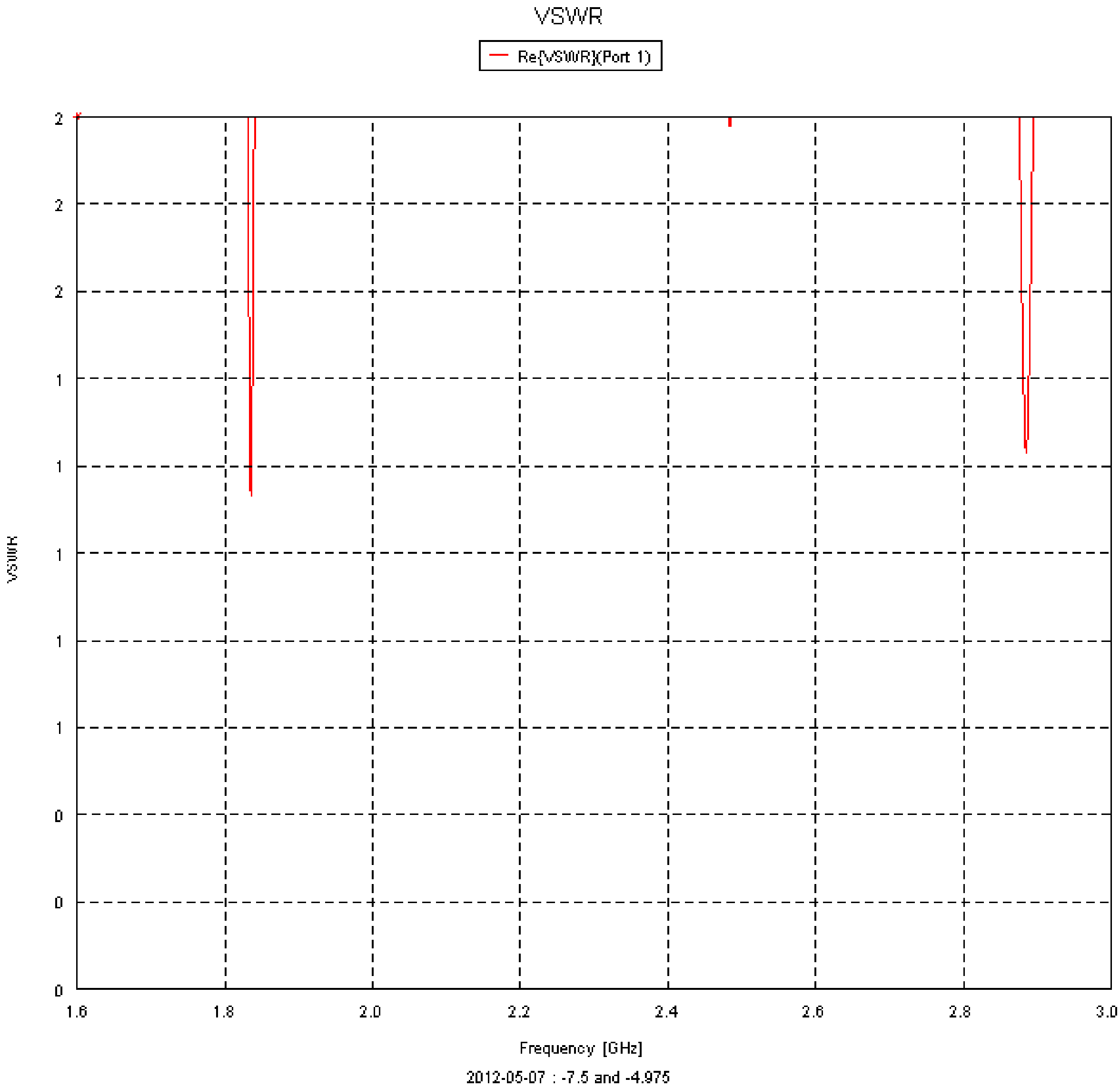
4.2.5 20%



Graph 4.2.5(a) Return loss for 20% Barium Ferrite



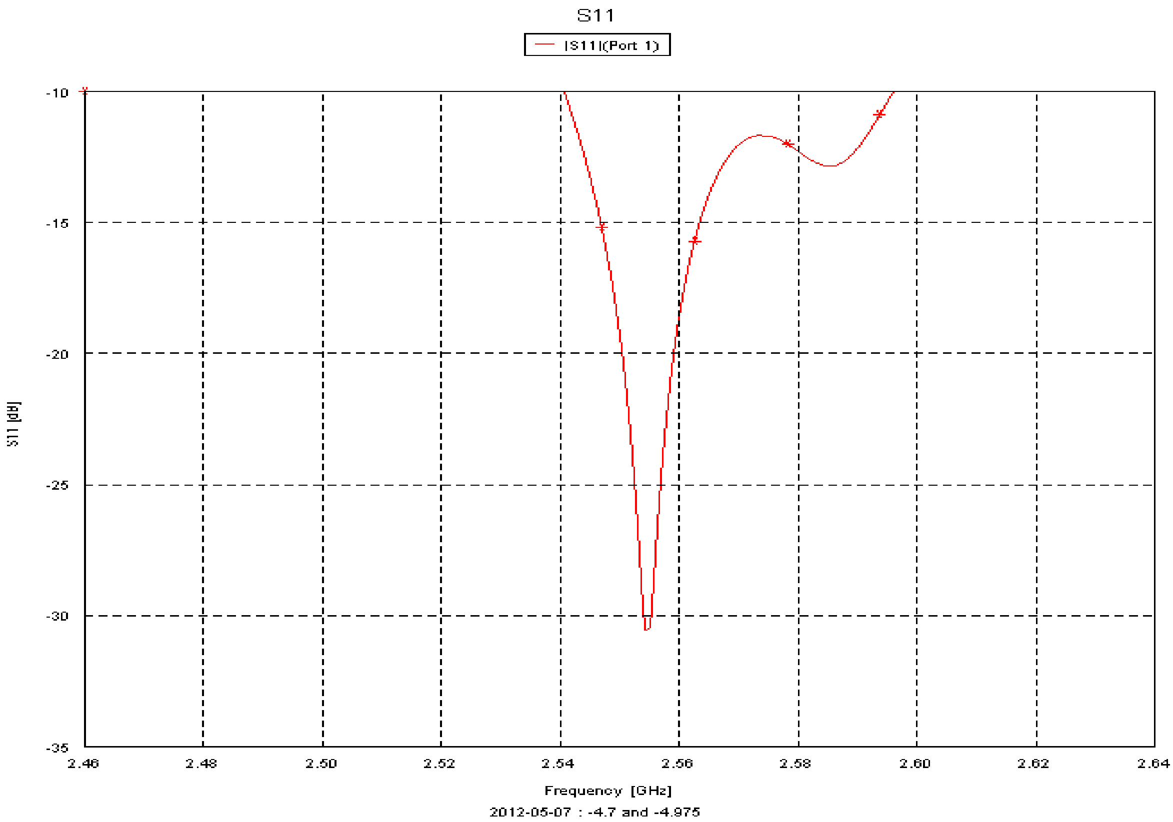
Graph 4.2.5(b) Impedance V/s Frequency for 20% Barium Ferrite



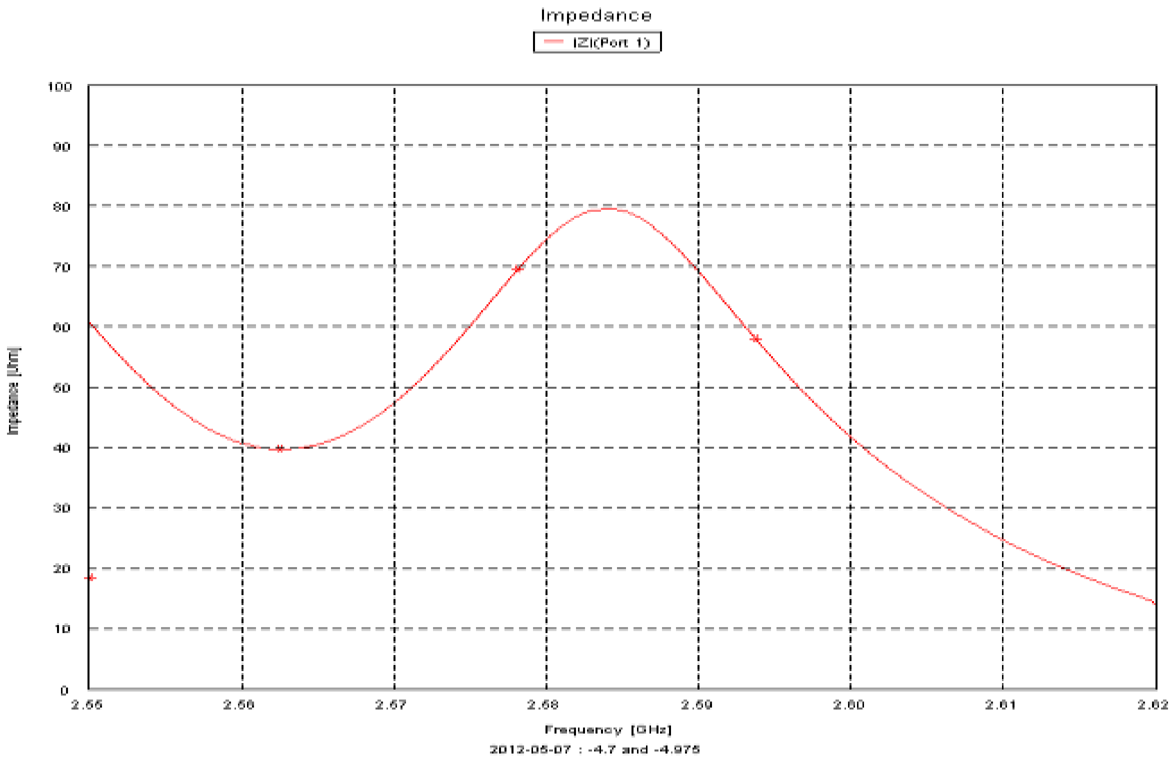
Graph 4.2.5(c) VSWR v/s Frequency (Impedance Bandwidth) for 20% Barium Ferrite

From graph 4.2.5(a) we see the variation of S11 v/s frequency which will provide us with the return loss measurement, having a value of -23.2 dB. Also, from graph 4.2.5(b) we see that it is a variation of impedance v/s frequency having a value of 68.25Ω .It can be observed the resulting bandwidth as shown in graph 4.2.5(c) consists of multiple resonating frequencies at f1=1.83GHz and f2=1.147Hz with the corresponding VSWR values of 1.474 and 1.538 respectively. The total resulting impedance bandwidth is 28.1MHz corresponding to 1.405% utilization.

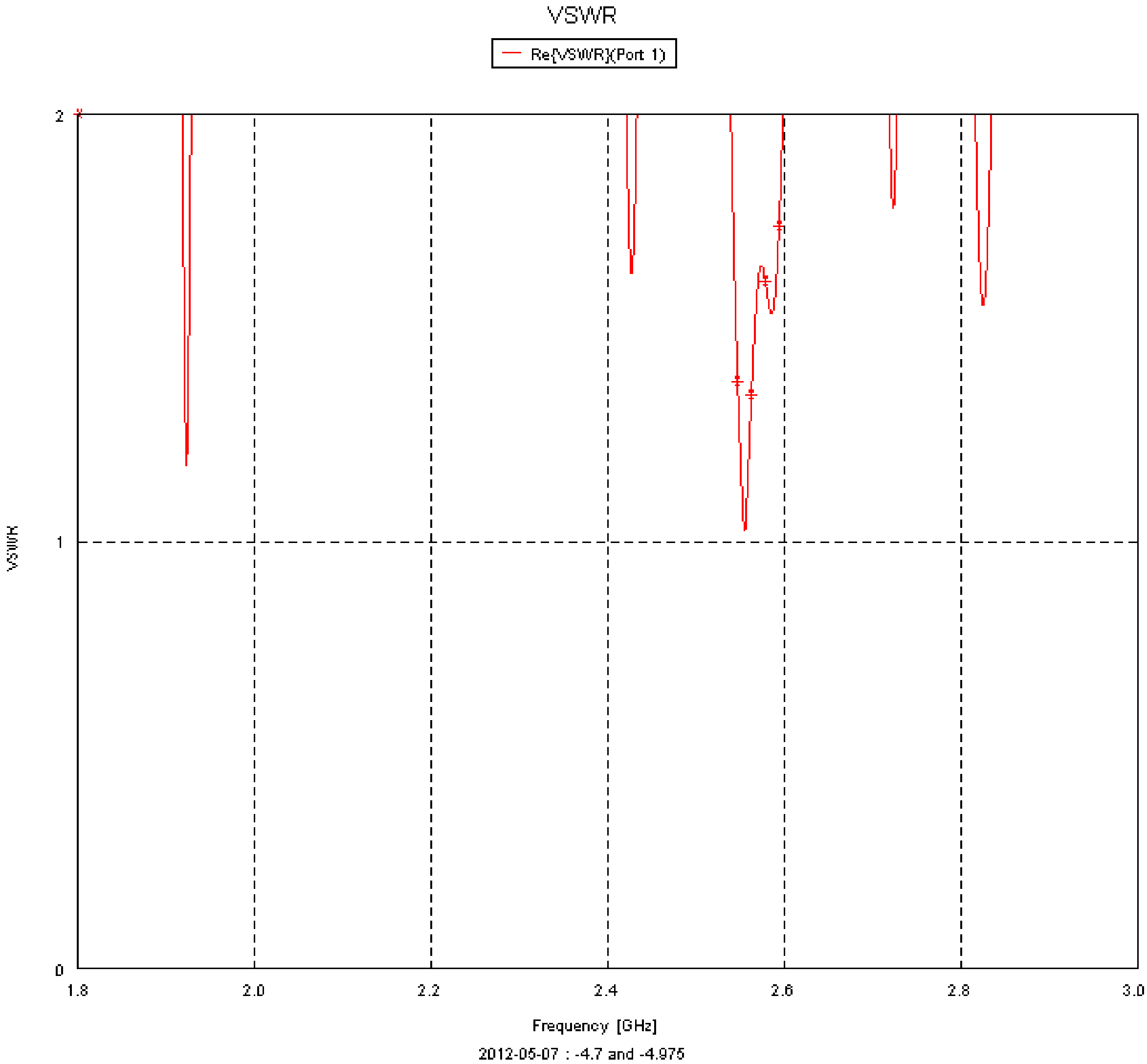
4.2.6 25%



Graph 4.2.6(a) Return loss for 25% Barium Ferrite



Graph 4.2.6(b) Impedance V/s Frequency for Barium Ferrite



Graph 4.2.6(c) Vswr V/s Frequency (Impedance Bandwidth) for 25% Barium Ferrite

From graph 4.2.6(a) we see the variation of S11 v/s frequency which will provide us with the return loss measurement, having a value of -30.3 dB, which is very close to the desired value of -30dB. Also, from graph 4.2.6(b) we see that it is a variation of impedance v/s frequency having a value of 79.45Ω .It can be observed the resulting bandwidth as shown in graph 4.2.6(c) consists of multiple resonating frequencies at f1=1.92GHz, f2=2.426Hz, f3=2.5544, f4=2.7232 and f5=2.8252GHz with the corresponding VSWR values of 1.22, 1.6873, 1.999,1.8455, and 1.605 respectively. The total resulting impedance bandwidth is 102.55MHz corresponding to 5.127% utilization.

4.2.7 TABLE OF SUMMARY

SAMPLES	ε_r	μ_r	Resonant Frequencies						Return Loss	Total BW (MHz)	BW(%)
			f1	f2	f3	f4	f5	f6			
pure(0%)	4.3648	0.9934	1.22	1.53	2.92	nil	nil	nil	-32.15	33.3	1.65
5%	4.2826	1.9287	2.55	2.59	1.92	2.8	nil	nil	-31.2	89.1	4.46
10%	4.3995	1.8776	1.81	2.47	2.86	nil	nil	nil	-25.2	38.1	1.91
15%	**4.8447**	**1.746**	**1.18**	**1.74**	**1.97**	**2.2**	**2.3**	**2.9**	**-22.65**	**128**	**6.42**
20%	4.3849	1.8581	1.83	2.88	nil	nil	nil	nil	-23.2	28.1	1.42
25%	4.3311	1.9405	1.92	2.43	2.55	2.7	2.8	nil	-30.3	102.55	5.13

Table 4.2 Resonant frequencies, Return loss, Total Bandwidth, and percentage bandwidth for different values of ε_r and μ_r of the samples

For a pure sample (**μ_r=1 and tanδ_μ=0)** , since the return loss is close to the desired value of -30dB and it has a good impedance matching, of 50Ω, the obtained bandwidth being 33MHz . For magnetic samples, with variations in their percentage concentrations have different values of **μ_r and tanδ_μ.** Changes in magnetic concentrations bring about changes in values of **μ_r, tanδ_μ, ε_r** and from the table it can be showed that the results show a varying trend which is sinusoidal. The maximum bandwidth however, was obtained for 15% concentration (**μ_r= 1.7476 and tanδ_μ= -0.588)** of the barium ferrite solution corresponding to 128Mhz and hence 6.42% bandwidth utilization, which is close to 3.89 times more than that of a pure sample .It also has multiple resonating peaks and hence, provides for a better bandwidth utilization. The sample readings have been obtained with respect to the return loss values, since a proper return loss value leads to better impedance matching and hence maximum bandwidth. It was observed that there is always a trade off between the return loss, impedance matching, with the bandwidth and thus, the feed point is located by a trial and error method by moving the feed line around the x-y axes ,with respect to one of the parameters under constraint. The parameter chosen here being return loss, is the most nearest value to -30dB that could be obtained. The other samples too show a large bandwidth, which is greater than the pure sample and also have multiple frequencies. The numbers of resonant frequencies are as high as 6 in case of the best bandwidth case, compared to pure sample, having only 3 resonating frequencies.

CHAPTER 5

CONCLUSION AND FUTURE SCOPE

CONCLUSION AND FUTURE SCOPE

5.1 CONCLUSION

The aim of this report was to design a rectangular antenna and study the effect of substrate's **μ** on the radiation properties.In most of the microstip antenna application, bandwidth is a major constraint for its usage. The bandwidth of the microstrip antenna depends on the size of the antenna.It is a very difficult task to achieve an impendance bandwidth of more than 7% for a single microstrip antenna using different concentrations of barium ferrite . The bandwidth is one of the thrust areas of research in small antennas. Many researchers have dedicated their effort to create new design or variations to the original antenna to increase the bandwidth or multiple frequency operation for simple, single microstrip elements.

In this investigation, we have shown that variation of substrate **μ** and magnetic loss factors $\tan\delta_\mu$ are going to play a prominent role in changing the bandwidth of microstrip antenna .Even though there are other disadvantages of introducing μ_r and $\tan\delta_\mu$ in the substrate but a huge improvement in the bandwidth is possible. Our simulation results indicate that proper selection of μ_r and $\tan\delta_\mu$ leads multiple frequency operations. This leads to increased bandwidth as well. In conclusion, present work indicates that μ_r and $\tan\delta_\mu$ are going to play a prominent role in increasing bandwidth as well as multi frequency operation for single element with minimum trade-off between the antenna properties.

5.2 SCOPE FOR FUTURE WORK

There is a lot of scope for future work in the present study. It is envisioned in the future that a precise rectangular antenna will be designed for a precise frequency of practical applications like cellular phone antennas having centre frequency of 3 GHz and to optimize full bandwidth. Future plan is also there for a systematic design and development of microstrip antenna with optimized values for practical, real time applications.

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