DESIGN OF MICROSTRIP PATCH ANTENNA

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ABSTRACT

With the constant changing of technology, frequency reconfigurable antennas are an important innovation to the RF world. The new device limits the physical space used by eliminating the need for multiple antennas. This is especially vital in mobile devices such as cell phones that receive multiple frequency bands like cellular tower reception, Wi-Fi, and GPS. The other alternative to frequency reconfigurable antennas is a wideband antenna; however, wideband antennas receive large frequency ranges introducing noise to the system. Frequency reconfigurable antennas narrow the bandwidth to specific frequencies, typically reducing the amount of noise for the signal. Wireless technology is one of the main areas of research in the world of communication systems today and a study of communication systems is incomplete without an understanding of the operation and fabrication of antennas. This was the main reason for our selecting a project focusing on this field.

Keywords: Wideband Antenna, Wifi, Gps, Wireless Technology, Bandwidth.

I INTRODUCTION

Our paper focuses on the hardware fabrication and software simulation of antenna. In order to completely understand the above it is necessary to start off by understanding various terms associated with antennas and the various types of antennas. This is what is covered in this introductory chapter.

1.1 Antenna parameters

An antenna is an electrical conductor or system of conductors Transmitter - Radiates electromagnetic energy into space Receiver - Collects electromagnetic energy from space The IEEE definition of an antenna as given by Stutzman and Thiele is, "That part of a transmitting or receiving system that is designed to radiate or receive electromagnetic waves". The major parameters associated with an antenna are defined in the following sections.

1.1.1 Antenna Gain

Gain is a measure of the ability of the antenna to direct the input power into radiation in particular direction and is measured at the peak radiation intensity. Consider the power density radiated by an isotropic antenna with input power P_0 at a distance R which is given by $S = P_0/4\pi R^2$. An isotropic antenna radiates equally in all directions, and its radiated power density S is found by dividing the radiated power by the area of the sphere $4\pi R^2$. An isotropic radiator is considered to be 100% efficient. The gain of an actual antenna increases the power density in the direction of the peak radiation:

Gain is achieved by directing the radiation away from other parts of the radiation sphere. In general, gain is defined as the gain-biased pattern of the antenna.

$$S(\theta,\phi) = \frac{P_0 G(\theta,\phi)}{4\pi R^2} \qquad \text{power density}$$

$$U(\theta,\phi) = \frac{P_0 G(\theta,\phi)}{4\pi} \qquad \text{radiation intensity}$$

1.1.2 Antenna Efficiency

The surface integral of the radiation intensity over the radiation sphere divided by the input power P_0 is a measure of the relative power radiated by the antenna, or the antenna efficiency.

$$\frac{P_r}{P_0} = \int_0^{2\pi}\int_0^{\pi} \frac{G(\theta,\phi)}{4\pi} \sin\theta \, d\theta \, d\phi = \eta_e \qquad \text{efficiency}$$

where *Pr* is the radiated power. Material losses in the antenna or reflected power due to poor impedance match reduce the radiated power.

1.1.3 Effective Area

Antennas capture power from passing waves and deliver some of it to the terminals. Given the power density of the incident wave and the effective area of the antenna, the power delivered to the terminals is the product.

$$P_d = S A_{\text{eff}}$$

For an aperture antenna such as a horn, parabolic reflector, or flat-plate array, effective area is physical area multiplied by aperture efficiency. In general, losses due to material, distribution, and mismatch reduce the ratio of the effective area to the physical area. Typical estimated aperture efficiency for a parabolic reflector is 55%. Even antennas with infinitesimal physical areas, such as dipoles, have effective areas because they remove power from passing waves.

1.1.4 Return Loss

It is a parameter which indicates the amount of power that is “lost” to the load and does not return as a reflection. Hence the RL is a parameter to indicate how well the matching between the transmitter and antenna has taken place. Simply put it is the S11 of an antenna. A graph of s11 of an antenna vs frequency is called its return loss curve. For optimum working such a graph must show a dip at the operating frequency and have a minimum dB value at this frequency.

1.1.5 Input Impedance

The input impedance of an antenna is defined as "the impedance presented by an antenna at its terminals or the ratio of the voltage to the current at the pair of terminals or the ratio of the appropriate components of the electric to magnetic fields at a point". Hence the impedance of the antenna can be written as given below.

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

where Z_{in} is the antenna impedance at the terminals

R_{in} is the antenna resistance at the terminals

X_{in} is the antenna reactance at the terminals

The imaginary part, X_{in} of the input impedance represents the power stored in the near field of the antenna. The resistive part, R_{in} of the input impedance consists of two components, the radiation resistance R_r and the loss resistance R_L. The power associated with the radiation resistance is the power actually radiated by the antenna, while the power dissipated in the loss resistance is lost as heat in the antenna itself due to dielectric or conducting losses.

1.1.6 Antenna Factor

The engineering community uses an antenna connected to a receiver such as a spectrum analyzer, a network analyzer, or an RF voltmeter to measure field strength E. Most of the time these devices have a load resistor ZL tha matches the antenna impedance.

We relate this to the antenna effective height:

$$\mathrm{AF} = \frac{E_i}{V_{\mathrm{rec}}} = \frac{2}{h}$$

AF has units meter^{-1} but is often given as dB(m^{-1}). Sometimes, antenna factor is referred to the open-circuit voltage. We assume that the antenna is aligned with the electric field; in other words, the antenna polarization is the electric field component measured.

$$AF = \sqrt{\frac{\eta}{Z_L A_{eff}}} = \frac{1}{\lambda}\sqrt{\frac{4\pi}{Z_L G}}$$

This measurement may be corrupted by a poor impedance match to the receiver and any cable loss between the antenna and receiver that reduces the voltage and reduces the calculated field strength.

II MICROSTRIP PATCH ANTENNA SCTRUCTURE

A microstrip patch antenna (MPA) consists of a conducting patch of any planar or non-planar geometry on one side of a dielectric substrate with a ground plane on other side. It is a popular printed resonant antenna for narrow-band microwave wireless links that require semi hemispherical coverage. Due to its planar configuration and ease of integration with microstrip technology, the microstrip patch antenna has been heavily studied and is often used as elements for an array. A large number of microstrip patch antennas have been studied to date. An exhaustive list of the geometries along with their salient features is available. The rectangular and circular patches are the basic and most commonly used microstrip antennas. These patches are used for the simplest and the most demanding applications. Rectangular geometries are separable in nature and their analysis is also simple. The circular patch antenna has the advantage of their radiation pattern being symmetric. A rectangular microstrip patch antenna in its simplest form is shown in Figure 1.1

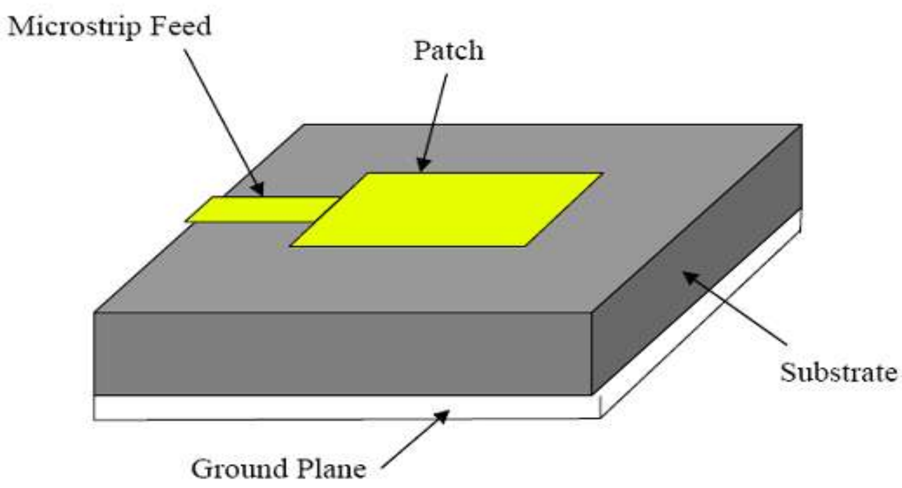

Figure 2.1 Structure of Microstrip patch antenna

The Microstrip 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.

2.1 Characteristics of Microstrip Patch Antenna

i) VSWR

VSWR stands for Voltage Standing Wave Ratio, and is also referred to as Standing Wave Ratio (SWR). VSWR is a function of the reflection coefficient, which describes the power reflected from the antenna. The VSWR is always a real and positive number for antennas. The smaller the VSWR is, the better the antenna matched to the transmission line and the more power is delivered to the antenna. The minimum VSWR is 1.0. In this case, no power is reflected from the antenna, which is ideal.

ii) Radiation Pattern

The patch's radiation at the fringing fields results in a certain far field radiation pattern. This radiation pattern shows that the antenna radiates more power in a certain direction than another direction. The antenna is said to have certain directivity. This is commonly expressed in dB. An estimation of the expected directivity of a patch can be derived with ease. The fringing fields at the radiating edges can be viewed as two radiating slots placed above a ground plane. Assuming all radiation occurs in one half of the hemisphere, this results in 3 dB directivity. This case is often described as a perfect front to back ratio.

iii) Gain

Gain is a measure of the ability of the antenna to direct the input power into radiation in particular direction and is measured at the peak radiation intensity.An isotropic radiator is considered to be 100% efficient. The gain of an actual antenna increases the power density in the direction of the peak radiation.

iv) Input Impedence

The input impedance of an antenna is defined as “the impedance presented by an antenna at its terminals or the ratio of the voltage to the current at the pair of terminals or the ratio of the appropriate components of the electric to magnetic fields at a point”. Hence the impedance of the antenna can be written as given below.

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X_{in} is the antenna reactance at the terminals

2.2 Shapes of Patch

In order to simplify analysis and performance prediction, the patch is generally square, rectangular, circular, triangular, elliptical or some other common shape as shown in Figure 2. For a rectangular patch, the length L of the patch is usually $0.3333\lambda_o < L < 0.5\lambda_o$, where λ_o 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 (ε_r) is typically in the range $2.2 \leq \varepsilon_r \leq 12$.

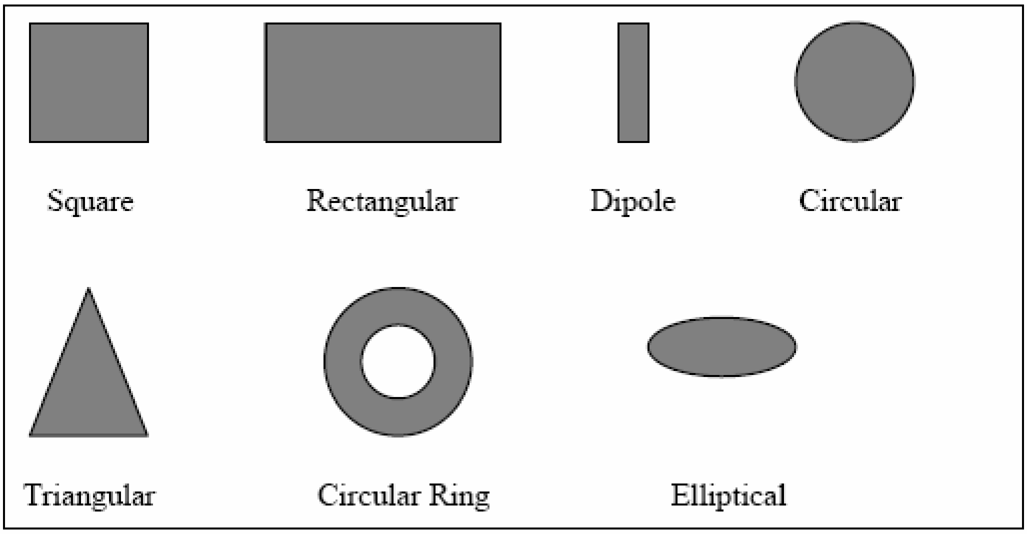


Figure -2.2 – Typical patch shapes

A patch radiates from fringing fields around its edges. The situation is shown in figure 3.3. Impedance match occurs when a patch resonates as a resonant cavity. When matched, the antenna achieves peak efficiency. A normal transmission line radiates little power because the fringing fields are matched by nearby counteracting fields. Power radiates from open circuits and from discontinuities such as corners, but the amount depends on the radiation conductance load to the line relative to the patches. Without proper matching, little power radiates. The edges of a patch appear as slots whose excitations depend on the internal fields of the cavity. A general analysis of an arbitrarily shaped patch considers the patch to be a resonant cavity with metal (electric) walls of the patch and the ground plane and magnetic or impedance walls around the edges.

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, higher dielectric constants must be used which are less efficient and result in narrower bandwidth. Hence a compromise must be reached between antenna dimensions and antenna performance.

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)

. 2.4.1 Microstrip Coaxial Feed

In this type of feed technique, a conducting strip is connected directly to the edge of the microstrip patch as shown in Figure 3.2. 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.

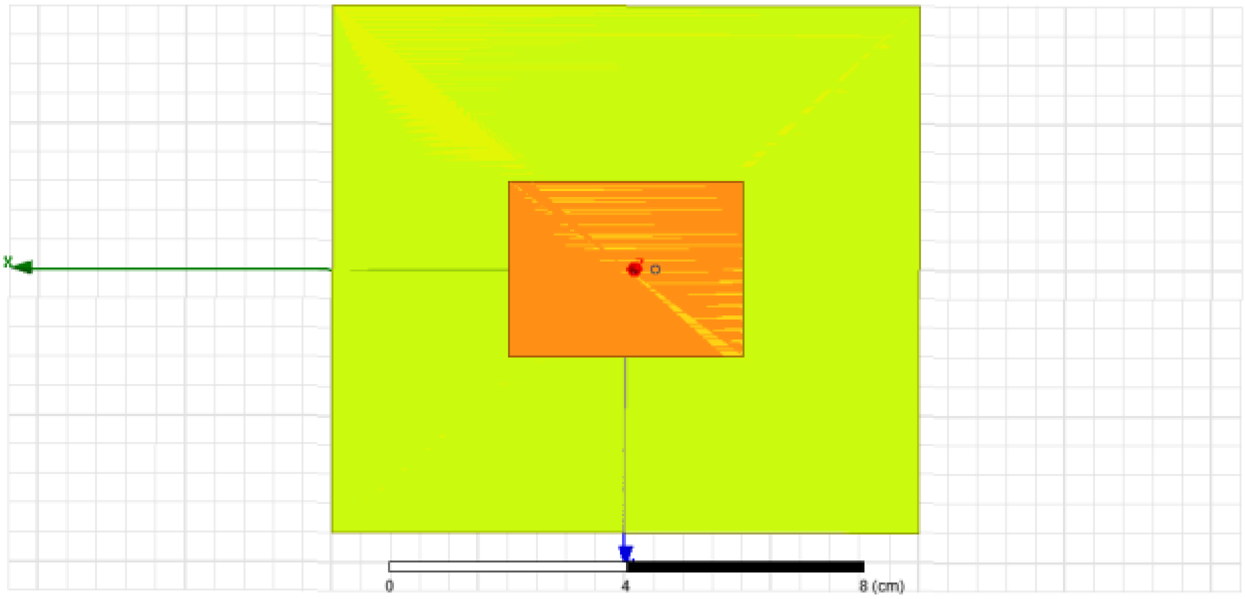


Figure:2.3 Microstrip patch: Top view

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.

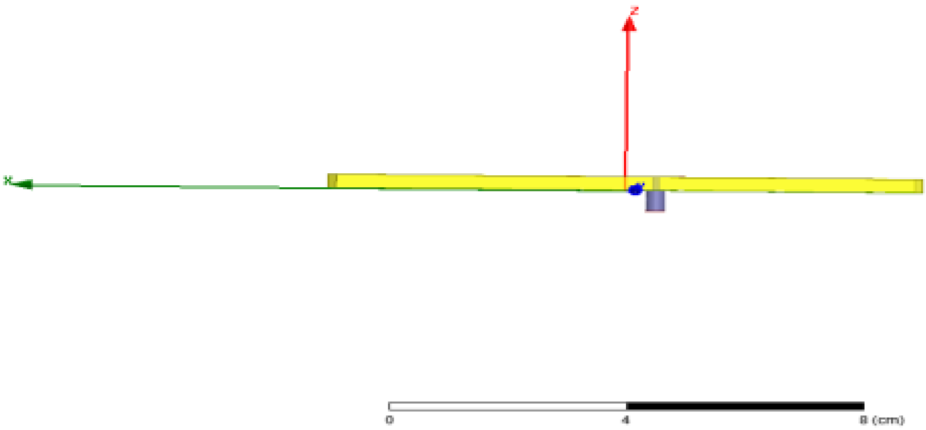


Figure:3.4 Microstrip patch: Lateral view

2.5 Applications of Microstrip Patch Antennas

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 microstrip patch antennas. Another area where they have been used successfully is in satellite communication.

2.6 Advantages and Disadvantages of Patch Antennas

Some of their principal advantages of microstrip patch antennas 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 a number of disadvantages as compared to conventional antennas. Some of their major disadvantages are given below:

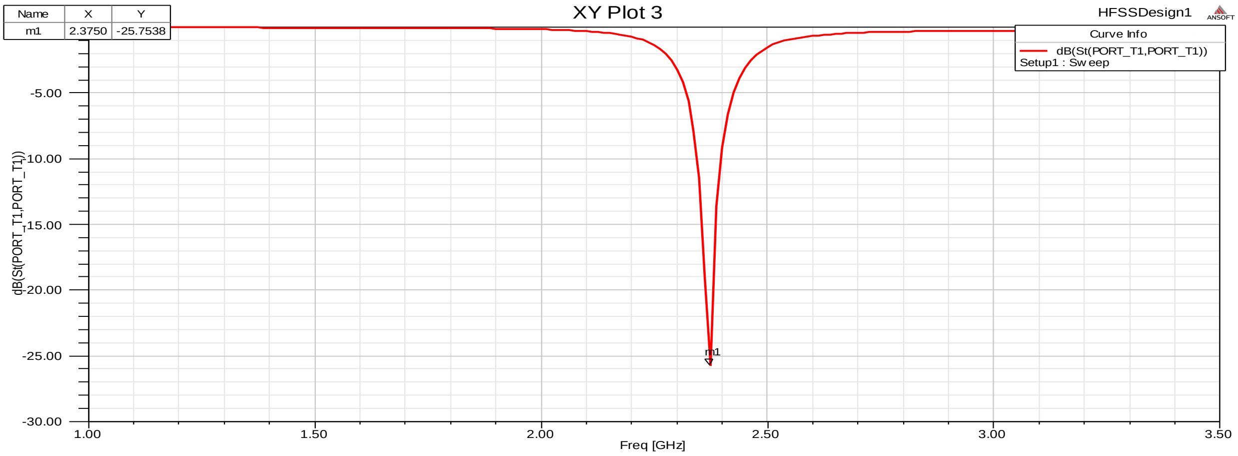
- Narrow bandwidth
- Low efficiency
- Low Gain
- Extraneous radiation from feeds and junctions
- Poor end fire radiator except tapered slot antennas
- Low power handling capacity.
- Surface wave excitation

Microstrip patch antennas have a very high antenna quality factor (Q). Q represents the losses associated with the antenna and 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. However, surface waves can be minimized by use of photonic bandgap structure. Other problems such as low gain and low power handling capacity.

III SIMULATION OF MICROSTRIP PATCH ANTENNA

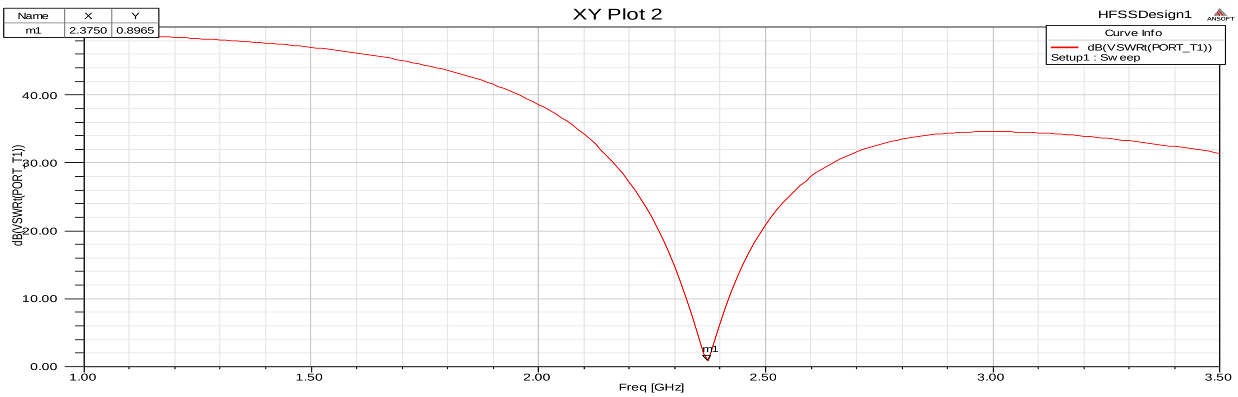
3.1 Simulation

3.1.1 Return Loss Graph I



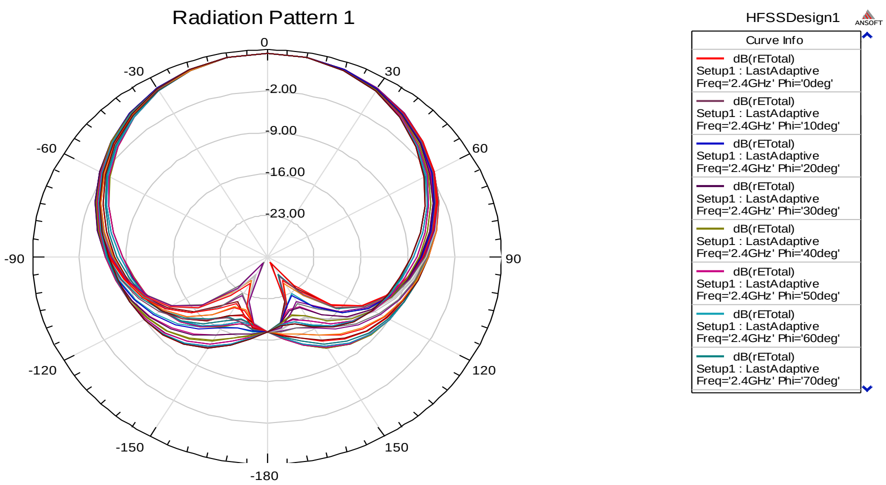
3.1 Figure:Return loss graph I

3.1.2 Return Loss Graph II



3.2 Figure:Return loss graph II

3.1.3 Radiation Pattern



3.3 Figure:Radiation Pattern

3.1.4 3-D POLAR PLOT

3.4 Figure: 3-D POLAR PLOT

IV CONCLUSION AND RESULT

Testing with MEMS switches will follow, but at the moment the antenna system behaves almost as intended beyond the resonant frequency locations. However, a larger bandwidth could have fixed these problems. This could be done with a thicker substrate or lower dielectric constant.Determining the cause of the change in resonant frequency will come with later testing.

4.1 Recommendations

The design behind the reconfigurable patch antenna has many possibilities for future work. First off, circular polarization can be added by truncated corners, slots, etc. It was dropped from the project due to time constraints and complexity it presented. Some preliminary work was done to show it was feasible, but the goal was to produce a working frequency reconfigurable antenna by the end of the semester. In addition, a single stub or double stub impedance matching network could be used instead of inset feed matching. While not entirely necessary, at different application frequencies these impedance matching networks will give more accurate matching for each resonant frequency. The downfall of these matching networks compared to inset feed matching is the complexity and physical size added into the project. For final fabrication and design of the patch antenna, due to variances between simulations and tests, it is suggested that multiple designs are made of the antenna. For these designs some patches should be made to resonant slightly higher than desired, some at desired, and some below desired during simulations. These, when fabricated, will help determine the final dimensions to be used for final product fabrication and thus will help eliminate any variances, like the ~60Mhz differences we noticed.

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