Design and Analysis of a Pattern Reconfigurable Antenna for Wi-Fi Base Station

By

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Declaration

This is to certify that the project work entitled "*Design and Analysis of a Pattern Reconfigurable Antenna for Wi-Fi Base Station*" has been carried out by *Md Nazmul Islam* in the Department of *Electronics and Communication Engineering*, Khulna University of Engineering & Technology, Khulna, Bangladesh. The above project work or any part of this work has not been submitted anywhere for the award of any degree or diploma.

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Approval

This is to certify that the project work submitted by *Md Nazmul Islam* entitled *"Design and Analysis of a Pattern Reconfigurable Antenna for Wi-Fi Base Station"* has been approved by the board of examiners for the partial fulfillment of the requirements for the degree of *Master of Science in Engineering* in the Department of *Electronics and Communication Engineering*, Khulna University of Engineering & Technology, Khulna, Bangladesh in November, 2018.

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Abstract

A unique concept for design of a pattern reconfigurable antenna and its simulation using CST-MW simulator is presented in this research. The proposed design is a special type of patch antenna and capable to make coverage at two directions without changing any common properties of a typical antenna. This antenna is able to reconfigure the beam pattern automatically, by using a pair of waveguide port without using any type of switching mechanism. The proposed antenna is able to switch the radiation beam from one direction to its 180^0 reverse angle without changing its operating frequency that is 2.4 GHz. Besides, Wi-Fi technology is the most popular and widely accepted WLAN (wireless local area network) that operated at 2.4 GHz. So, this proposed antenna may have been easily adopted by Wi-Fi (wireless fidelity) technology. This antenna provides wider bandwidth that is 455 MHz. This enormous bandwidth makes the speed of data flow at higher rate along the WLAN, that's the more advantageous for designing a base station. The CST simulator carried out the simulated result of return loss is -24.5 dB that is acceptable for telecommunication transmitter or receiver. It covers the region of 48^0 to 131^0 and 228^0 to 312^0 in azimuth plane. The footprint of the radiation beam pattern is 82^0 (3dB points) for both ports. The beam of the antenna focuses at these directions with directivity of 1.8 dBi. The simulated VSWR (voltage standing wave ratio) value of antenna is 1.12 for both ports that can be chosen able for wireless communication technology. It's compactness in size and fabrication simplicity are the attracting features for the base station designer. Thus, this proposed antenna can be easily embedded in Wi-Fi system.

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Nomenclature

RL	Return Loss
Γ	Reflection Coefficient
ε_M	Beam efficiency
Z_A	Input impedance
A_{eff}	Effective Area
T_A	Antenna Temperature
ε_r	Dielectric constant of substrate
ε_{reff}	Effective dielectric constant

CHAPTER I

Introduction

CHAPTER I

Introduction

1.1 Background

The present world may be thought as a sculpture of communication network. And the communication is more familiar and attractive to people after development of the wireless communication technology. The wireless technology now grows up day by day. Antenna is the significant and functional part of the wireless system. An antenna, called reconfigurable antenna, is able to changes operating frequency or radiation pattern dynamically, that is better than using antenna array or multiband antenna technology doing the same job. Therefore, the wireless systems are using reconfigurable antennas now and these antennas play an important role for the wireless applications. The idea of reconfiguring an antenna is relatively old. In the early 1930, the nulls of a two element array were steered by using a calibrated variable phase changer in order to determine the direction of arrival of a signal. In 1979, the re-configurability defined as "the ability to adjust the beam shapes upon command". The authors used a six-beam antenna to dynamically change the coverage area for a communication satellite. Another papers reported other reconfigurable space-based arrays [1]. In the 1990s, a research group in England described their efforts, to alter the reflecting surface of the parabolic-reflector antenna in order to control the radiation pattern. From the mid-1990s until the present, reconfigurable antenna project has mostly involved microstrip antenna, and various semiconductors technology applied to altering the current flow in the microstrip antenna [2].

1.2 Problem Statement

The present world is developed day by day in field of wireless technology. Wi-Fi (wireless fidelity) is the one of the most wireless technology that has great contribution to familiar wireless communication and network. The transmission characteristics are the major factor that reliable to transfer information on a network of wireless media. Antenna is the main and significant part of a transmission station. For a developed and secure communication, it is important to use a modern and technologically high profiled antenna.

Another burning issues like limited channel bandwidth, interference and restricted coverage range are arising proportionally

increase with the continuous growth of wireless communication system. The best solution is direct the radiation on desired direction. The pattern reconfigurable antenna is such type of antenna, where one antenna is able to make coverage in several directions without changes any common parameter of antenna. For the application in communication field, the reconfigurable antenna has achieved significant attention, in recent year. Specially, to demonstrate electronic tunability for different antenna structures, preliminary studies have been carried out [3][4][5]. An antenna can be reconfigured in three dimension, for instances-frequency reconfiguration, polarization reconfiguration and pattern reconfiguration. The method of reconfiguring the pattern has been chosen to design this proposed antenna. The operating frequency of the antenna can be reconfigured by electronically tuned whereas the structure is made by a single-fed resonant slot loaded with a series of PIN diode [6]. By using switchable v-slot frequency of an antenna may also have reconfigured where an on-off switch is used to changes frequency between low magnitude and high magnitude [7]. Another method is proposed for reconfiguring frequency where a monopole antenna and an inverted F-antenna are combine embedded in the same place [8]. Another option to reconfigure the antenna is polarization reconfiguration. This type of reconfiguration is implemented by using cross slots switching between circular and linear polarization [9]. Some described methods are uses several type of manual switching system that is complex in fabrication and more switched are made by PIN diode, where the diode may be destroyed. Some methods use slotting technology which is hard for implementation. Both are the harmful for reliable and smooth communication. Last but not the least solution is the configuring the pattern. One example of pattern reconfiguration is provided in [10], where used RF-Micro Electro Mechanical System (MEMS) switches to switch the pattern one direction to another direction. Another method is proposed to reconfigure the pattern is implemented based on a two element dipole array model [11]. Array technology also used in [12] for reconfigure pattern, where one active element and two parasitic elements are combine placed. In [13], a dipole array is used to reconfigure the angular diversity as quad corner reflector array at 2.4 GHz which motivates the research. But using antenna array is complex to fabrication and ambiguous. To avoid this type of constraint another concept is provided where a design of a beam-sweeping antenna using a new active frequency selective surface (FSS) is implemented [14]. This technology also used PIN diode for its on-off characteristics, so it’s an electronically switching based technology. But this paper demonstrated, without using any type of complex hardware the radiation pattern of the proposed antenna is radiates energy at two opposite directions. This proposed antenna is a type of radio antenna that is a single patch and can be attached on a flat surface. This antenna is able to reconfigure the radiation pattern at bidirectional that 180^0 reverse from each another. In switching method diode may destroyed also switch may fuse. The proposed designation avoided swathing to control beam pattern for drawback of switching technology. This two ported patch antenna is suitable for Wi-Fi system for its operating frequency and enhanced bandwidth. The voltage standing wave ratio(VSWR) is small that is expected for wireless communication, it may increase the antenna's demand showed in [15] which proposed a reconfigurable antenna. Furthermore, the proposed antenna has many attractive advantages, i.e. fabrication simplicity, wideband, low cost, low profile and light weight.

1.3 Objectives of the Project

The major objectives of this research work are as follows:

- To design and analyze performance of a pattern reconfigurable antenna
- To enhance the performance over the conventional methods of reconfiguring the pattern.
- The results obtained from this reconfiguration process will be compared to other pattern reconfigurable antenna under different conditions.
- To analyze the result of proposed design of special type of patch antenna, that is able to make coverage in two directions by using a pair of waveguide port without using any type of switching technology.

1.4 Scopes of the Project

This work has following scopes:

- The proposed antenna will able to make coverage in two directions by using a pair of waveguide ports without using any type of switching technology. Therefore, it's may use as bidirectional antenna.
- There is no appreciable change will occur in operating frequency due to the use of two waveguide ports, so it may have implemented easily.
- It is also showed that there will have no need to use any type of switching element in this designation.

- This research demonstrates the proposed antenna will provide wider band that may increase the speed of network.
- This antenna's operating frequency is 2.4 GHz that is perfect for Wi-Fi system.
- This antenna will provide high directivity and preferable gain for Wi-Fi technologies.

1.5 Outline of the Research

This report has 6 memoranda; They are summarized below:

- In CHAPTER I, it describes the introduction of the project work. It also describes the background and problem statement of the research. The objectives and scopes of the thesis are discussed here.

- In CHAPTER II, it says antenna definition and reconfigurable antenna, need for using reconfigurable antenna, types of reconfigurable antenna, wireless standards and applications and signal to noise ratio for Wi-Fi application. It also demonstrates microstrip patch antenna, general structure of patch antenna, dielectric substrate, feeding methods, transmission line model and Cavity model.

- In CHAPTER III, it describes designer software, design specifications, design procedure and modeling in CST studio.

- In CHAPTER IV, it presents the simulation process by using CST simulator, different type of tools and parametric sweep methods.

- In CHAPTER V, it says about simulated result analysis, s-parameter, VSWR (voltage standing wave ratio), efficiency and radiation pattern analysis

- In CHAPTER VI, it describes the comparisons between proposed antenna and others, conclusions and the future scope of this proposed design.

CHAPTER II

Reconfigurable Patch Antenna

CHAPTER II

Reconfigurable Patch Antenna

2.1 Antenna

An antenna can be defined as an electrical conductor or system of conductors used either for radiating electromagnetic energy into space or for collecting electromagnetic energy from space [16]. In other word, An antenna (or aerial) is an electrical device which converts electric power into radio waves, and vice versa[17]. The antenna is also referred to as aerial. Antenna is a device which converts an electric wave guided by a conductor into free space, unguided electromagnetic wave and vice versa. The IEEE Standard Definitions of terms for Antennas defines the antenna as “a means for radiating or receiving radio waves.” In other words, the antenna is the transitional structure between free space and a guiding device. Combining all these definitions, we can extract an excellent definition of antenna as “a metallic (usually) device used for radiating or receiving electromagnetic waves which acts as the transition region between free spaces and guiding structure like a transmission line in order to communicate even in a longer distance”. Antennas are essential components of all equipment that uses radio. They are used in systems such as radio broadcasting, broadcast television, two-way radio, communications receivers, radar, cell phones, and satellite communications, as well as other devices such as garage door openers, wireless microphones, Bluetooth-enabled devices, wireless computer networks, baby monitors, and RFID tags on merchandise. Typically, an antenna consists of an arrangement of metallic conductors (elements), electrically connected (often through a transmission line) to the receiver or transmitter. An oscillating current of electrons forced through the antenna by a transmitter will create an oscillating magnetic field around the antenna elements, while the charge of the electrons also creates an oscillating electric field along the elements. These time-varying fields radiate away from the antenna into space as a moving transverse electromagnetic field wave. Conversely, during reception, the oscillating electric and magnetic fields of an incoming radio wave exert force on the electrons in the antenna elements, causing them to move back and forth, creating oscillating currents in the antenna.

2.2 Reconfigurable Antenna

Antennas are a necessary and critical component of all personal electronic devices, Microwave and satellite communication systems, radar systems and military surveillance and reconnaissance platforms. In many of these systems, there is a requirement to perform a multitude of functions across several frequency bands and operating bandwidths. In most cases, these requirements cannot be served by a single antenna but rather require the use of multiple antennas of varying form-factors and geometries. This results in an increase in fabrication costs, system weight, system volume, and resources required for maintenance/repair. Reconfigurable antennas show significant promise in addressing these system-requirements, given their ability to modify their geometry and behavior to adapt to changes in environmental conditions or system requirements (such as enhanced bandwidth, change in operating frequency, polarization, radiation pattern etc.). Reconfigurable antennas can deliver the same throughput as a multi-antenna system using dynamically variable and adaptable single-antenna geometry without increasing the real estate required to accommodate these antennas. Reconfigurable antenna scan thus provides great versatility in applications such as cognitive radio, MIMO systems, RFIDs, smart antennas, etc. A reconfigurable antenna is an antenna capable of modifying dynamically its frequency and radiation properties in a controlled and reversible manner[18]. In order to provide a dynamical response, reconfigurable antennas integrate an inner mechanism (such as RF switches, varactors, mechanical actuators or tunable materials) that enable the intentional redistribution of the RF currents over the antenna surface and produce reversible modifications over its properties. The reconfiguration capability of reconfigurable antennas is used to maximize the antenna performance in a changing scenario or to satisfy changing operating requirements.

2.3 Need for Using Reconfigurable Antenna

Static single-antenna structures can be tailored to fit specific requirements, such as bandwidth, operating frequency, radiation pattern, directivity, etc. while keeping other factors (efficiency, return loss, input impedance, gain, etc.) at desired operating levels. However, when some of the specified requirements are altered, even by a slight margin, the designed antenna structure can be rendered useless. In current modern-day applications, where adaptability and versatility have become key factors in antenna design, static single-antenna structures are no longer an option. For this reason, coupled with low-cost implementations and advanced simulation environments, reconfigurable antennas have been gaining enormous popularity over the years. The reconfigurable aspect of the antenna structure can be achieved through different methods; for example, by altering the physical structure of the antenna, changing feeding methods, implementing antenna arrays, etc. The choice of reconfiguration method is directly tied to the design requirements and desired performance levels.

The advantages of using reconfigurable antenna compared to multi-band/wideband antennas or multiple antennas can be summarized as follows:

1- Ability to support more than one wireless standard
   a) Minimizes cost.
   b) Minimizes space requirement.
   c) Allows easier integration.
   d) Good isolation between different wireless standards.

2- Lower front-end complexity
   a) No need for front-end filtering
   b) Good for out-of-band rejection

3- Best object for software defined radio
   a) Capability to adapt and learn.
   b) Automated via a microcontroller or a field programmable gate array (FPGA).

2.4 Types of Reconfigurable Antenna

Reconfigurable antennas can be classified according to the antenna parameter that is dynamically adjusted, typically the frequency of operation, radiation pattern or polarization[19].

2.4.1 Frequency Reconfigurable Antenna

In frequency reconfigurable antenna technology, the operating frequency of the antenna can have varied dynamically, whether abruptly or continuously where other parameters of this antenna, such as its radiation pattern or its polarization should always stay the same, by using switching technology. Frequency reconfiguration is in most cases obtained by an alteration of the effective length of the antenna or by an alteration of the field distribution of the antenna [20], [21].

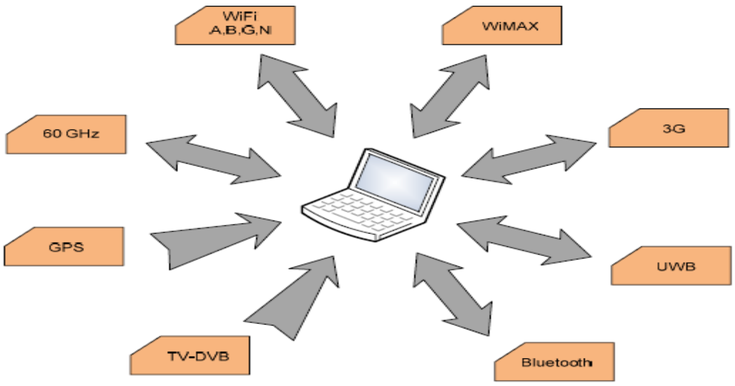


Figure 2.1: A single PC suports sevaral communication standards [9]

For example, as Fig. 2.1 shows, laptop computers will be required to support a number of communication standards in the near future [9]. Very similar situation is present in development of other wireless mobile platforms [22]. In [7], an antenna has been designed for special application which need small frequency ratio.

2.4.2 Pattern Reconfigurable Antenna

In pattern reconfigurable antenna technology, the radiation pattern of the antenna can have varied dynamically, either abruptly or continuously where other parameters of this antenna, such as its resonant frequency or its polarization should always stay the same. In practice, the polarization often changes along with the radiation pattern, because reconfiguration is usually associated with exciting a particular current distribution (mode) of an antenna [12], [23]. Also, the pattern reconfiguration can be realized by the use of a reconfigurable reactive loading of an antenna [24]. Antenna arrays equipped with reconfigurable feeding networks and reconfigurable reflect arrays are also the forms of the pattern reconfigurable antennas [25]. A pattern reconfigurable antenna can improve the system performance by using a diversity approach like the switched combining. This is especially effective in multipath propagation conditions where it is unlikely that all the signals received by all the radiation patterns provided by the antenna are in deep fade. In other words, it is possible to find a signal by switching the radiation patterns which is of significantly higher level than the others at a time [26].

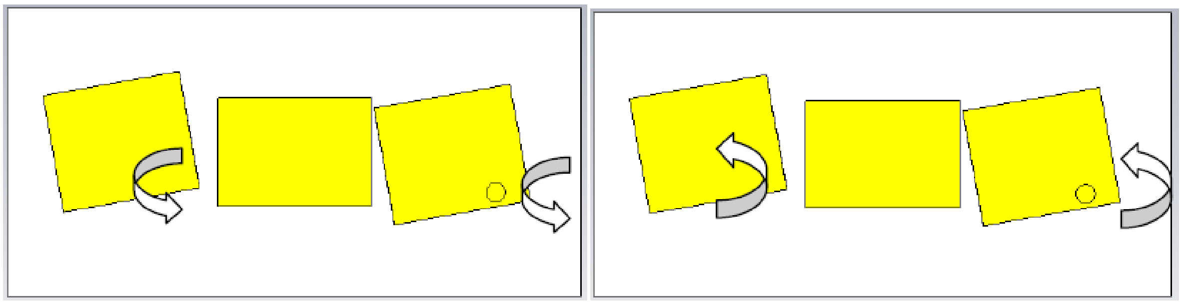


Figure 2.2: Rotated parasitic elements clockwise and counter clockwise to reconfigure the pattern [12]

Figure 2.2 shows an antenna array that is used to reconfigurable the radiation pattern, where two parasitic elements are used with an active element avoiding switching technologies [12].

2.4.3 Polarization Reconfigurable Antenna

A polarization reconfigurable antenna is an antenna which polarization can be varied electronically. The variation is usually abrupt, between orthogonal polarizations, linear and circular polarizations, and between linear polarizations of a different skew. There are three basic principles how this can be done [11] by changing the current distribution of an antenna by means of reconfigurable reactive loading, by altering the current path of the antenna, by employing a reconfigurable phase shifter to control the phase difference between orthogonally polarized components. The antenna resonant frequency should remain the same, although there are applications where this is not the case. Polarization reconfigurable antennas are useful for many applications. They can provide polarization diversity, with similar benefits as in the case of the pattern diversity.

2.4.4 Combination of Frequency, Pattern and Polarization Reconfigurable Antennas

It is a combination of the above three types to exhibit many properties combined together. For example, one can achieve a frequency reconfigurable antenna with polarization diversity at the same time.

Table 2.1: The process of achieving the required reconfigurability

Types	Process
Frequency Reconfigurable Antennas	Change the surface current distribution
Pattern Reconfigurable Antennas	Change the radiating edges, slots or the feeding network
Polarization Reconfigurable Antennas	Change the antenna surface structure or the feeding network
Combination of three types	Combination of the above processes depending on the antenna functionality

2.5 Wireless Standards and Applications

Some wireless standards and applications name are given below:

Table 2.2: The different wireless standards [27]

Wireless Services	Frequency Bands	Number of Antennas
Wi-Fi	EEE 802.11 b/g/n: 2.4-2.48 GHz IEEE 802.11 a/n: 5.15-5.85 GHz	3X 3 MIMO
WiMAX	IEEE 802.16: 2.3-2.4 GHz, 2.5-2.7 GHz, 3.3-3.8 GHz, 5.15-5.85 GHz	Diversity: main and aux (1X Tx, 2X Rx)
3G	GSM 850: 824-894 MHz GSM 900: 880-960 MHz DCS 1800: 1.71-1.88 GHz PCS 1900: 1.85-1.99 GHz	Diversity: main and aux (1X Tx, 2X Rx)
Bluetooth	IEEE 802.15.1: 2.4-2.48 GHz	Single
GPS	1.575 GHz	Single
UWB	3-10 GHz	Single

Table 2.3 shows Different types reconfigurable antenna and its applications below, by analyzing this table the demand of reconfigurable antenna is clear.

Table 2.3: Different types reconfigurable antenna and its applications

Types	Applications
Frequency Reconfigurable Antennas	WLAN, GSM, UMTS, PCS, Bluetooth, Cognitive Radio
Pattern Reconfigurable Antennas	MIMO, Software Defined Radio,
Polarization Reconfigurable Antennas	Satellite Communication, MIMO, Cognitive Radio
Combination of three types	Combination of the above applications

Signal to noise ratio for Wi-Fi application

> 40dB SNR = Excellent signal, always associated, lightning fast.

25dB to 40dB SNR = Very good signal, always associated, very fast.

15dB to 25dB SNR = Low signal, always associated, usually fast.

10dB - 15dB SNR = Very low signal, mostly associated, mostly slow.

2.6 Microstrip Patch Antenna

A patch antenna is a type of radio antenna with a low profile, which can be mounted on a flat surface. It consists of a flat rectangular sheet or patch of metal, mounted over a larger sheet of metal called a ground plane[28]. Microstrip devices are planar components for microwaves and high frequency electronics, which can replace bulky wave-guides whenever the frequency or the power level of signals permits. At low frequencies one uses open structures whereas at high frequencies metal enclosures surround the circuits to avoid radiation. These days, a plenty of various types of patch antennas are at our disposal. These antennas differ in the shape of the antenna elements (rectangular, circular, annular etc.), in polarization they operate with, in feeding techniques considered, etc. Small impedance bandwidth is a common property of patch antennas. For classical patch antennas, the bandwidth is about 2 to 3 percent and for aperture fed antennas it is about 4 to 6 percent. High quality factor of patches is the reason. Antenna efficiency is another important parameter. Radiation efficiency (computed for lossless antenna) is given by the ratio of radiated power (integrating pointing vector in the far region over the whole half-space) and real power on the input port of the antenna. Energy, which is not radiated by the antenna, is taken away in the form of surface waves along the infinite dielectric substrate (in real situation, the substrate is limited, of course).

2.7 Need for Patch Antenna

Communication has expanded much rapidly in the past couple of decades, and the ever expanding need of communication bandwidth defines new communication protocols which in turn expect better technology to fill in the gap. Microstrip patch antenna has attracted lots of interest in the field of mobile communications due to its important characteristics along with easy to achieve multi frequency operation and relatively large area consumption. Patch antennas are usually used within the frequency range of 2-30 GHz [29]. Microstrip are printed circuits operating in the microwave range, over the gigahertz region of the electromagnetic spectrum. Realized by the photolithographic process, they let designers reduce the size, weight, and cost of components and systems for low signal-level applications by replacing the more cumbersome wave-guide components and assemblies. At microwave frequencies, all dimensions become important, so the realization of Microstrip requires more care than that of low-frequency printed circuits. Microstrip lines were first proposed in 1952 and were increasingly used in the late 1960s and 1970s to realize circuits, generally called Microwave Integrated Circuits (MICs) since radiation leakage is most unwanted in circuits, particular care was taken to avoid it. Microstrip antennas appeared as a by-product of Microstrip circuits, which by then had become a mature technology. Their design and realization took advantage of the techniques developed for Microstrip circuits and used Microstrip circuit substrates. In high performance aircraft, spacecraft, satellite and missile application, where size, weight, cost, performance, ease of installation and aerodynamic profile are constraints, this type of low profile antennas may be required.

2.8 General Structure of Patch Antenna

A microstrip antenna generally consists of a dielectric substrate sandwiched between a radiating patch on the top and a ground plane on the other side as shown in Fig. 2.3. The patch is mainly 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. Components can be included in the circuit either by implanting lumped components (resistors, inductors, capacitors, semiconductors, and ferrite devices) or by realizing them directly.

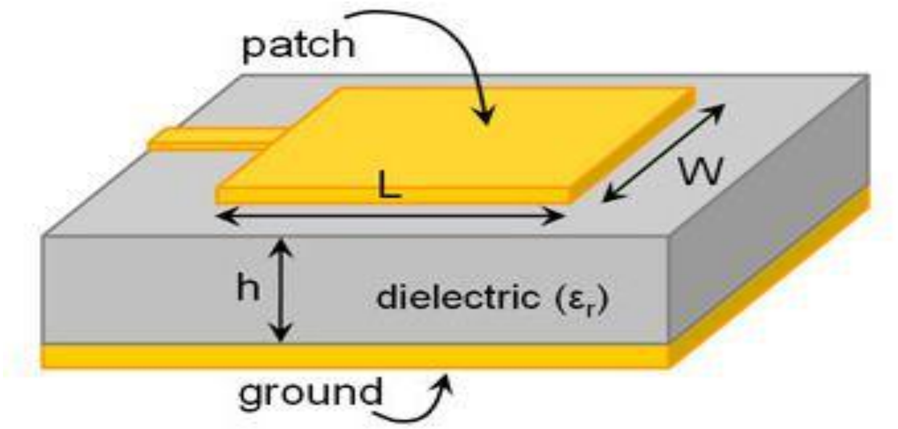


Figure 2.3: Structure of a Microstrip Patch Antenna [30]

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 Fig. 2.4 [31].

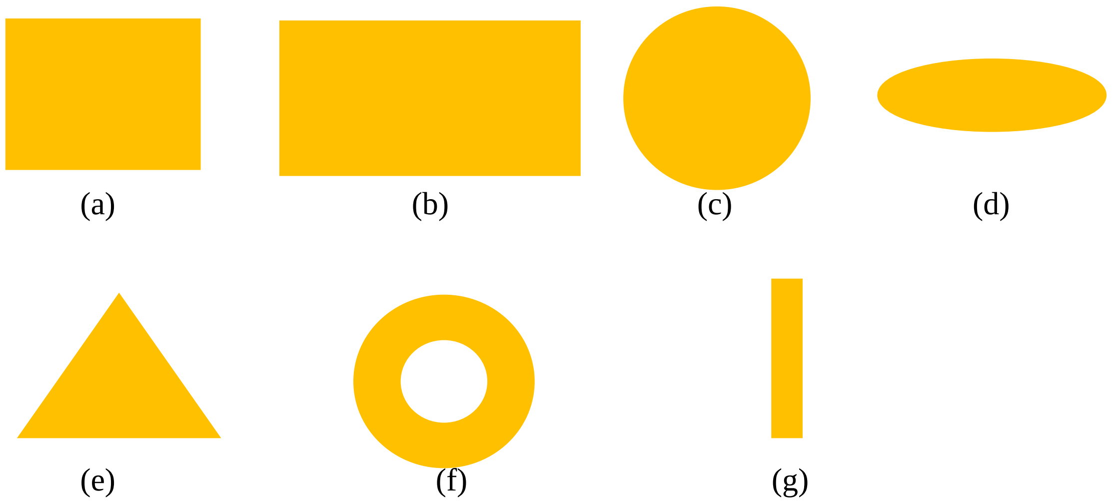


Figure 2.4: Common Shape of Microstrip Patch Element (a)Square, (b) Rectangular, (c) Circular, (d) Elliptical, (e) Triangular, (f) Circular Ring and (g) Dipole [31]

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. Microstrip patch antennas consist of a very thin, t, ($t<<\lambda_0$, where λ_0 is the free space wavelength) metallic strip (patch) placed a small fraction of wavelength ($h<< \lambda_0$ usually $0.003\ \lambda_0 \leq h \leq 0.05\ \lambda_0$) above a ground plane. For a rectangular patch, the length, L, of the element is usually $\lambda_0 /3 < L < \lambda_0 /2$. The patch and the ground plane are separated by a dielectric sheet, referred to as the substrate. There are numerous substrates those can be used for the design of microstrip antennas, and their dielectric constants (ε_r) are usually in the range $1.28 \leq \varepsilon_r \leq 12$.

2.8.1 Conductor Layers

Nowadays, many commercial suppliers provide a wide range of Microstrip substrates, already metalized on both faces. The conductor on the upper face is chemically etched to realize the circuit pattern by a photographic technique. A mask of the circuit of the antenna is drawn, generally at convenient scale, and then reduced and placed in close contact with a photo resistive layer, which was previously deposited on top of the metalized substrate. The lower metal part is the ground plane. The ground plane, besides acting as a mechanical support, provides for integration of several components and serves also as a heat sink and dc bias return for active devices The resulting sandwich is then exposed to ultraviolet rays, which reach the photosensitive layer where it is not covered by the mask. The exposed parts are removed by the photographic development, and the metal cover is etched away from the exposed area. This process is called the subtractive process.

2.8.2 Dielectric Substrate

The Dielectric substrate is the mechanical backbone of the Microstrip circuit. It provides a stable support for the conductor strips and patches that make up connecting lines, resonators and antennas. It ensures that the components that are implanted are properly located and firmly held in place, just as in printed circuits for electronics at lower frequencies. The substrate also fulfills an electrical function by concentrating the electromagnetic fields and preventing unwanted radiation in circuits. The dielectric is an integral part of the connecting transmission lines and deposited components: its permittivity and thickness determine the electrical characteristics of the circuit or of the antenna. The ones that are the most desirable for good antenna performance are thick substrates whose dielectric constant is in the lower end of the range because they are provide better efficiency, larger bandwidth, loosely bound fields for radiation into space, but at the expense of larger element size. Thin substrates with higher dielectric constants are desirable for microwave circuitry because they require tightly bound fields to minimize undesired radiation and coupling, and lead to smaller element size.

2.9 Feeding Methods

In Microstrip patch antenna, there are various type of feed methods are use, these methods are categorized in two main types,

a. Contacting
b. Non-contacting

In contacting method technique, RF power is directly applied to the patch through BNC connector. The contacting feed methods are Microstrip Feed Line and Coaxial Probe. In non-contacting method the power has given through coupling. It depends on the Aperture Coupled Feed and Proximity Coupled Feed. The four most popular feeding methods are:

- The Microstrip line,
- Coaxial probe,
- Aperture coupling and
- Proximity coupling [31]

2.9.1 Microstrip Line Feed

In this type of feed technique, a conducting strip is connected directly to the edge of the Microstrip patch as shown in Fig. 2.5. 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 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.

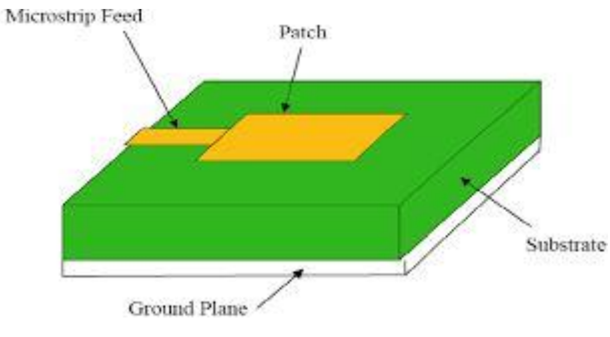
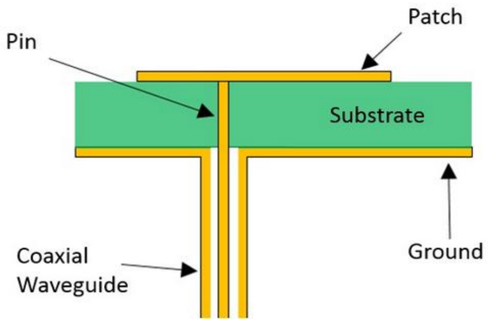


Figure 2.5: Typical Microstrip Line Feed [30].

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 [33]. The feed radiation also leads to undesired cross polarized radiation.

2.9.2 Coaxial Line Feed

In this method, the inner conductor of the coax is attached to the radiating patch while the outer conductor is connected to the ground plane as shown in Fig. 2.6. The coaxial probe feed is also easy to fabricate and match, and it has low spurious radiation. However, there are some drawbacks in applying this feeding technique, such as it has narrower bandwidth and it is more difficult to model, especially for thick substrates (h >0.02λ_o).



(a)

(b)

Figure 2.6: Coaxial line feed (a) Typical Coaxial Probe Feed and (b) Coaxial Probe [30].

2.9.3 Aperture Coupling Feed

The aperture coupling is the most difficult of all four to fabricate and it also has narrow bandwidth. However, it is somewhat easier to model and has moderate spurious radiation. The aperture coupling consists of two substrates separated by a ground plane. On the bottom side of the lower substrate there is a Microstrip feed line whose energy is coupled to the patch through a slot on the ground plane separating the two substrates. This arrangement allows independent optimization of the feed mechanism and the radiating element. Typically, a high dielectric material is used for the bottom substrate and thick low dielectric constant material for the top substrate. The ground plane between the substrates also isolates the feed from the radiating element and minimizes interference of spurious radiation for pattern formation and polarization purity for this design. A basic model has shown in Fig. 2.7.

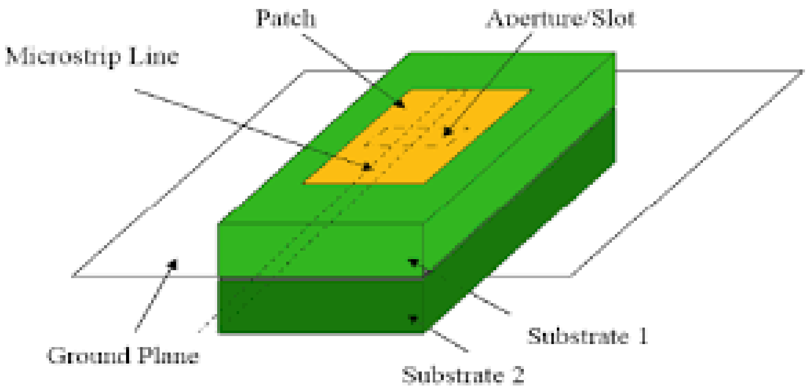


Figure 2.7: Typical Aperture Coupling Feed [30].

2.9.4 Proximity Coupled Feed

In this method two dielectric substrates are used such that the feed line is between the two substrates and radiating patch is on top of the upper substrate. Its fabrication is not easy as compare to other feed techniques. The length of the feeding stub and the width to line ratio of the patch can be used to control the match point. Advantage of this feed is that it almost eliminates spurious radiation and provides high bandwidth (as high as 13%), due to overall increase in the thickness of the Microstrip patch antenna. This scheme also provides choice between two different dielectric media, one for the patch and one for the feed line to optimize the individual performance. A basic model has shown in Fig. 2.8.

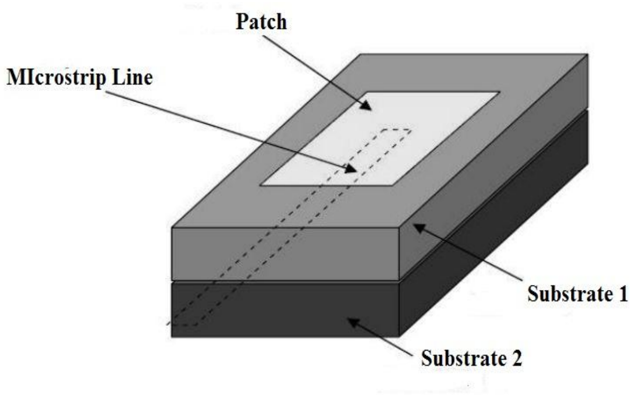


Figure 2.8: Typical Proximity Coupling Feed [30].

2.9.5 Comparing the Different Feed Techniques

From above discussion it can be found that different feeding techniques have different advantages and disadvantages. These are given below:

Table 2.4: Comparing the different feed techniques [33]

Characteristics	**Microstrip Line Feed**	**Coaxial Feed**	**Aperture Coupled Feed**	**Proximity Coupled Feed**
Spurious Feed Radiation	More	More	Less	Minimum
Reliability	Better	Poor to Soldering	Good	Good
Ease of Fabrication	Easy	Soldering and Drilling needed	Alignment Required	Alignment Required`
Impedance Matching	Easy	Easy	Easy	Easy
Bandwidth	2-5%	2-5%	2-5%	13%

2.10 Methods of Analysis

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

2.10.1 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.

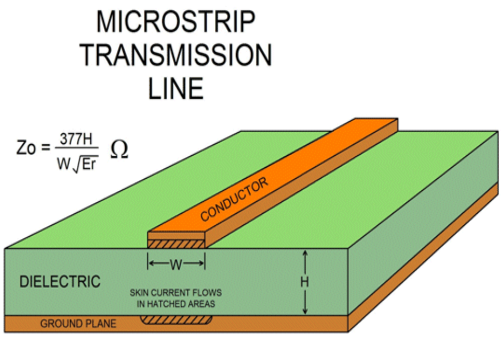


Figure 2.9(a): Microstrip Line [30]

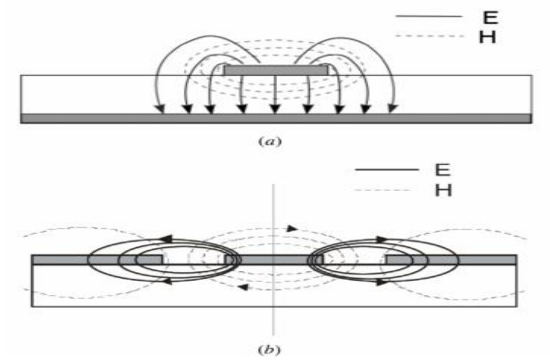


Figure 2.9(b): Electric Field Lines [30]

Hence, as seen from Fig. 2.9(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 (ε_{reff}) must be obtained in order to account for the fringing and the wave propagation in the line. The value of ε_{reff} is slightly less than ε_r because the fringing fields around the periphery of the patch are not confined in the dielectric substrate but are also spread in the air. The expression for ε_{reff} is given [33] as:

$$\varepsilon_{reff} = \frac{\varepsilon_r+1}{2} + \frac{\varepsilon_r-1}{2}\left[1 + 12\frac{W}{h}\right]^{\frac{1}{2}} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2.1)$$

Where,

ε_{reff} = Effective dielectric constant

ε_r = Dielectric constant of substrate

h = Height of dielectric substrate

W = Width of the patch

Consider Fig. 2.9(c) 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.

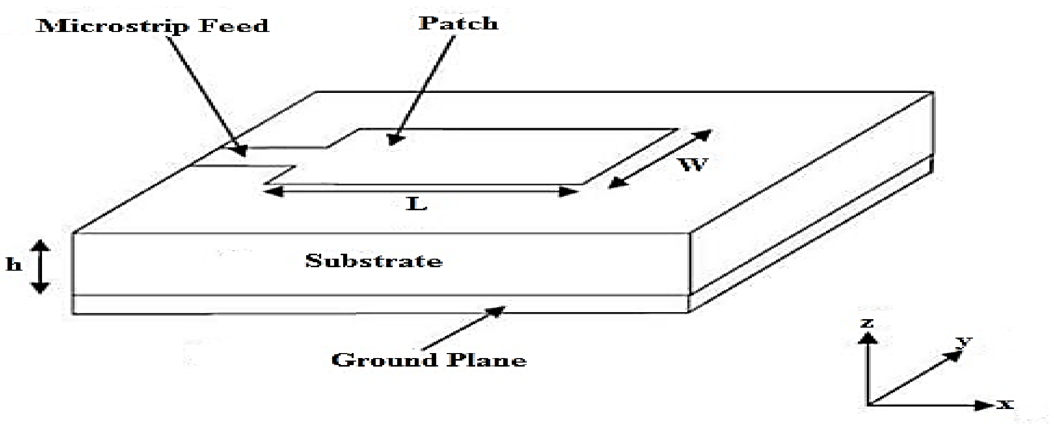
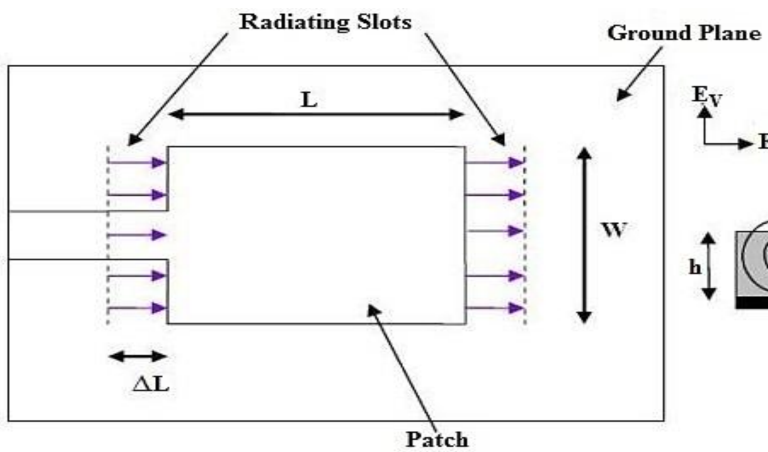


Figure 2.9(c): Microstrip Patch Antennas

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 $\lambda o/\sqrt{\varepsilon_{reff}}$ where λo is the free space wavelength. The TM_{10} mode implies that the field varies one λ/2 cycle along the length, and there is no variation along the width of the patch. In the Fig. 2.9(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.



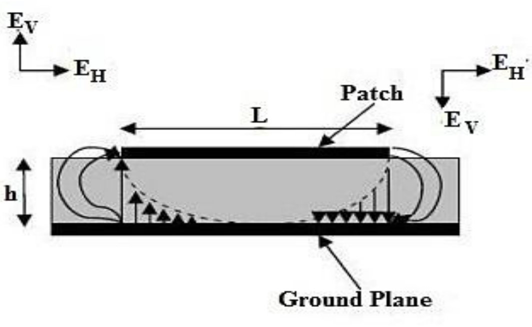


Figure 2.9(d): Top View of Antenna

Figure 2.9(e): Side View of antenna

It is seen from Fig. 2.9(e) that the normal components of the electric field at the two edges along the width are in opposite directions and thus out since the patch is λ/2 long and hence they cancel each other. The edges along can be represented as two radiating slots, which are λ/2 apart and excited in phase and radiating in the half space above the ground plane. The fringing fields along the width can be modeled as radiating slots and electrically the patch of the microstrip antenna looks greater than its physical dimensions. The dimensions of the patch along its length have now been extended on each end by a distance ΔL which is given empirically as

$$\Delta L = 0.412h \frac{(\varepsilon_{reff}+0.3)(\frac{W}{h}+0.264)}{(\varepsilon_{reff}-0.8)(\frac{W}{h}+0.8)} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2.2)$$

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

$$L_{eff} = L + 2\Delta L \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2.3)$$

For a given resonance frequency f_o is given by:

$$L_{eff} = \frac{c}{2\, f_o \sqrt{\varepsilon_{reff}}} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2.4)$$

For a rectangular microstrip patch antenna, the resonance frequency for any TM_{mn} mode is given by James and Hall [16] as:

$$f_o = \frac{c}{2\sqrt{\varepsilon_{reff}}} [(\frac{m}{L})^2 + (\frac{n}{W})^2]^{\frac{1}{2}} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2.5)$$

Where m & n are modes along L & W respectively.
For efficient radiation, the width W is given by Bahl and Bhartia [31] as

$$W = \frac{c}{2\, f_o \sqrt{\frac{\varepsilon_r + 1}{2}}} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2.6)$$

2.10.2 Cavity Model

The cavity model helps to give insight into the radiation mechanism of an antenna, since it provides a mathematical solution for the electric and magnetic fields of a microstrip antenna. It does so by using a dielectrically loaded cavity to represent the antenna. This technique models the substrate material, but it assumes that the material is truncated at the edges of the patch. The patch and ground plane are represented with perfect electric conductors and the edges of the substrate are modeled with perfectly conducting magnetic walls.

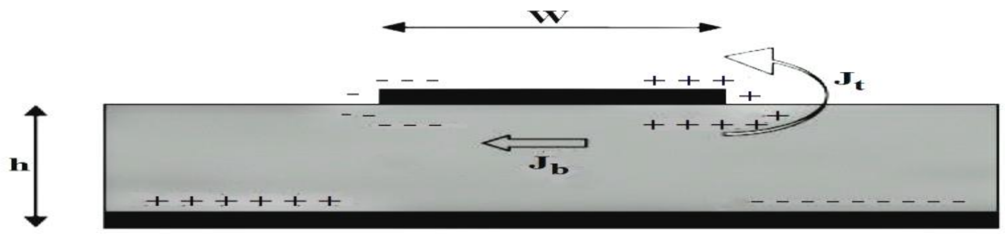


Figure 2.10: Charge Distribution and Current Density Creation on the Microstrip Patch [28]

Consider Fig. 2.10 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. 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. Hence, the four sidewalls could be modeled as perfectly magnetic conducting surfaces. Therefore, we only need to consider TM modes inside the cavity.

2.11 Advantages and Disadvantages of Microstrip Patch Antenna

Microstrip patch antennas are increasing in popularity for use in wireless technologies due to their low profile structure. Therefore, their extremely compatibility for embedded antennas in handheld wireless devices such as cellular phone, pager etc. The telemetry and communication antennas on missile need to be thin and conformal and are often microstrip patch antennas. Some of their main advantages are given below:

- Light weight and low volume.
- Ease of installation.
- Simple & inexpensive to fabricate.
- Conformable to planer & non-planer surfaces.

- Capable of dual and triple frequency operations.
- Attractive radiation characteristics.
- Supports both, linear as well as circular polarization.
- Relatively inexpensive to design & manufacture because of the simple 2 dimensional physical geometries.
- Compatible with Hybrid Microwave Integrated Circuits (HMIC), Monolithic Microwave Integrated Circuits (MMIC) and micro machine technology.
- 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.

2.12 Applications of Microstrip Patch Antenna

The microstrip patch antenna, because of its small size, lightweight, low profile, and low manufacturing cost, is finding increasing interest in both commercial and military applications. With continued research and development and increased usage, microstrip patch antennas are ultimately expected to replace conventional antennas for most applications. Some notable applications for which microstrip patch antenna have been developed include [35].

- Satellite communications
- Doppler and other radars
- Radio altimeters
- Command and control systems
- Missiles and telemetry
- Remote sensing
- Feed elements in complex antennas
- Mobile communications

2.13 Approximate performance trade of a Rectangular Patch

The more general features of microstrip patch antennas such as the trade-offs are listed in the following table.

Table 2.5: Approximate performance trade of a Rectangular Patch

Requirement	**Substrate height**	**Substrate Relative Permittivity**	**Patch Width**
High radiation efficiency	Thick	Low	Wide
Low dielectric loss	Thin	Low	……….
Low conductor loss	Thick	……….	……….
Wide bandwidth	Thick	Low	Wide
Light weight	Thin	Low	……….
Strong	Thick	High	……….
Low sensitivity to tolerance	Thick	Low	Wide

2.14 Motivation

The design of reconfigurable antennas has received big attention in recent years, especially the development of reconfigurable multi frequency antennas. With the increasing needs of more antennas bandwidth, it's essential to have a single antenna element that can be reconfigured to operate at different frequency bands for different wireless communication systems. Moreover, new reconfigurable antennas offer many potential features such as compact size and reducing the adverse coupling effects of antennas. It also offers direct the beam to a desired user. Therefore, pattern reconfigure is motivates this work.

CHAPTER III

Methodology

CHAPTER III

Methodology

3.1 Introduction

In this chapter, the procedure of design a pattern reconfigurable antenna by using CST (Computer Simulation Technology) software is explained. The proposed antenna is a patch antenna, so, it has concentrated on the analysis of common characteristics (return loss, gain, directivity, bandwidth, efficiency etc.) of patch and highly concentrated on the directions of radiation. The suggested design of antenna is a pattern reconfigurable antenna which radiation pattern can dynamically changes but other characteristics of the antenna are remaining same.

3.2 Simulation Software

The design is done using CST (Computer Simulation Technology) STUDIO 2015. CST MICROWAVE STUDIO® (CST MWS) is a specialist tool for the 3D EM simulation of high frequency components. CST MWS' unparalleled performance making it first choice in technology leading R&D departments. CST MWS enables the fast and accurate analysis of high frequency (HF) devices such as antennas, filters, couplers, planar and multi-layer structures and SI and EMC effects. Exceptionally user friendly, CST MWS quickly gives you an insight into the EM behavior of your high frequency designs. It simplifies the process of creating the structure by providing a powerful graphical solid modeling front end which is based on the ACIS modeling kernel. After the model has been constructed, a fully automatic meshing procedure is applied before a simulation engine is started. Since no one method works equally well for all applications, the software contains several different simulation techniques such as transient solvers, frequency domain solvers, integral equation solver, multilayer solver, asymptotic solver, and Eigen mode solver to best suit various applications. Anyone who has to deal with electromagnetic problems in the high frequency range can use CST MICROWAVE STUDIO. The program is especially suited to the fast and efficient analysis.

3.3 Design of 2-Port Reconfigurable Antenna

3.3.1 Design Specifications (2-Port Antenna)

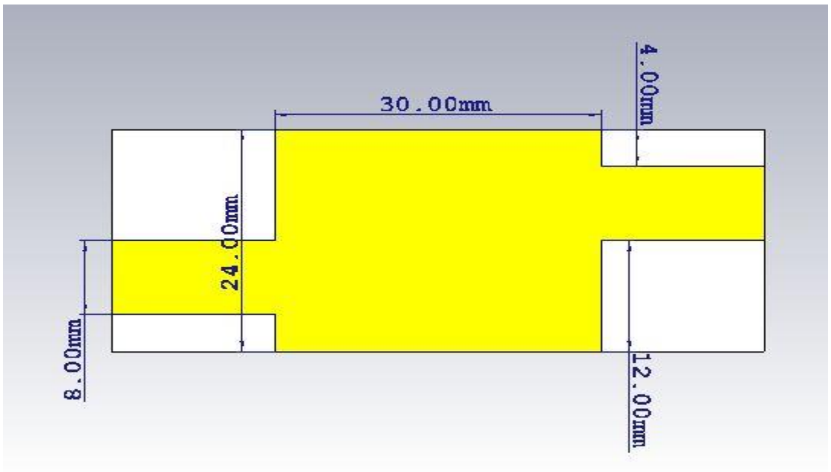
The most three important parameters for the design of rectangular microstrip patch antenna are:

- **Frequency of Operation (f_o):** The operating frequency selected for the design is 2.4 GHz. That is suitable for Wi-Fi technology.

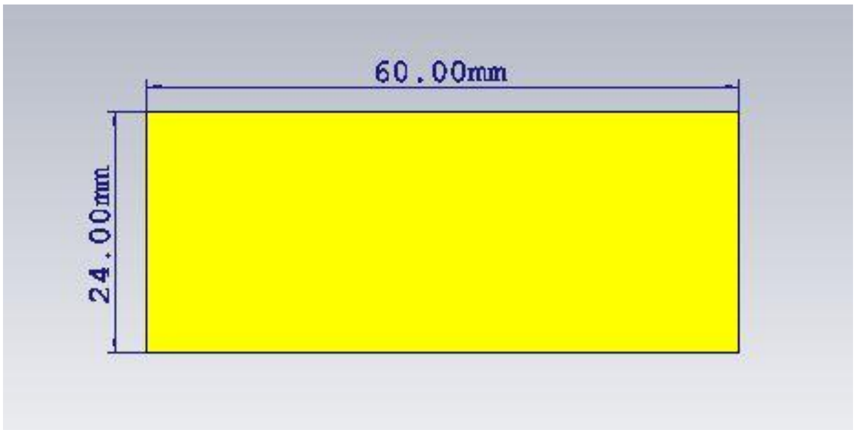
- **Dielectric Constant of the Substrate (ε_r):** The dielectric substrate selected for my design is FR-4 (lossy) which has characteristics with Differential Impedance, Zo = 50Ω, Dielectric Constant , ε_r = 4.4 and Substrate Loss Tangent = 0.01 (assumed constant)

- **Height of Dielectric Substrate(h):** Microstrip patch antenna has been designed in order to rule out the conventional antenna as the patch antennas are used in most of the compact devices. Hence, the height of the dielectric substrate is proposed 1 mm.

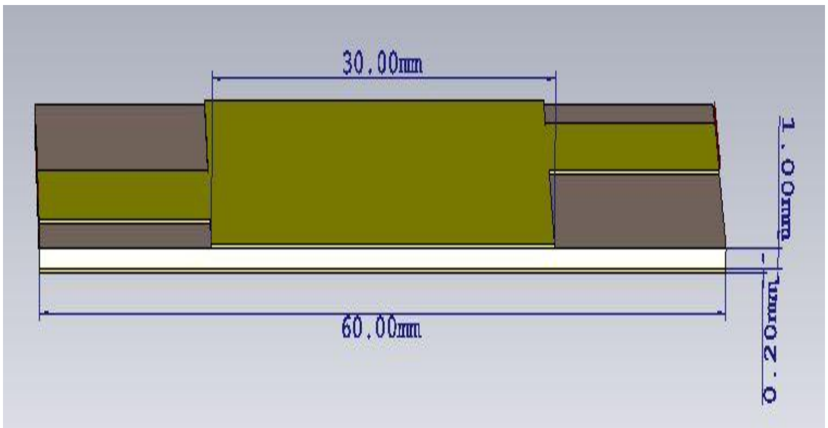
Figure 3.1 shows the geometric and detailed information of the proposed reconfigurable patch antenna that ground has been made with copper (lossy) and substrate with FR-4 (lossy) with relative permittivity constant of 4.4 and the thickness of 1 mm. The total dimension of the antenna is 60×24×1.4 mm^3 are suitable for any wireless base station. The height of the patch and ground both has been selected as 0.2 mm that preferable to design an effective patch. The length and width of the antenna is chosen to design the patch on the basis of operating frequency 2.4 GHz. The chosen length and width of the patch is 24mm and 30mm respectively which has been shown in Fig. 3.1 (a) and it works at the same frequency for port-1 and port-2. These waveguide ports are the active element of the antenna. To get two opposite directional radiation pattern microstrip feeding line is aligned in opposite side of patch. For connect the port-1 to the patch, the feed line is situated at -30 to -15 along x-dimension and -8 to 0 along y-dimension. For connect the port-2 to the patch, the feed line is situated at 15 to 30 along x-dimension and 0 to 8 along y-dimension. Both feed line contains the same width that is 8 mm. The length and the width of the microstrip feeding line are same for the both port. Two port of the proposed antenna are aligning with patch in 180^0 apart from each other.



(a)



(b)



(c)

Figure 3.1: Proposed 2-port antenna for Wi-Fi based station. (a) Front side, (b) Back side, and (c) Side view

Table 3.1: Parameters of Proposed antenna for Wi-Fi based station

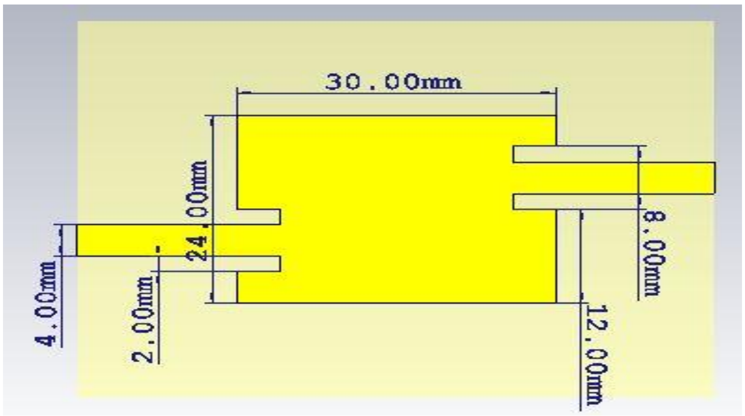
Parameters	**Value**
Design frequency	2.4GHz
Height of substrate	1mm
Length of substrate	24mm
Width of substrate	60mm
Width of patch	30mm
Length of patch	24mm
Height of patch	0.2mm
Permittivity	4.4

3.3.2 Design Specifications (2-Port Antenna with Slot)

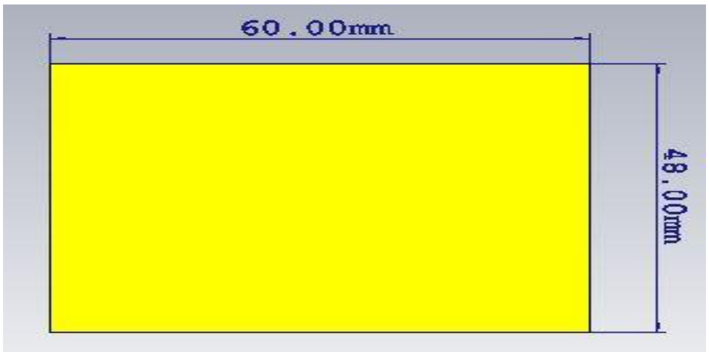
The most three important parameters for the design of rectangular microstrip patch antenna are:

- **Frequency of Operation (f_o):** The operating frequency selected for the design is 2.4 GHz. That is suitable for Wi-Fi technology.
- **Dielectric Constant of the Substrate (ε_r):** The dielectric substrate selected for my design is FR-4 (lossy) which has characteristics with Differential Impedance, Zo = 50Ω, Dielectric Constant , ε_r = 4.4 and Substrate Loss Tangent = 0.01 (assumed constant) .
- **Height of Dielectric Substrate(h):** Microstrip patch antenna has been designed in order to rule out the conventional antenna as the patch antennas are used in most of the compact devices. Hence, the height of the dielectric substrate is proposed 1 mm shown in Fig. 3.2(c).

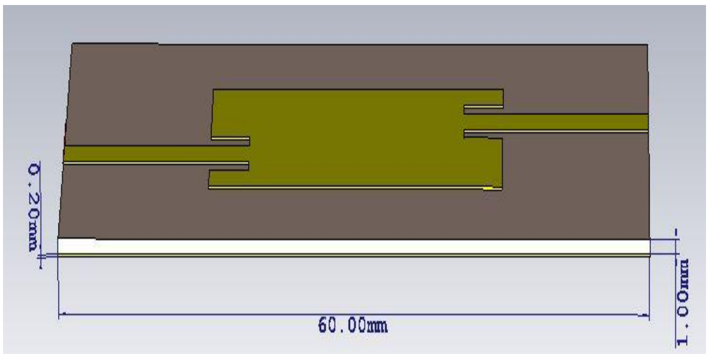
Figure 3.2 shows the geometric and detailed information of the designed 2-port reconfigurable patch antenna with slot that ground has been made with copper (lossy) and substrate with FR-4 (lossy) with relative permittivity constant of 4.4 and the thickness of 1 mm. The total dimension of the antenna is $60 \times 48 \times 1.4$ mm^3. The height of the patch and ground both has been selected as 0.2 mm that preferable to design an effective patch. The length and width of the antenna is chosen to design the patch on the basis of operating frequency 2.4 GHz. The chosen length and width of the patch is 24mm and 30mm respectively which has been shown in Fig. 3.2 (a) and it works at the same frequency for port-1 and port-2. These waveguide ports are the active element of the antenna. To get two opposite directional radiation pattern microstrip feeding line is aligned in opposite side of patch. Both feed line contains the same width that is 4 mm. The length and the width of the microstrip feeding line are same for the both port. Two port of the proposed antenna are aligning with patch in 180^0 apart from each other.



(a)



(b)



(c)

Figure 3.2: 2-port antenna with slot for Wi-Fi based station. (a) Front side, (b) Back side, and (c) Side view

Table 3.2: Parameters of 2-port antenna with slot for 2.4 GHz

Parameters	Value
Design frequency	2.4GHz
Height of substrate	1mm
Length of substrate	48mm
Width of substrate	60mm
Width of patch	30mm
Length of patch	24mm
Height of patch	0.2mm
Permittivity	4.4

3.3.3 Design Procedure (Proposed 2-Port Antenna)

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

Step 1 Calculation of Width (W) of Patch by the formula

$$W = \frac{c}{2f_o\sqrt{\left(\frac{\varepsilon_r + 1}{2}\right)}} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots..3.1$$

Calculated result, W= 30 mm

Step 2 Calculation of effective Dielectric constant (ε_{reff})

By the formula

$$\mathcal{E}_{reff} = \frac{\mathcal{E}_r + 1}{2} + \frac{\mathcal{E}_r - 1}{2}[1 + 12\frac{W}{h}]^{\frac{1}{2}} \ldots\ldots\ldots\ldots\ldots\ldots 3.2$$

Calculated result, ε_{reff} = 4.4

Step 3 Calculation extension Length (ΔL)

ΔL is used for calculating resonant frequency of the microstrip antenna,

By the formula:

$$\Delta L = 0.412h\frac{(\varepsilon_{reff}+0.3)(\frac{W}{h}+0.264)}{(\varepsilon_{reff}-0.8)(\frac{W}{h}+0.8)} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots .3.3$$

Calculated result, ΔL = 1.2 mm

Step 4 Calculation of Length (L_{eff}) By the formula:

$$L_{eff} = \frac{c}{2f_o\sqrt{\varepsilon_{reff}}} \ldots\ldots\ldots\ldots\ldots\ldots\ldots .3.4$$

Calculated result, L_{eff} = 26.4mm

Step 5 Calculation of actual length of patch (L)

It is given by

$$L = L_{eff} - 2\Delta L \ldots\ldots\ldots\ldots\ldots .3.5$$

Calculated result, L= 24 mm

Step 6 Calculation of inset depth

By the formula

$$G_{pf} = \frac{v_0}{\sqrt{2\times\varepsilon_{reff}}} \cdot \frac{4.65\times10^{-12}}{f} \ldots\ldots\ldots\ldots\ldots\ldots .3.6$$

where, v_0 is the velocity of electromagnetic wave, $v_0 = 3\times10^{11} mm/s$

Step 7 Calculating Z_0

Using Bessel function from APPCAD it can be find out, Z_0 =50 ohm

3.4 Design of 4-Port Reconfigurable Antenna

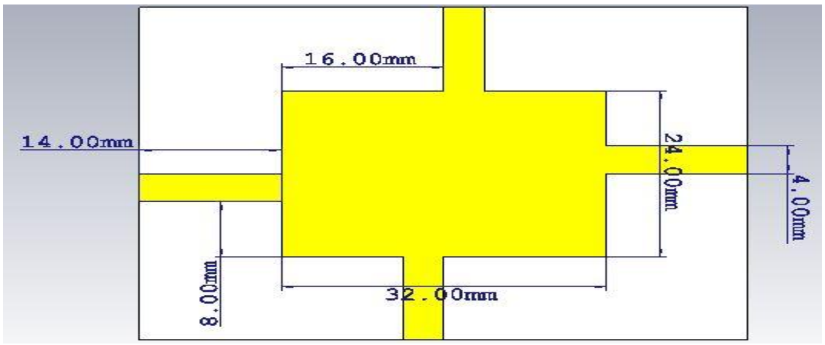
3.4.1 Design Specifications (4-Port Antenna)

The most three important parameters for the design of rectangular microstrip patch antenna are:

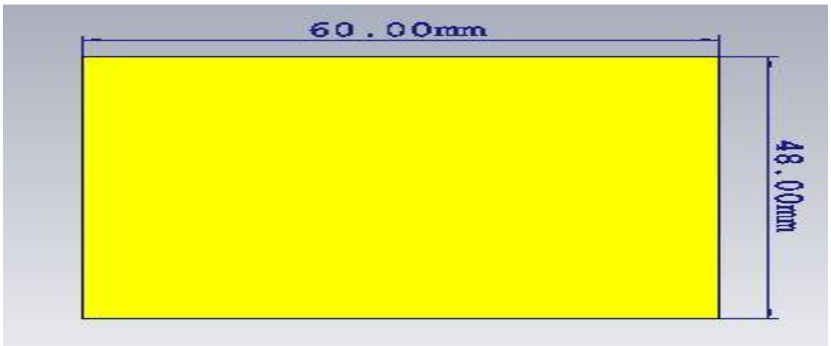
- **Frequency of operation:** The desire operating frequencies selected for the design are

2.45 GHz and 2.6 GHz.

- **Dielectric constant of the substrate:** The dielectric substrate selected for my design is FR-4 (lossy) which has characteristics with Differential Impedance Zo = 50Ω, Dielectric Constant, ε_r = 4.4, Substrate Loss Tangent = 0.01 (assumed constant).
- **Height of Dielectric Substrate(h):** Microstrip patch antenna has been designed in order to rule out the conventional antenna as the patch antennas are used in most of the compact devices. Hence, the height of the dielectric substrate is proposed 1 mm shown in Fig. 3.3(c).

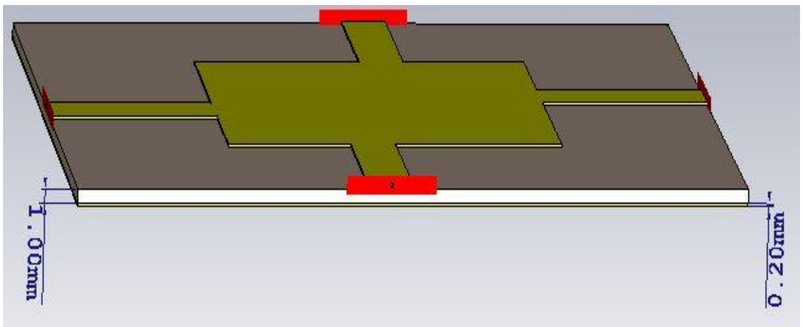


(a)



(b)

Figure 3.3: Four port antenna for Wi-Fi based station. (a) Front side, and (b) Back side



(c)

Figure 3.3: Four port antenna for Wi-Fi based station. (c) Side view

Figure 3.3 shows the geometric and detailed information of the proposed reconfigurable patch antenna that ground has been made with copper (lossy) and substrate with FR-4 (lossy) with relative permittivity constant of 4.4 and the thickness of 1 mm. The total dimension of the antenna is 60×48×1.4 mm^3.

Table 3.3: Design antenna Parameters for Wi-Fi

Parameters	**Value**
Desire frequency	2.4 GHz
Height of substrate	1mm
Length of substrate	48mm
Width of substrate	60mm
Width of patch	32mm
Length of patch	24mm
Height of patch	0.2mm
Permittivity	4.4

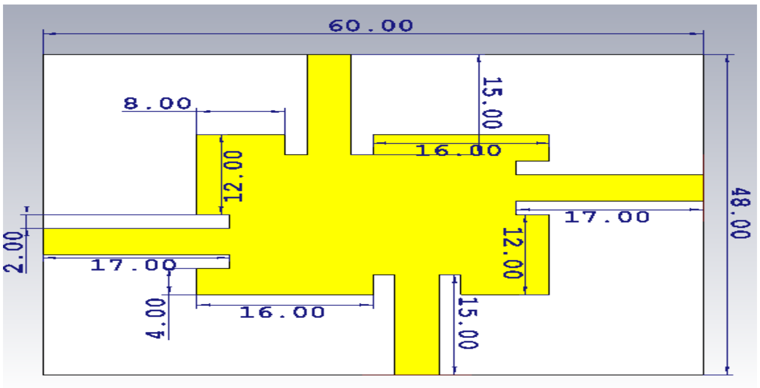
3.4.2 Design Specifications (4-Port Antenna with Slot)

The most three important parameters for the design of rectangular microstrip patch antenna are:

- **Frequency of operation:** The operating frequencies selected for the design are 2.45 GHz and 2.6 GHz.

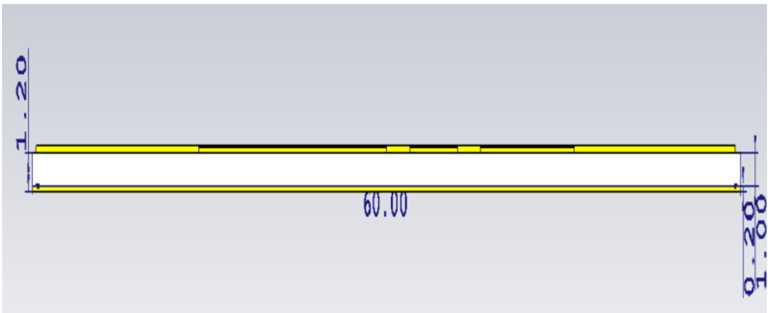
- **Dielectric constant of the substrate:** The dielectric substrate selected for my design is FR-4 (lossy) which has characteristics with Differential Impedance Zo = 50Ω, Dielectric Constant, ε_r = 4.4, Substrate Loss Tangent = 0.01 (assumed constant). A substrate with a high dielectric constant has been selected as it reduces the dimensions of antenna.

- **Height of Dielectric Substrate(h):** Microstrip patch antenna has been designed in order to rule out the conventional antenna as the patch antennas are used in most of the compact devices. Hence, the height of the dielectric substrate is proposed 1 mm shown in Fig. 3.4(c).

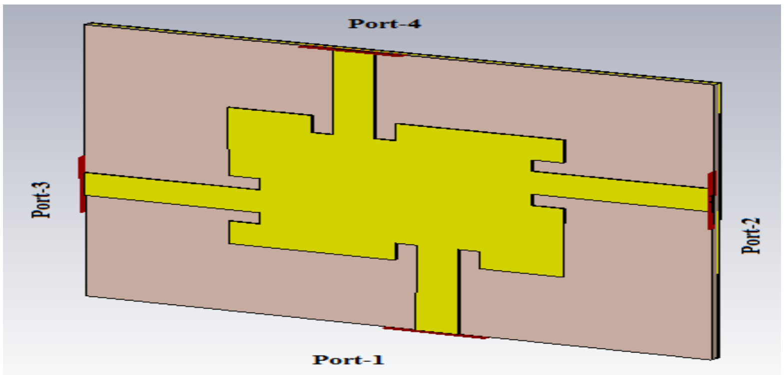


(a)

(b)



(c)



(d)

Figure 3.4: Four port antenna with slot for Wi-Fi based station.

(a) Front side, and (b) Back side (c) Side view, and (d) Full antenna

Figure 3.4 shows the geometric and detailed information of the proposed reconfigurable patch antenna that ground has been made with copper (lossy) and substrate with FR-4 (lossy) with relative permittivity constant of 4.4 and the thickness of 1 mm. The total dimension of the antenna is 60×48×1.2 mm^3. It is a four port patch antenna, where port 1 and port 4 are worked as Wi-Fi system and port 2 and port 3 are worked as WiMAX system. For reconfiguration, here polarization effect has been used & the angle is 180^0. By using this method, it can be possible to cover 360^0 & used in both two directions which is not possible with other methods. This antenna is worked for both Wi-Fi and WiMAX at the frequencies of 2.45 GHz and 2.6 GHz. So it not only pattern reconfigure but also frequency reconfigure. The common parameters that are used to design the antenna are shown in Table 3.4.

Table 3.4: Design antenna Parameters for Wi-Fi and WiMAX

Parameters	**Value**
Design frequency	2.45GHz and 2.6 GHz
Height of substrate	1mm
Length of substrate	48mm
Width of substrate	60mm
Width of patch	32mm
Length of patch	24mm
Height of patch	0.2mm
Permittivity	4.4

3.4.3 Design procedure (4-Port Antenna)

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

Step 1 Calculation of Width (W) By the formula

$$W = \frac{c}{2f_o\sqrt{\left(\frac{\varepsilon_r + 1}{2}\right)}} \dots\dots\dots\dots\dots\dots\dots\dots\dots..3.7$$

Calculated result, W= 32 mm

Step 2 Calculation of effective Dielectric constant (ε_{reff})

By the formula

$$\varepsilon_{reff} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2}[1 + 12\frac{W}{h}]^{\frac{1}{2}} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 3.8$$

Calculated result, ε_{reff} = 4.4

Step 3 Calculation extension Length (ΔL)

ΔL is used for calculating resonant frequency of the microstrip antenna,

By the formula:

$$\Delta L = 0.412h\frac{(\varepsilon_{reff}+0.3)(\frac{W}{h}+0.264)}{(\varepsilon_{reff}-0.8)(\frac{W}{h}+0.8)} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 3.9$$

Calculated result, ΔL = 1.2 mm

Step 4 Calculation of Length (L_{eff}) By the formula:

$$L_{eff} = \frac{c}{2f_o\sqrt{\varepsilon_{reff}}} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 3.10$$

Calculated result, L_{eff} = 26.4mm

Step 5 Calculation of actual length of patch (L)

It is given by

$$L = L_{eff} - 2\Delta L \ldots\ldots\ldots\ldots\ldots\ldots\ldots 3.11$$

Calculated result, L= 24 mm

Step 6 Calculation of inset depth by the formula

$$G_{pf} = \frac{v_0}{\sqrt{2 \times \varepsilon_{reff}}} \cdot \frac{4.65 \times 10^{-12}}{f} \ldots\ldots\ldots\ldots\ldots\ldots 3.12$$

where, v_0 is the velocity of electromagnetic wave, $v_0 = 3 \times 10^{11} mm/s$

Step 7 Calculating Z_0

Using Bessel function from APPCAD it can be find out, Z_0 =50 ohm

CHAPTER IV

Simulation of Pattern Reconfigurable Antenna

CHAPTER IV

Simulation of Pattern Reconfigurable Antenna

4.1 Simulation in CST Studio

CST microwave studio is a specialist tool for the 3D EM simulation of high frequency components. CST MWS has enormous tools for designing and analyzing the output. Antenna modeling is done in CST by using different modeling tools like brick, sphere, cone, torus, cylinder, extrusion, faces and apertures.

4.2 Simulation of 2-Port Antenna

4.2.1 Brick Tool

This is used for defining the dimensions of the substrate, ground plane, and antenna element. Materials for those elements are selected from material library. Figure 4.1 shows how to define the length width height of a substrate for modeling an antenna.

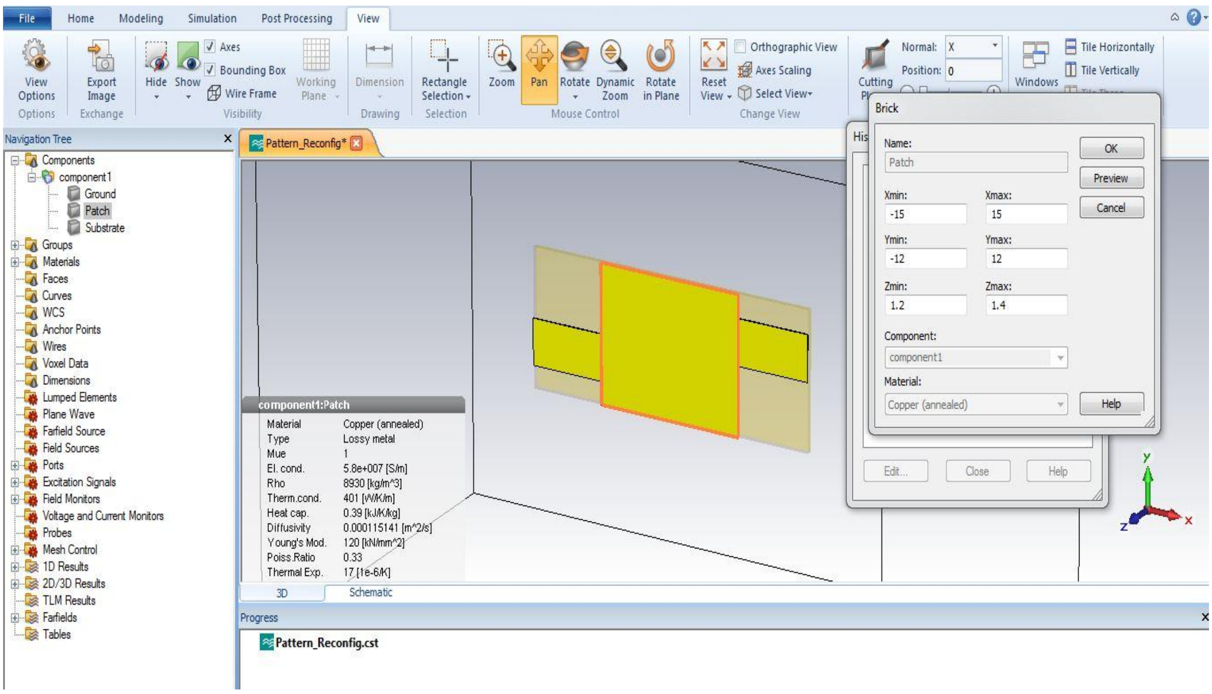


Figure 4.1: Defining Patch (2-port antenna)

4.2.2 Boolean Function Tool

By using Boolean Function, several part of a designed antenna may add or subtract from one another. Boolean add tool is used to adding the feed with active patch. Figure 4.2 shows the adding process of feed with patch by using Boolean add tool.

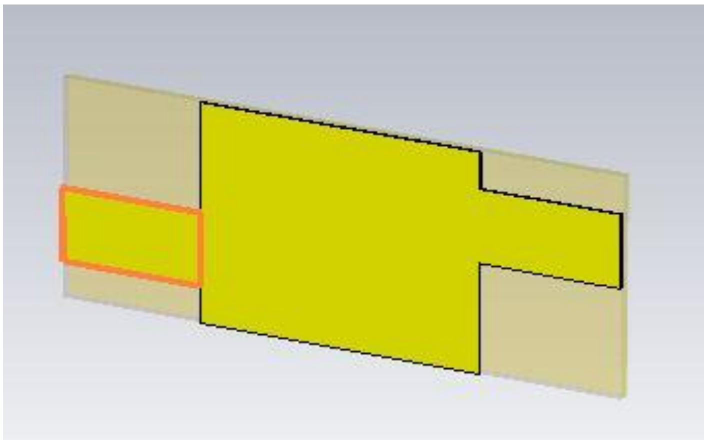


Figure 4.2: Boolean Adding Process (2-port antenna)

4.2.3 Modeling of Waveguide Port

Figure 4.3 shows waveguide port installation with feed line. To attach a waveguide port with feed line at first need to select the feed face. Then the face of feed is needed to picked to complete the port alignment. After pick the face we go to menu bar and select wave guide port from the Simulation menu. Here comes a mini window by which we can modify the waveguide port.

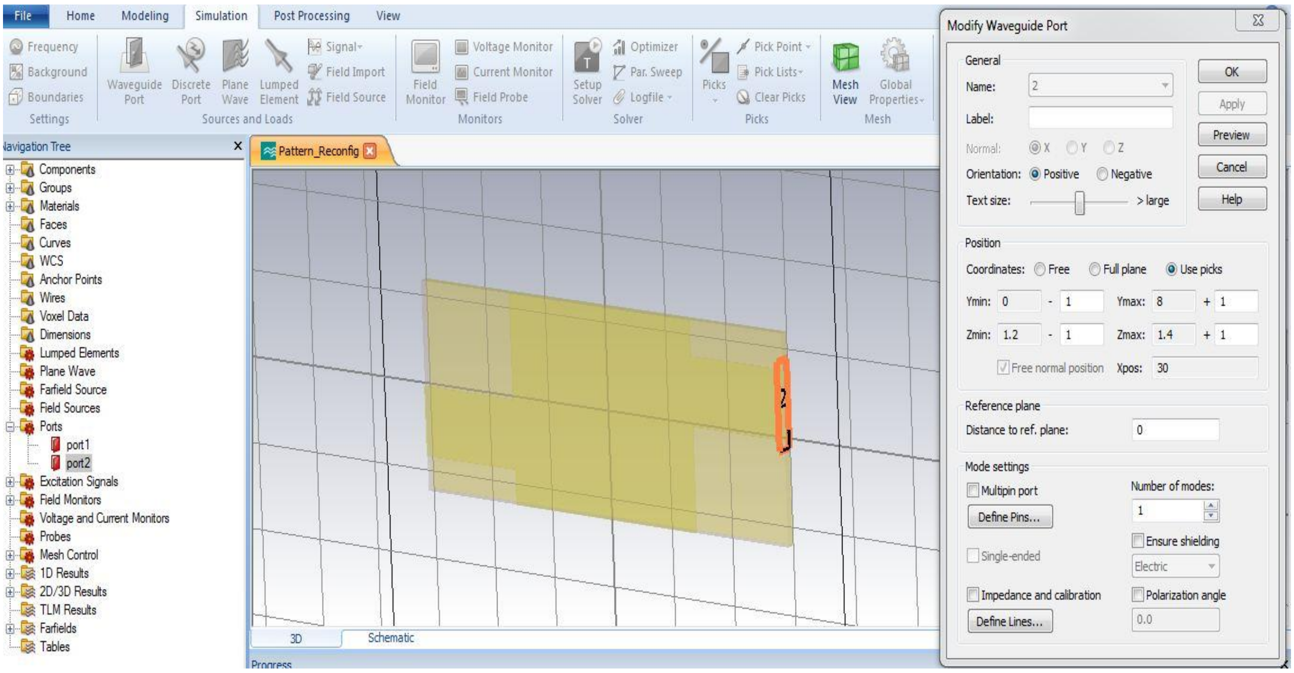


Figure 4.3: Defining Port (2-port antenna)

4.3 Simulation of 4-Port Antenna

4.3.1 Brick Tool

Figure 4.4 shows how to define the length width height of a substrate for modeling a 4-ported antenna.

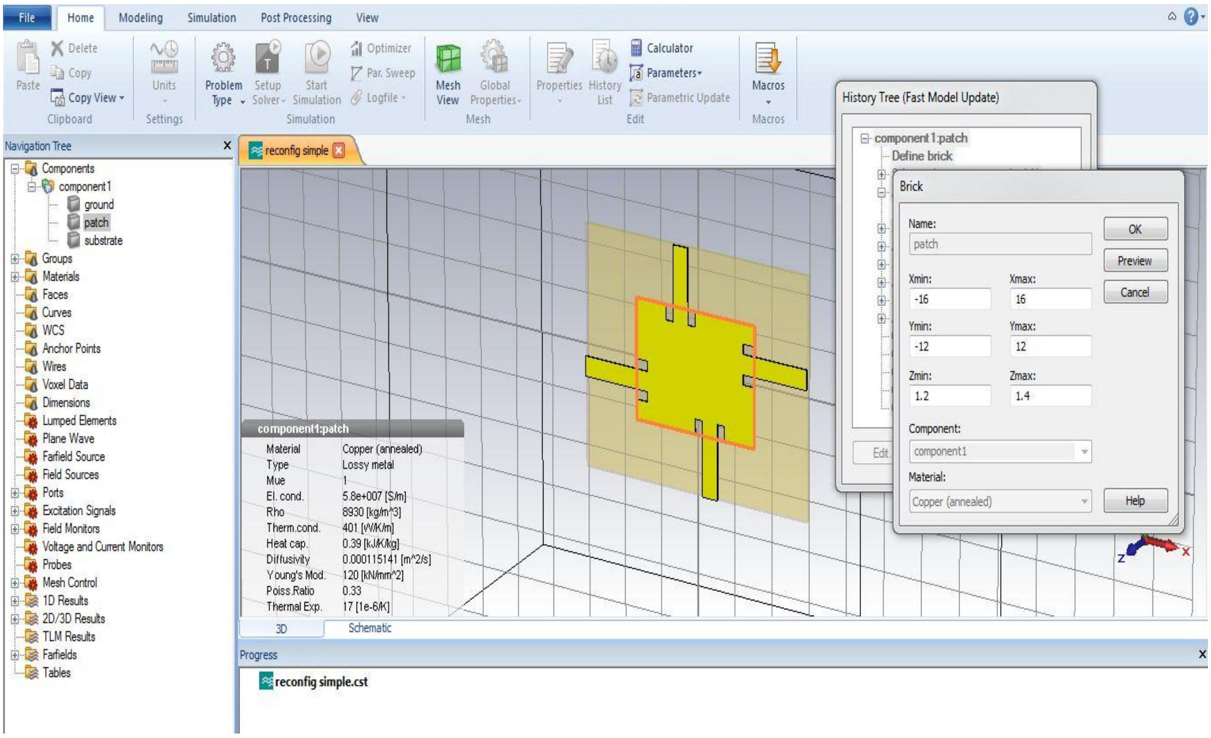


Figure 4.4: Defining Patch (4-port antenna)

4.3.2 Boolean Function Tool

Figure 4.5 shows the adding process of feed with patch by using Boolean add tool.

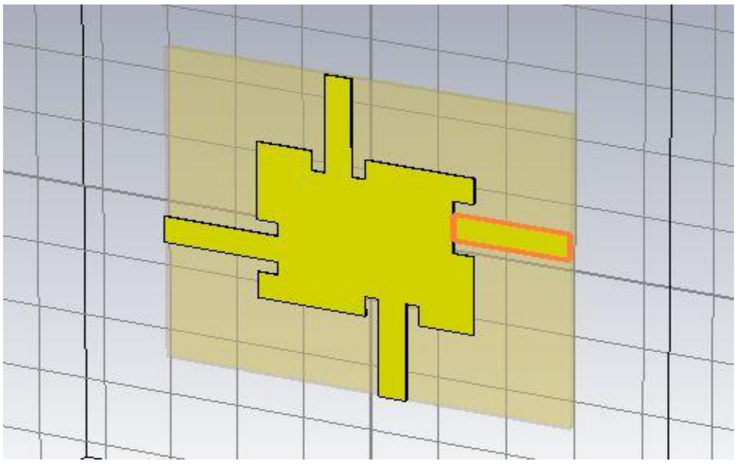


Figure 4.5: Boolean Adding Process (4-port antenna)

Figure 4.6 shows the subtracting process, here some portion of patch is eliminated.

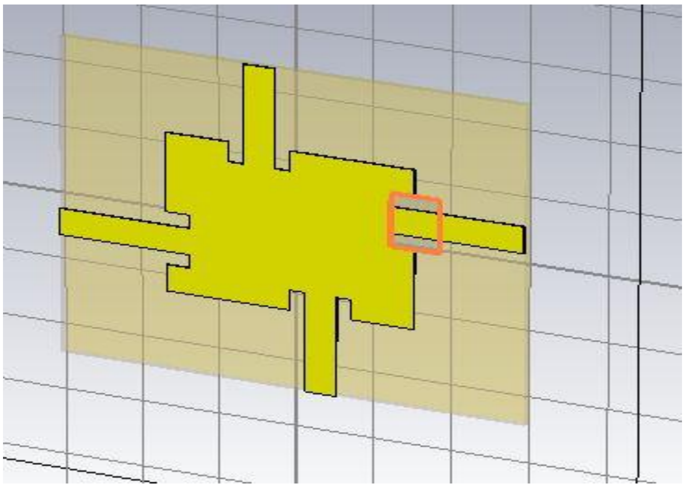


Figure 4.6: Boolean Subtracting Process (4-port antenna)

4.3.3 Modeling of Waveguide Port

Figure 4.7 shows waveguide port installation with feed line to design a 4-ported antenna. To attach a waveguide port with feed line at first need to select the feed face. Then the face of feed is needed to picked to complete the port alignment. After pick the face we go to menu bar and select wave guide port from the Simulation menu. Here comes a mini window by which we can modify the waveguide port.

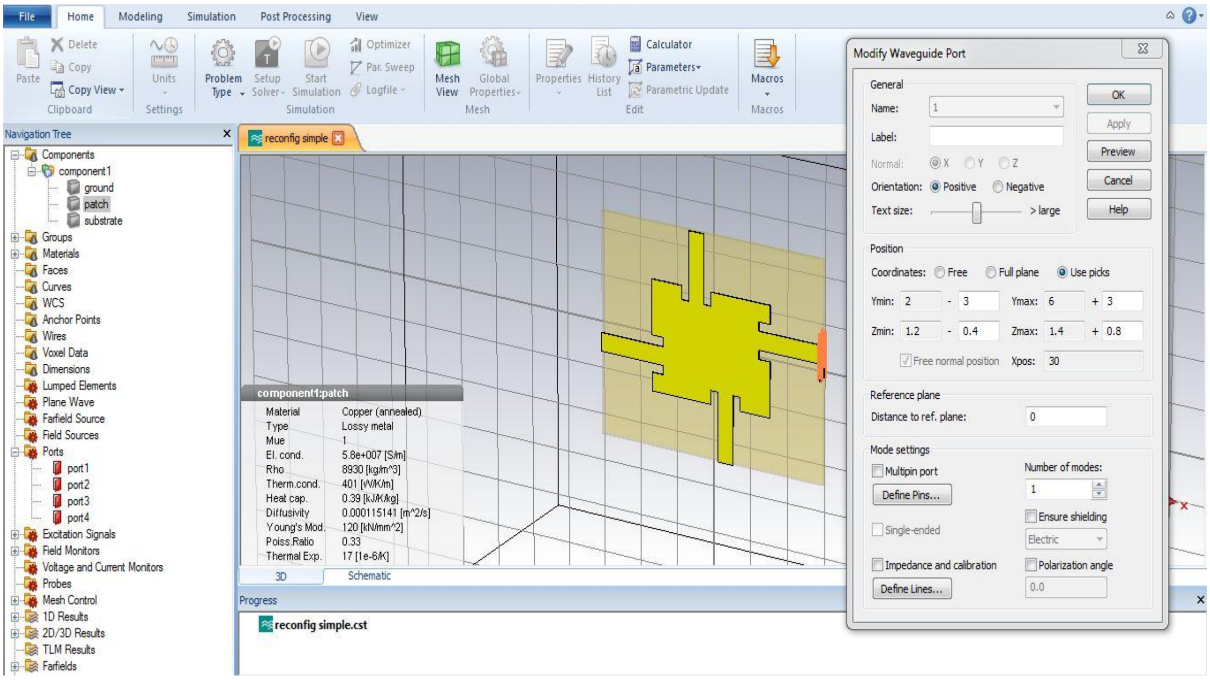


Figure 4.7: Defining Port (4-port antenna)

4.4 Parameter Sweep Tool

In a parameter sweep, the analysis in CST studio adjusts the value of a parameter by sweeping the parameter values through a user defined range. It is often necessary to perform several iterations of an antenna design in order to meet desired output. Figure 4.8 shows the user defined parameter sweep technique in CST studio.

In this figure the parameter is gnd which defines the length of the ground initially the value of this parameter is1 mm and will be increased to 20 mm through this sweep technique. The iterations depend on the number of samples or the step width such as for this sweep there will 6 iteration result. The result template shows in Fig. 4.9 define the output parameter for that parameter sweep.

It is also used for gain and directivity estimation for ranges of frequencies. In Fig. 4.8 (a) the name of the sequence is changed to the Ground Plane any name is allowed. Parameter selection in Fig. 4.8 (b) is the basic determination for which parameter one want the sweep technique. The template based processing is required for the determination of the desired output evaluation. Parametric sweep technique helps antenna modeling in a great extent.

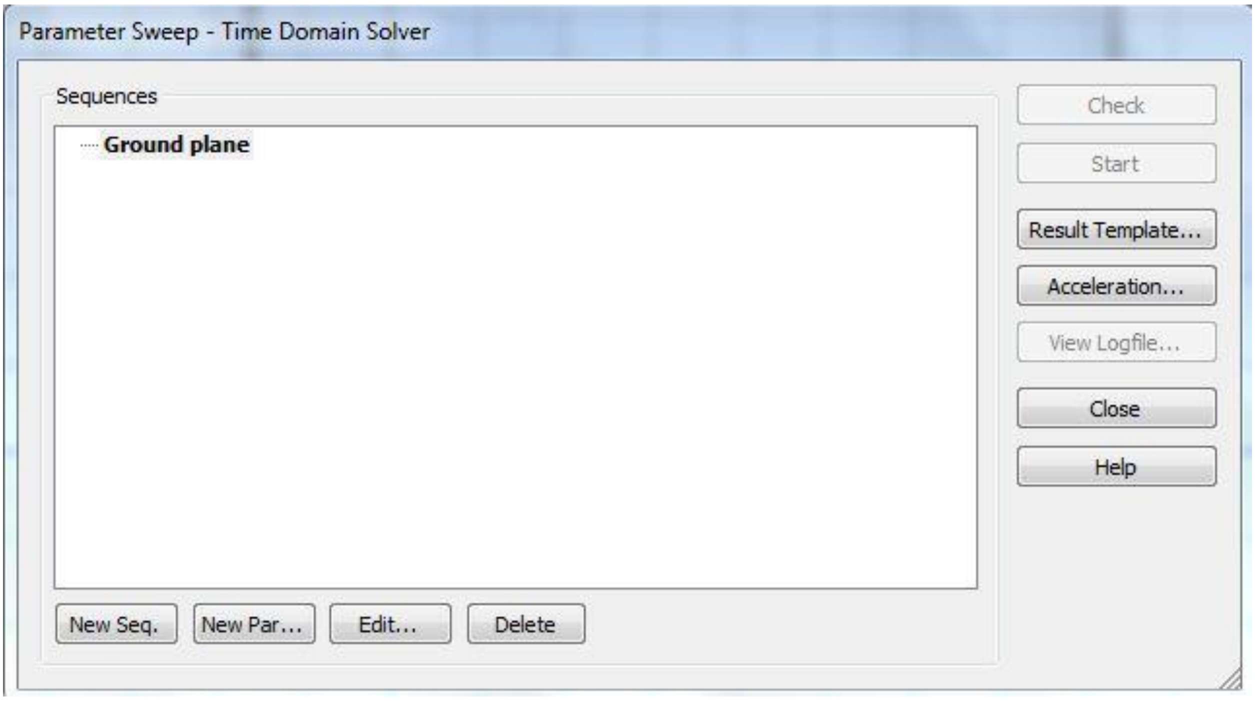


Figure 4.8 (a): Sequence Specification

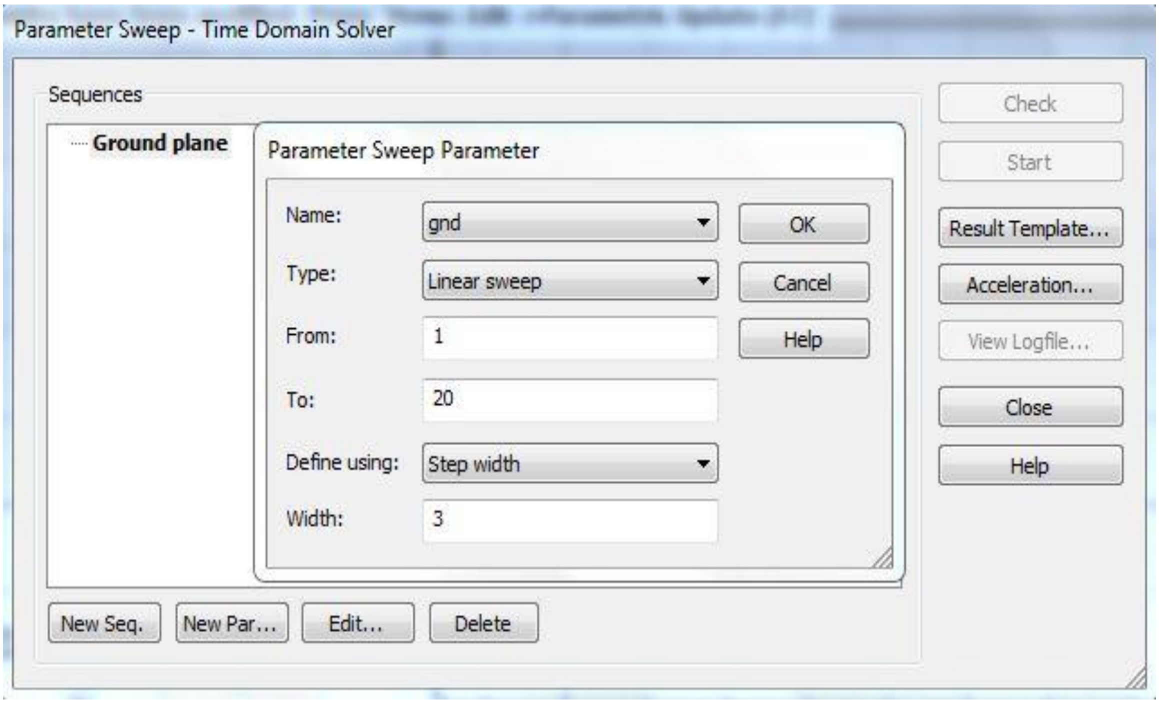


Figure 4.8(b): Parameter Specification.

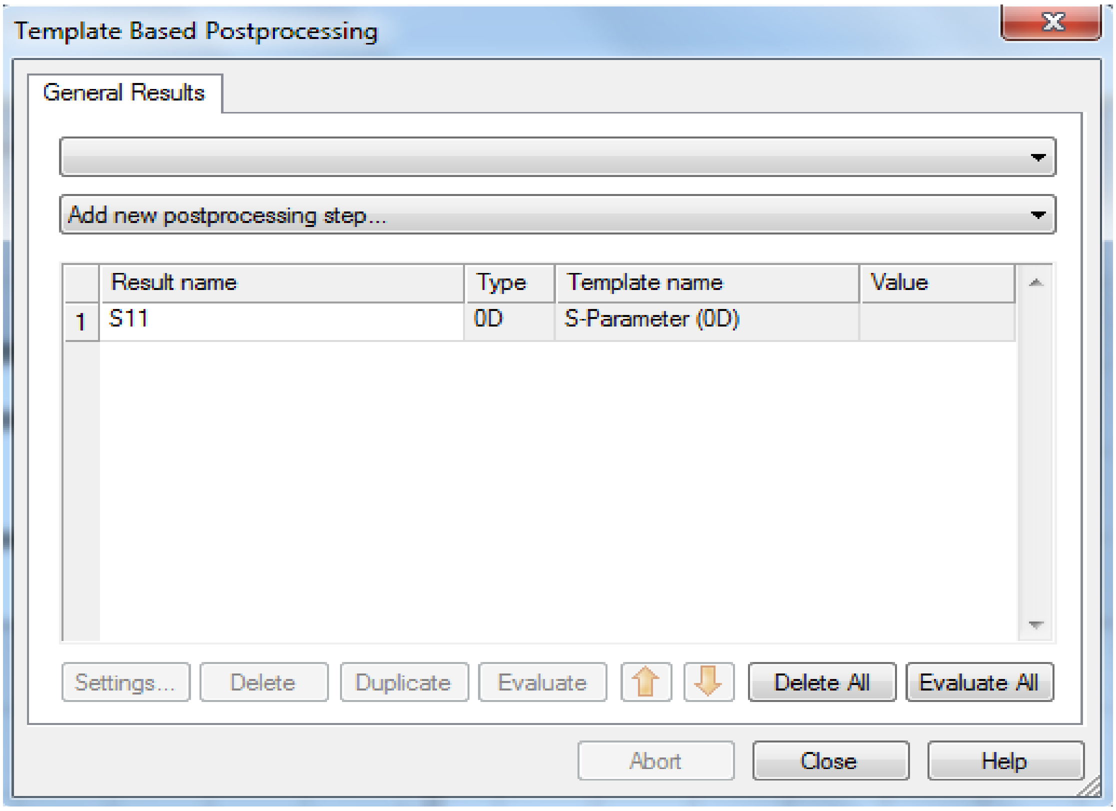


Figure 4.9: Template based output processing

CHAPTER V

Results and Discussions

CHAPTER V

Results and Discussions

5.1 Result Analysis for 2-Port Antenna

The proposed 2-port antenna has been designed and simulated by CST Studio Suite. To measure the antenna characteristics this system uses Time Domain simulation technology. The simulated results of this antenna are pointed out below.

5.1.1 Return Loss

Return loss or reflection loss is the reflection of signal power from the insertion of a device in a transmission line or optical fibre. It is expressed as ratio in dB relative to the transmitted signal power. The return loss is given by:

$$RL\ (dB) = 10\log\frac{Pr}{Pi} \qquad \text{5.1}$$

Where P_i is the power supplied by the source and P_r is the power reflected.

If V_i is the amplitude of the incident wave and V_r that of the reflected wave,
then the return loss can be expressed in terms of the reflection coefficient, г, as:

$$RL = -20|г| \qquad \text{5.2}$$

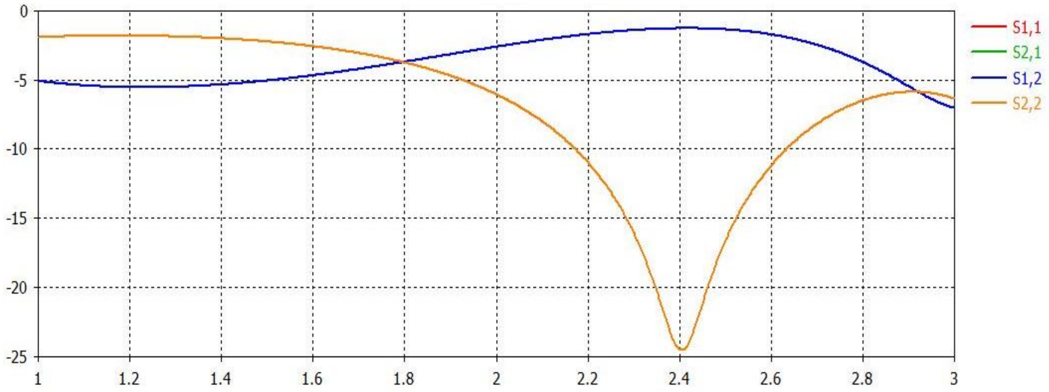
and the reflection coefficient, г, can be expressed as;

$$г = \frac{Vr}{Vi} \qquad \text{5.3}$$

For an antenna to radiate effectively, the return loss should be less than −10 dB [35].

Figure 5.1(a) shows that antenna's operating frequency is 2.4 GHz for both port-1 and port-2. It should be noted that 2.4 GHz frequency is preferable for Wi-Fi system. Figure 5.1 (b) shows s-parameter for port 1 having return loss of -24.5 dB and bandwidth of above 450 MHz that measure at -10dB [36] and Fig. 5.1 (c) shows s-parameter for port 2 having the same return loss of -24.5 dB and the same bandwidth of above 450 MHz This bandwidth is suitable for Wi-Fi systems for one channel.

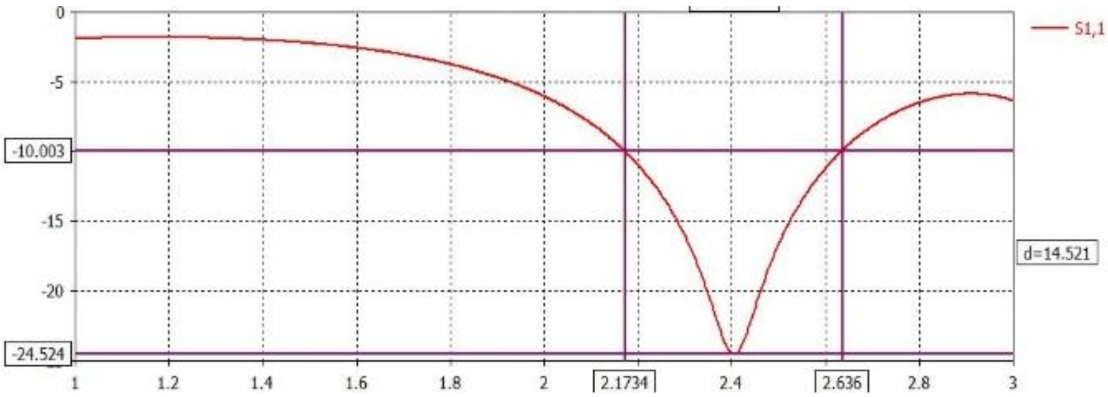
S-Parameters [Magnitude in dB]



Frequency/GHz

Figure 5.1(a): **S**-Parameter of the reconfigurable patch antenna

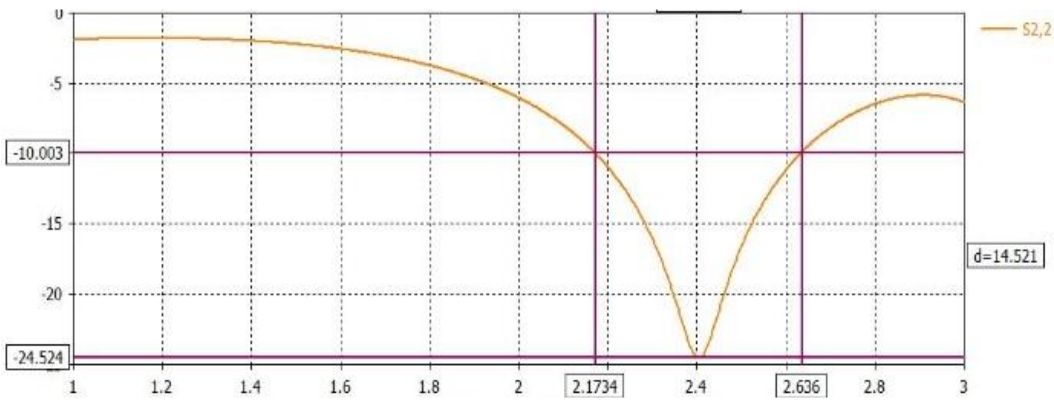
S-Parameters [Magnitude in dB]



Frequency/GHz

Figure 5.1(b): Measurement of return loss and bandwidth for port-1

S-Parameters [Magnitude in dB]



Frequency/GHz

Figure 5.1 (c): Measurement of return loss and bandwidth for port-2.

Table 5.1: S-parameter Analysis (2-port antenna)

Port	Operating frequency (GHz)	Bandwidth (MHz)	Return loss (dB)
Port-1	2.4	Above 450	-24.5
Port-2	2.4	Above 450	-24.5

Table 5.1 shows the summarized data from S-parameter of two ports of proposed antenna.

5.1.2 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. Then the Voltage Standing Wave Ratio (VSWR) can be defined as:

$$VSWR = \frac{Vmax}{Vmin} \qquad \text{……………………….5.4}$$

If the incident and reflected voltages are in phase, this will occur maximum voltage value and If the incident and reflected voltages are out of phase then minimum voltage will occur, as

$$|V_{max}|=|V_i|+|V_r| \qquad \text{……………………………5.5}$$

$$|V_{min}|=|V_i|-|V_r| \qquad \text{……………………………5.6}$$

Where V_i referred to the r.m.s. (root mean square) value of incident voltage and V_r referred to the r.m.s. (root mean square) value of reflected voltage. From VSWR and reflection coefficient definition yields out the correlation between them as follows:

$$VSWR=\frac{1+|r|}{1-|r|} \qquad \text{…………………..5.7}$$

The value of VSWR should be between 1 and 2 for efficient performance of an antenna [37].

Figure 5.2 shows VSWR of the proposed antenna is about 1.12 for port-1 and port-2 at 2.4 GHz which have been worked for Wi-Fi application.

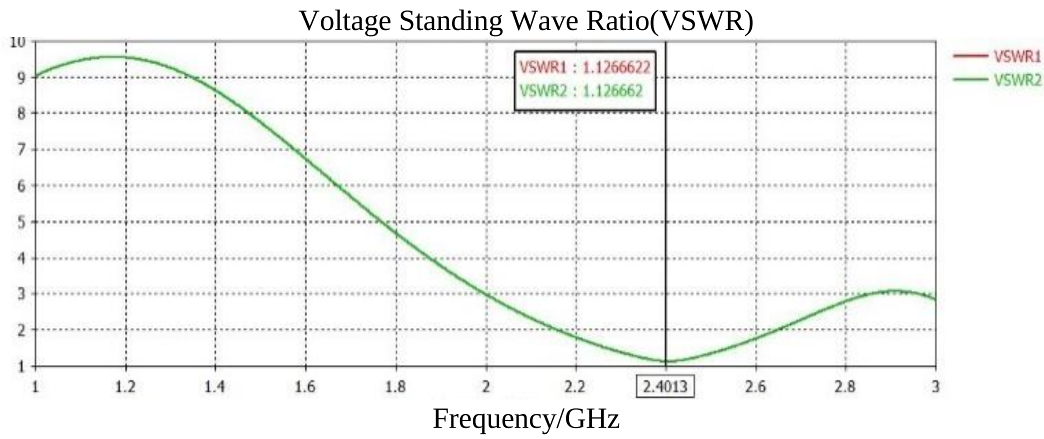


Figure 5.2: VSWR of the reconfigurable antenna for 2.4 GHz

Table 5.2: VSWR Analysis (2-port antenna)

Port	Operating Frequency (GHz)	VSWR
Port- 1	2.4	1.12
Port- 2	2.4	1.12

5.1.3 Efficiency

The total efficiency of an antenna is the radiated efficiency multiplied by impedance mismatch loss of the antenna, when connected to a transmission line or receiver. If ε_t is the total efficiency, I_L is the impedance mismatch loss or antenna's loss and ε_r is the radiated efficiency then,

$$\varepsilon_t = I_L * \varepsilon_r \quad \text{...........................5.8}$$

I_L is from 1 to 0 in value. For that reason, total efficiency is less radiated efficiency, equal will be occurred when there is no antenna loss or impedance mismatch loss. From the Fig. 5.3, it can be assumed that radiated efficiency and total efficiency is almost same at 3 GHz. So here it can be concluded that the mismatch is low.

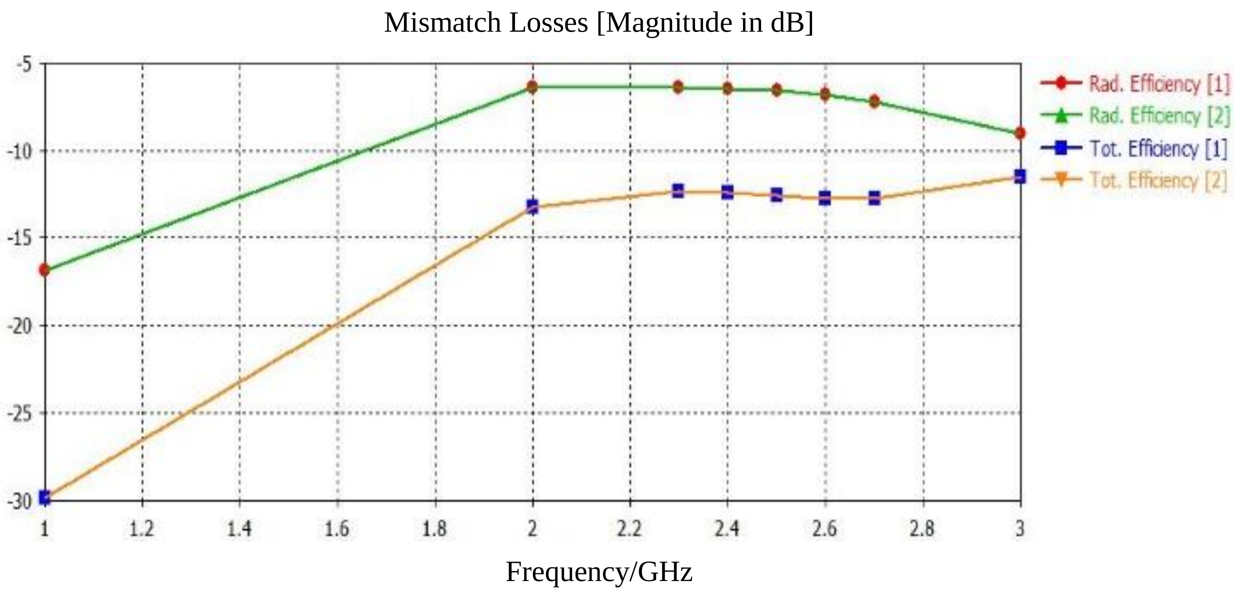
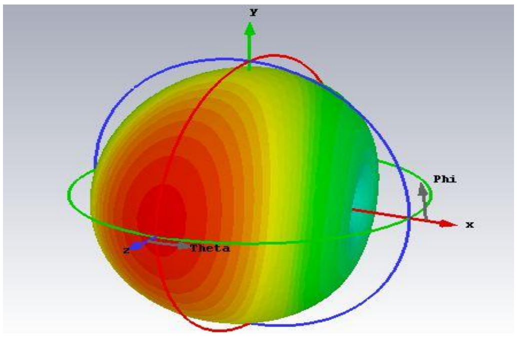


Figure 5.3: Comparison between radiated efficiencies (2-Port antenna)

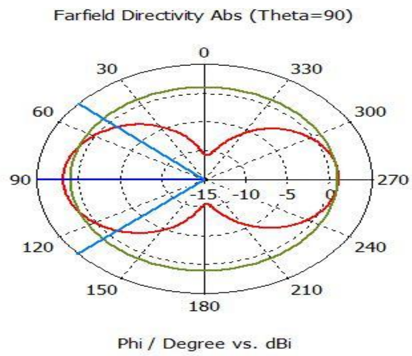
5.2 Radiation Pattern Analysis for 2-Port Antenna

5.2.1 Radiation Pattern for Port 1

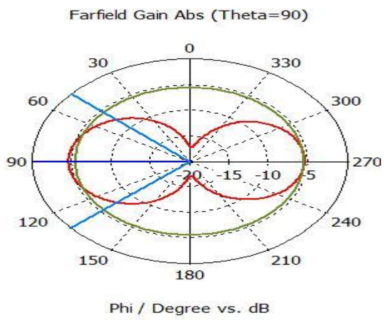
At 2.4 GHz, for Wi-Fi application of port-1, from the analysis of far-field in Fig. 5.4, it is directive antenna and directivity is 1.8 dBi. Main lobe direction is 90^0, angular bandwidth at 3dB point is 82^0 and side lobe level is -0.7 dB. It covers the region of about 48^0 to 131^0. For the e-field, the main lobe magnitude is 4.09 dBV/m and for the h-field, the main lobe magnitude is -47.4 dBA/m and power of the pattern is -21.7 dBW/m^2. The gain of the radiation pattern is -4.73dB for main lobe magnitude. Total efficiency is -30dB and radiated efficiency is -17dB.



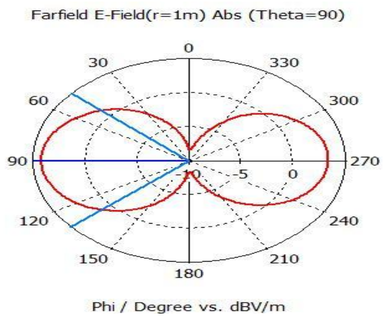
(a)



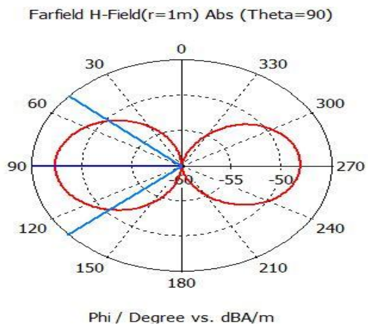
(b)



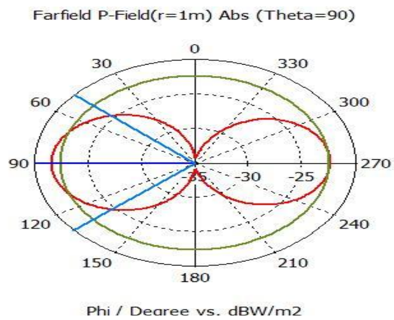
(c)



(d)



(e)

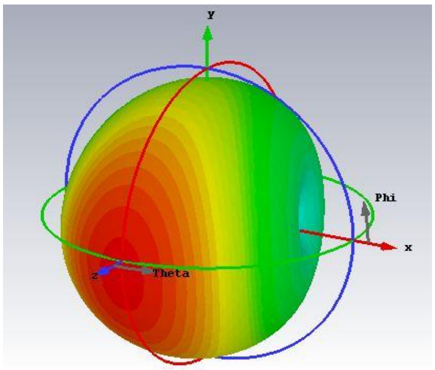


(f)

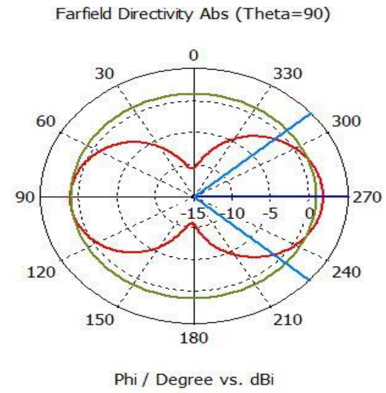
Figure 5.4: Radiation pattern at 2.4 GHz of port-1
(a) 3d view, (b) Directivity, (c) Gain, (d) E-field, (e) H-field, and (f) Power pattern

5.2.2 Radiation Pattern for Port 2

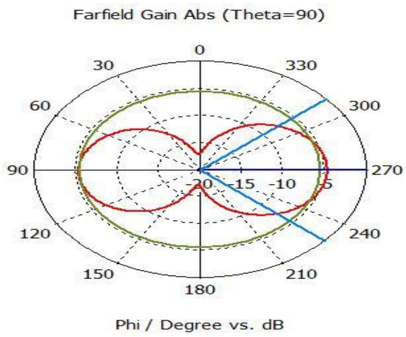
At 2.4 GHz, for Wi-Fi application of port-2, from the analysis of far-field in Fig. 5.5, it is directive antenna and directivity is 1.8 dBi. Main lobe direction is 270^0, angular bandwidth at 3dB point is 82^0 and side lobe level is -0.7 dB. It covers the region of about 228^0 to 312^0. For the e-field, the main lobe magnitude is 4.09 dBV/m and for the h-field, the main lobe magnitude is -47.4 dBA/m and power of the pattern is -21.7 dBW/m^2. The gain of the radiation pattern is -4.73dB for main lobe magnitude. Total efficiency is -30dB and radiated efficiency is -17dB.



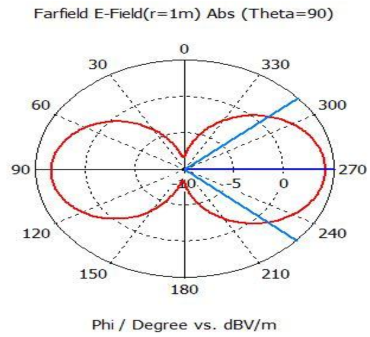
(a)



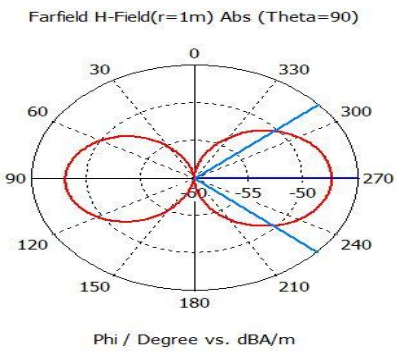
(b)



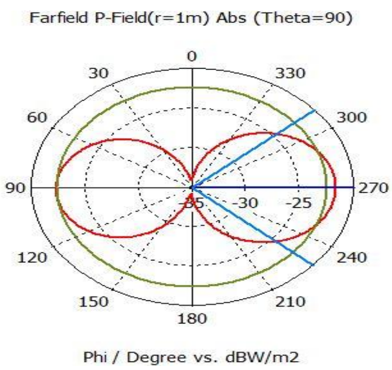
(c)



(d)



(e)



(f)

Figure 5.5: Radiation pattern at 2.4 GHz of port -2
(a) 3d view, (b) Directivity (c) Gain, (d) E-field, (e) H-field, and (f) Power Pattern

Table 5.3: Analysis of radiation pattern for 2-port antenna

Port	Frequency (GHz)	Directivity (dBi)	Gain (dB)	E-Field (dBV/m)	H-Field (dBA/m)	Power Pattern (dBW/m^2)	Angular BW 3dB (Degree)
Port 1	2.4	1.8	-4.73	4.09	-47.4	-21.7	82
Port 2	2.4	1.8	-4.73	4.09	--47.4	-21.7	82

5.3 Result Analysis for 2-Port Antenna with Slot

Another 2-port antenna with slot has been designed and simulated by CST Studio Suite. To measure the antenna characteristics this system uses Time Domain simulation technology. The simulated results of this antenna are pointed out below.

5.3.1 Return Loss

Figure 5.6 shows that antenna's operating frequency is 2.45 GHz for both port-1 and port-2. It should be noted that 2.45 GHz frequency is also preferable for Wi-Fi system. This also shows another resonant frequency at 2.74 GHz that is undesirable.

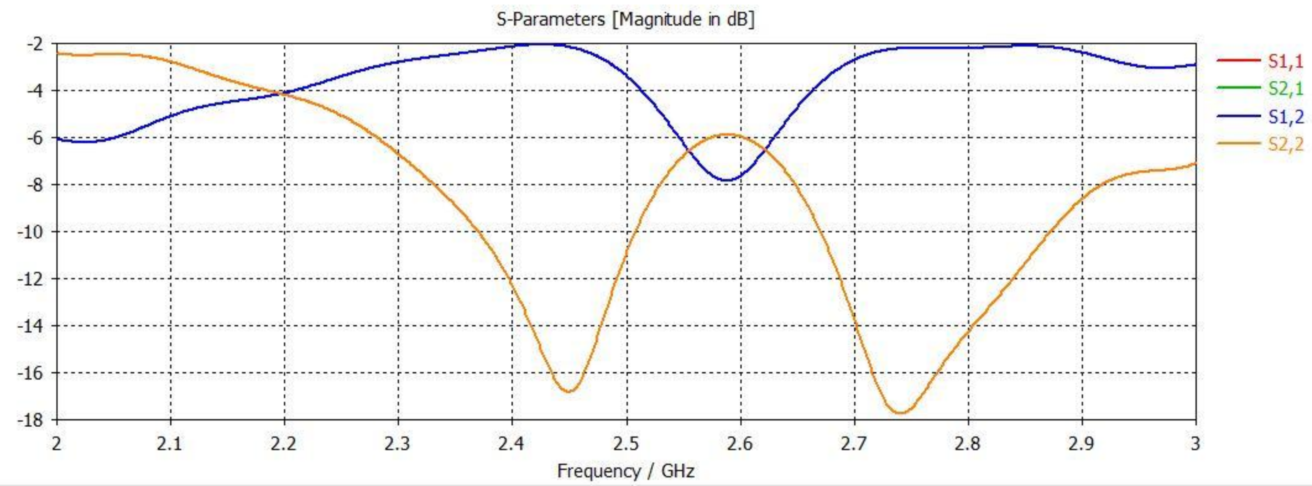
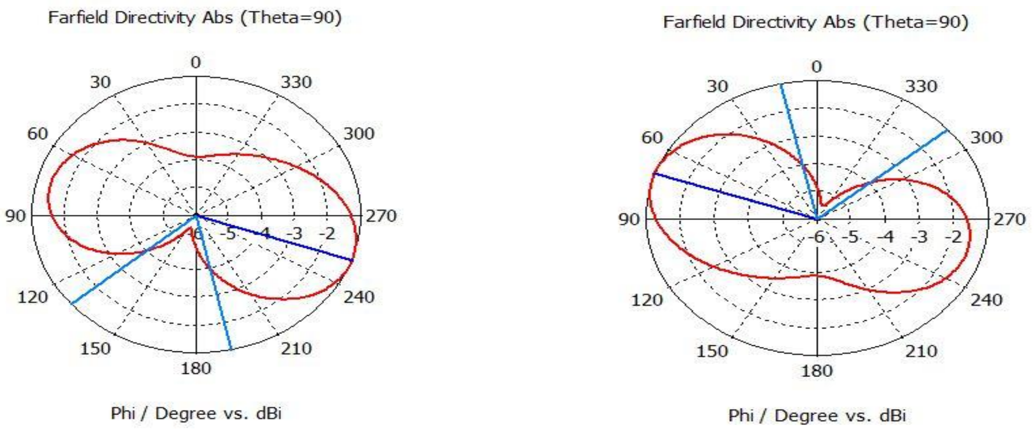


Figure 5.6: **S**-Parameter of the reconfigurable 2-port patch antenna with slot.

5.4 Radiation Pattern Analysis for 2-Port Antenna with Slot



(a) (b)

Figure 5.7: Radiation pattern at 2.45 GHz. (a) Port -1 and (b) Port-2

Figure 5.7 shows from the analysis of far-field, at 2.45 GHz, for Wi-Fi application for both port, it is directive antenna and directivity is -1 dBi, that is unexpected. The main lobe direction for port-1 is 251^0, angular bandwidth at 3dB point is 298^0. and the main lobe direction for port-1 is 71^0, angular bandwidth at 3dB point is also 298^0.

5.5 Result Analysis for 4-Port Antenna

A four port antenna has been designed and simulated by CST Studio Suite. To measure the antenna characteristics this system uses Time-Domain simulation technology. The simulated results of this 4-port antenna are pointed out below.

5.5.1 Return Loss

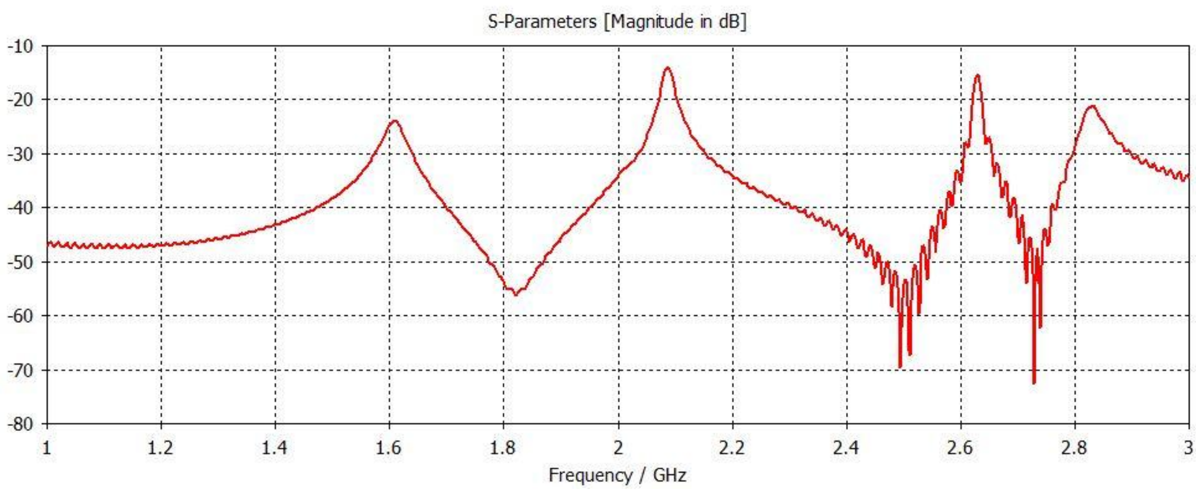


Figure 5.8: **S**-Parameter of the reconfigurable 4-port patch antenna for port-1 & port-3.

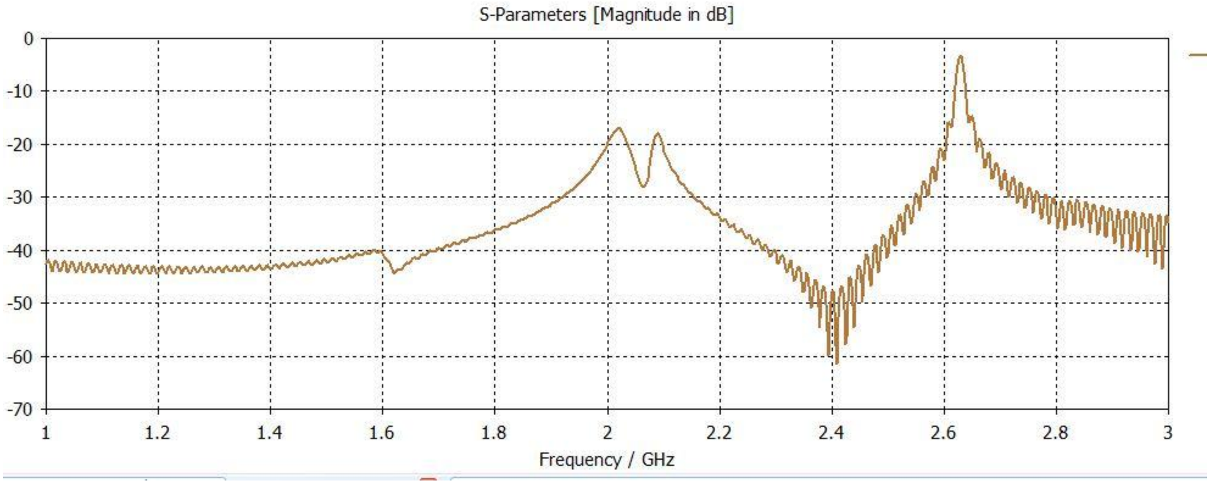
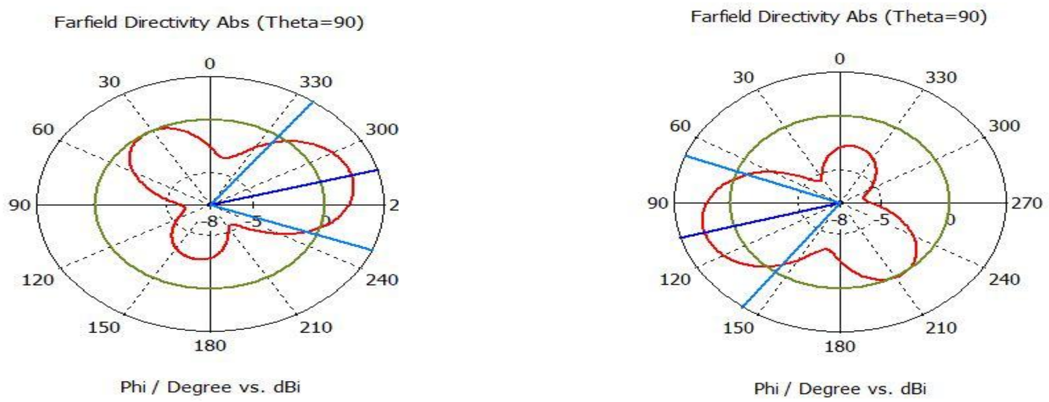


Figure 5.9: **S**-Parameter of the reconfigurable 4-port patch antenna for port-2 & port-4.

Figure 5.8 shows that the antenna has multi operating frequencies for port-1 and port-3 which does not desire. It should be noted that 2.45 GHz frequency is preferable for Wi-Fi system. Figure 5.9 shows that antenna's operating frequency is 2.4 GHz for port-2 and port-4. It should be noted that 2.45 GHz frequency is also preferable for Wi-Fi system

5.6 Radiation Pattern Analysis for 4-Port Antenna



(a) (b)

Figure 5.10(a): Radiation pattern at 2.4 GHz. (a) Port -1 and (b) Port-3

Figure 5.10(a) shows from the analysis of far-field, at 2.4 GHz, for Wi-Fi application for port-1 & port-2, it is directive antenna and directivity is 2.13 dBi. The main lobe direction for port-1 is 286^0, angular bandwidth at 3dB point is 74.9^0. and the main lobe direction for port-3 is 106^0, angular bandwidth at 3dB point is also 74.9^0.

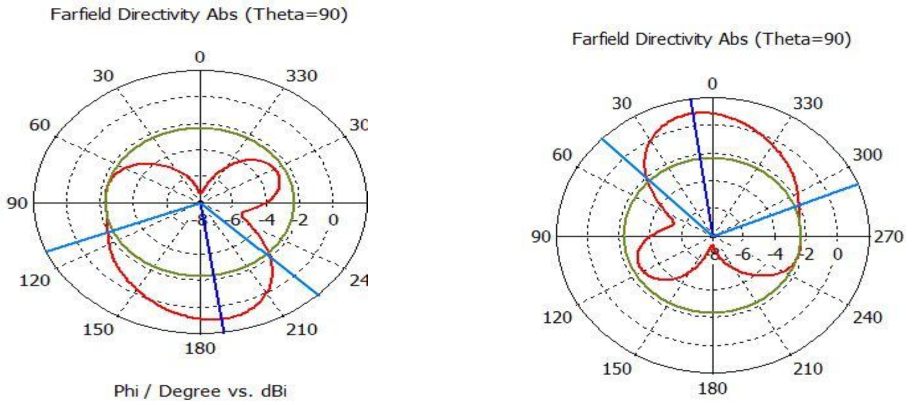


Figure 5.10 (b): Radiation pattern at 2.4 GHz. (a) Port -2 and (b) Port-4

Figure 5.10(b) shows from the analysis of far-field, at 2.4 GHz, for Wi-Fi application for port-2 & port-4, it is directive antenna and directivity is 0.94 dBi, that is not reasonable. The main lobe direction for port-2 is 188^0, angular bandwidth at 3dB point is 113.2^0. and the main lobe direction for port-4 is 8^0, angular bandwidth at 3dB point is also 113.2^0.

5.7 Result Analysis for 4-Port Antenna with Slot

Another four port antenna with slot has been designed and simulated by CST (Computer Simulation Technology) Studio Suite. To measure the antenna characteristics this system uses Time-Domain simulation technology. The simulated results of this 4-port antenna are pointed out below.

5.7.1 Return Loss

Figure 5.11(a) shows that antenna's operating frequencies are 2.45 GHz for port 1 and port 4 and 2.6 GHz for port 2 and port 3. Here 2.45 GHz works for Wi-Fi and 2.6 GHz works for WiMAX. From the Fig. 5.11 (b) shows s-parameter for port 1 and port 4 having return loss of -49.2 dB and bandwidth of 21 MHz. From the figure 5.11(c) shows s-parameter for port 2 and port 3 having return loss of -45 dB and bandwidth of 51 MHz. The bandwidth is suitable for both Wi-Fi and WiMAX systems for one channel.

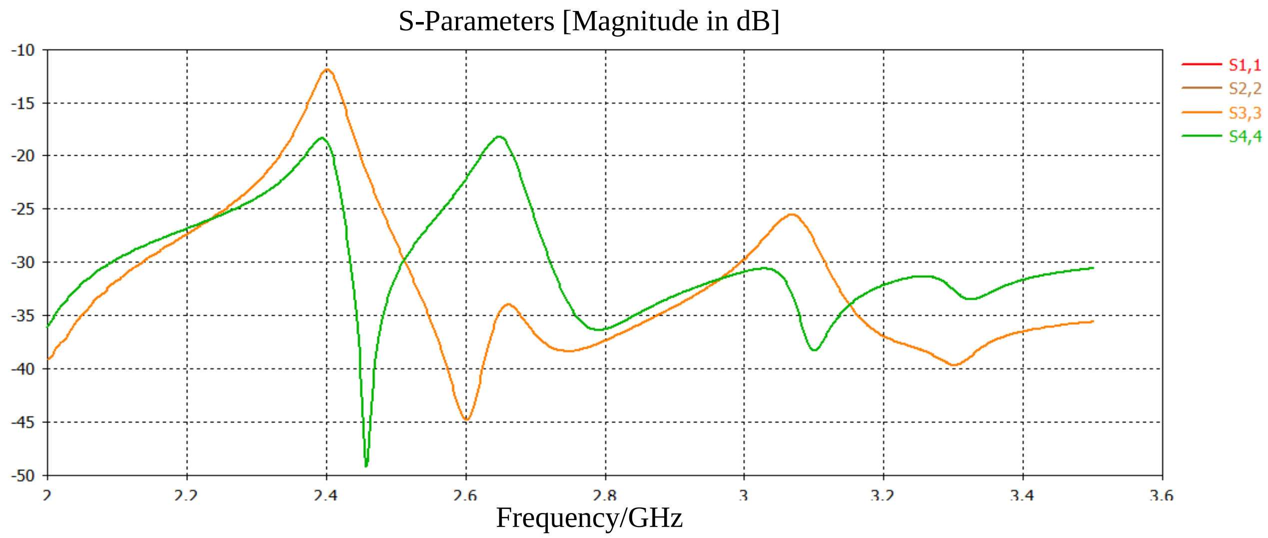


Figure 5.11(a): S-Parameter of the reconfigurable patch antenna

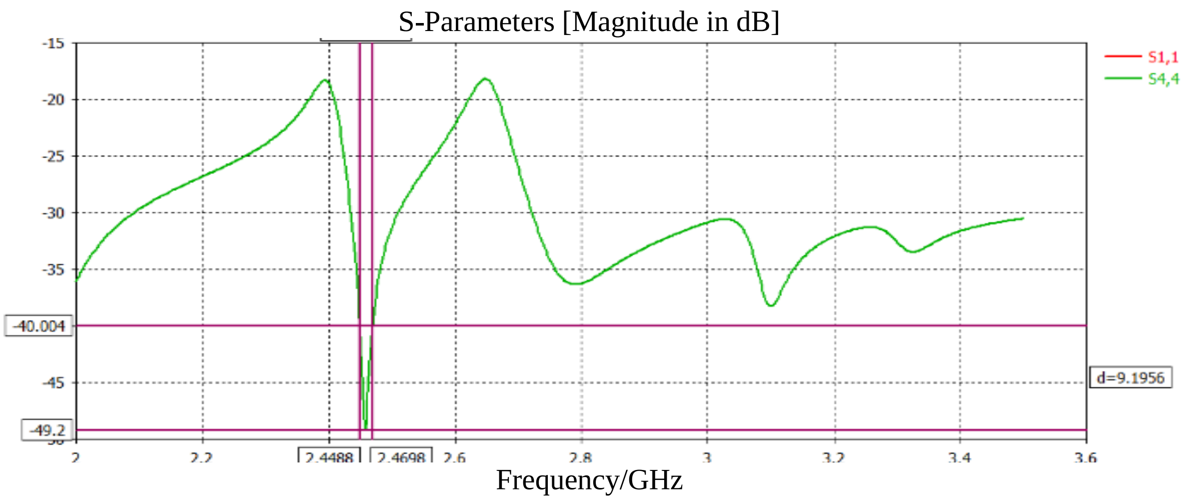


Figure 5.11(b): Measurement of return loss and bandwidth for Wi-Fi

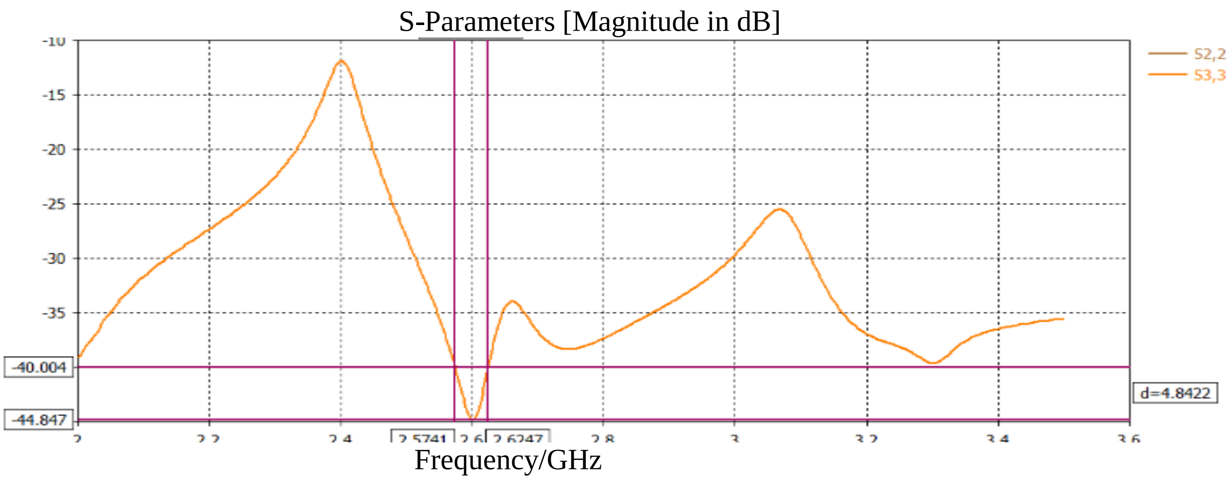


Figure 5.11(c): Measurement of return loss and bandwidth for WiMAX.

Table 5.4: S-parameter Analysis (4-port antenna)

Applications	Operating frequency (GHz)	Bandwidth (MHz)	Return loss (dB)
Wi-Fi	2.45	21	-49.2
WiMAX	2.6	51	-45

5.7.2 VSWR

Figure 5.12 (b) shows VSWR is about 1.006 for port-1 and port-4 at 2.45 GHz which have been worked for Wi-Fi and Fig. 5.12(c) shows VSWR is about 1.01 for port 2 and port 3 at 2.6 GHz which have been worked for WiMAX.

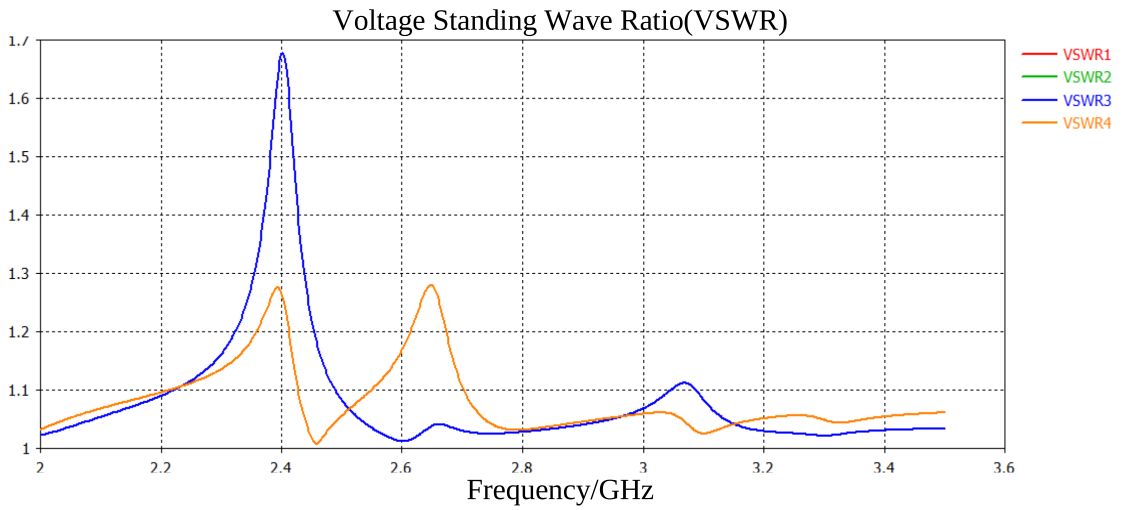


Figure 5.12(a): VSWR of the reconfigurable antenna for all ports

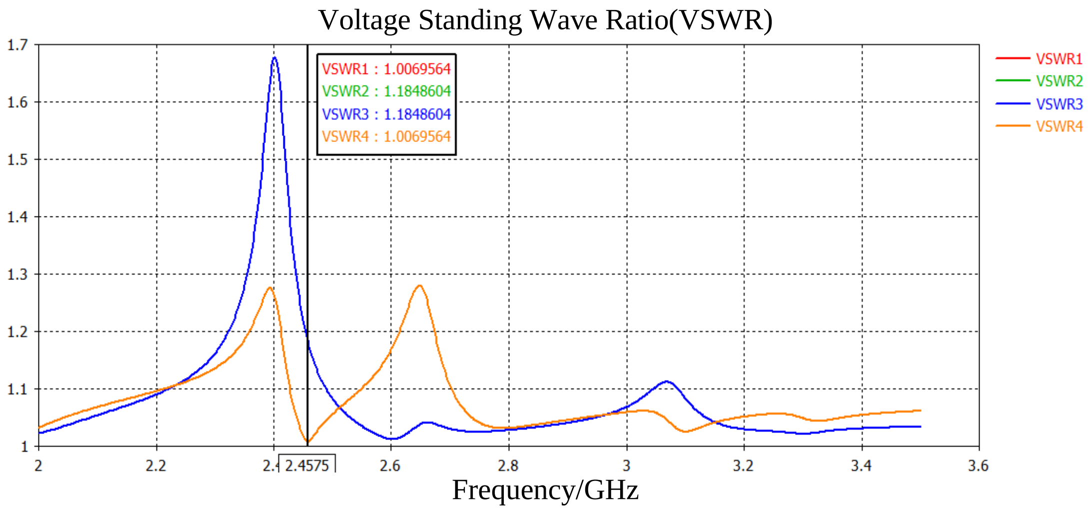


Figure 5.12(b): VSWR of the reconfigurable antenna for 2.45 GHz (Wi-Fi)

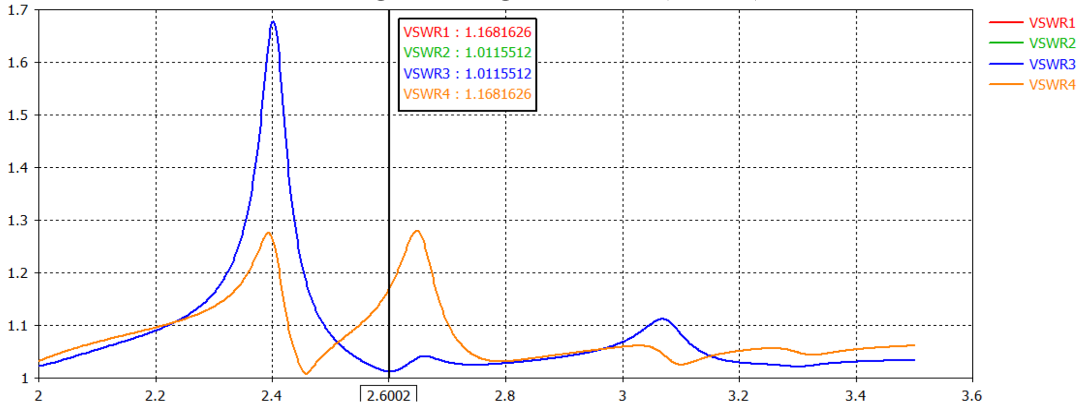


Figure 5.12(c) : VSWR of the reconfigurable antenna for 2.6 GHz (WiMAX)

Table 5.5: VSWR Analysis (4-port antenna)

Systems	Operating Frequency (GHz)	VSWR
Port 1 & Port 4 (W-Fi)	2.45	1.006
Port 2 & Port 3 (WiMAX)	2.6	1.01

5.7.3 Efficiency

From the Fig. 5.13, it can be assumed that radiation efficiency and total efficiency is almost same at 2.44 GHz for port 1 and port 4, it is about -14 dB and at 2.5 GHz or later for port 2 and port 3, it is about -16dB. So, here, it can be concluded that the mismatch is low almost null at the operated frequency for all the ports of this antenna.

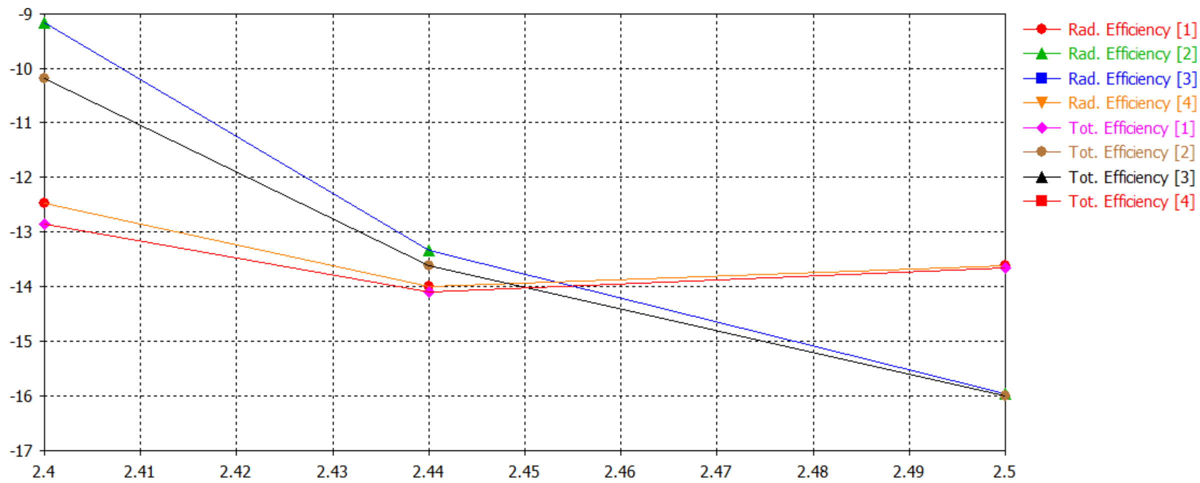
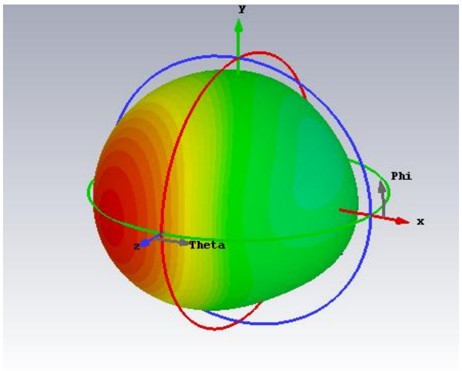


Figure 5.13: Comparison between radiated efficiencies (4-Port antenna)

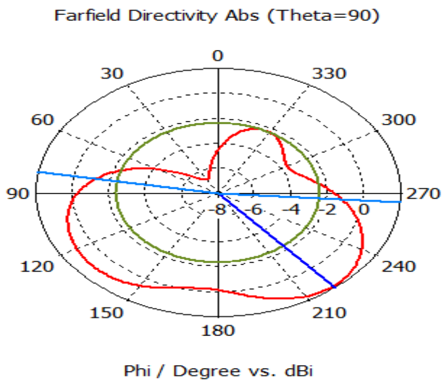
5.8 Radiation Pattern Analysis 4-Port Antenna

5.8.1 Radiation Pattern for Port 1

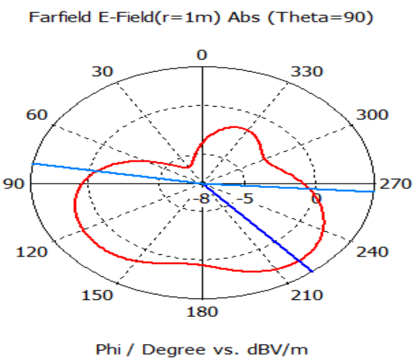
Figure 5.14 shows that, it is a directive antenna and its directivity is 2 dBi at 2.45GHz for port-1. This frequency operates Wi-Fi system. Main lobe direction is 220^0 degree, angular bandwidth at 3dB point is 185^0 degree and side lobe level is -4.1 dB. It covers the region of about 80^0 to 265^0. The e-field for main lobe magnitude is 2.44 dBV/m, h-field for main lobe magnitude is -49.1 dBA/m and power of the pattern is -23.3 dBW/m^2. The gain of the radiation pattern is -4.1dB for main lobe magnitude.



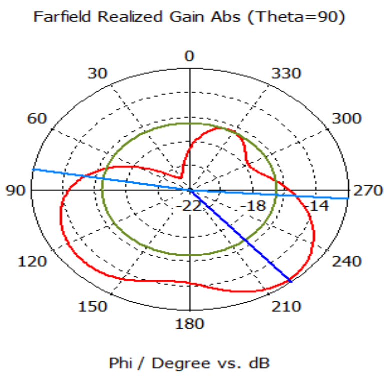
(a)



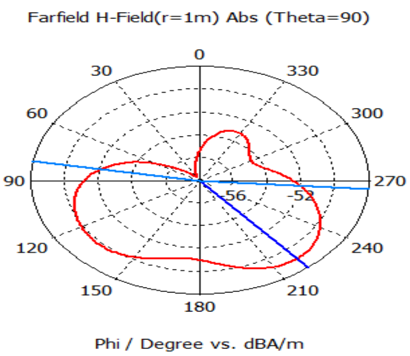
(b)



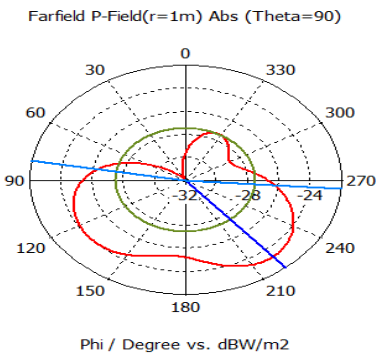
(c)



(d)



(e)



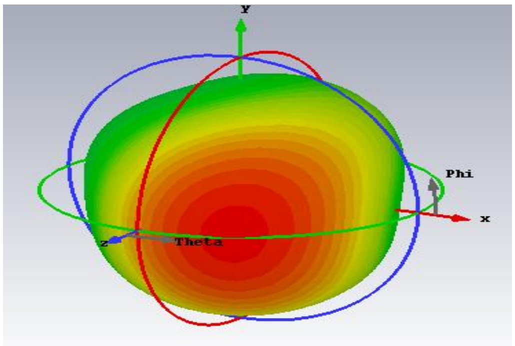
(f)

Figure 5.14: Radiation pattern at 2.45 GHz for Wi-Fi of port1

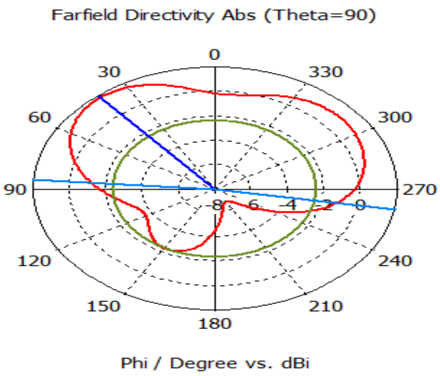
(a) 3d view, (b) Directivity, (c) H-field, and (d) Gain, (e) H-field, and (f) Power Pattern

5.8.2 Radiation Pattern for Port 4

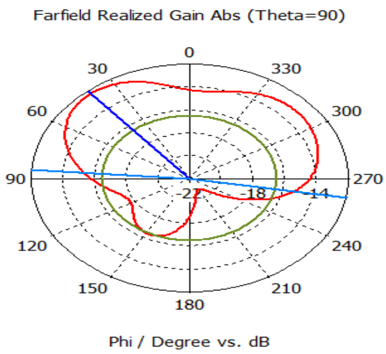
At 2.45 GHz, for Wi-Fi application of port-4, from the analysis of far-field in Fig. 5.15, it is directive antenna and directivity is 2 dBi. Main lobe direction is 40^0, angular bandwidth at 3dB point is 185^0 degree and side lobe level is -4.1 dB. It covers the region of another half of about 80^0 to 265^0, so total 360^0 is covered by the 2 ports: port-1 and port-4. The e-field for main lobe magnitude is 2.44 dBV/m, h-field for main lobe magnitude is -49.1 dBA/m and power of the pattern is -23.3 dBW/m^2. The gain of the radiation pattern is -4.1 dB for main lobe magnitude.



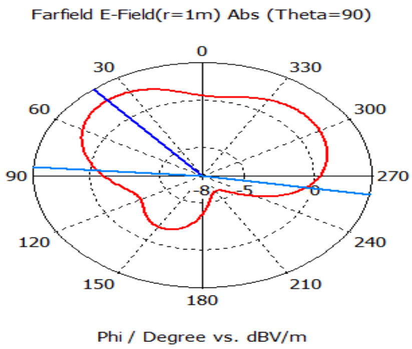
(a)



(b)



(c)



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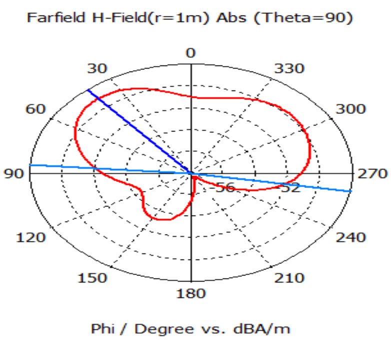

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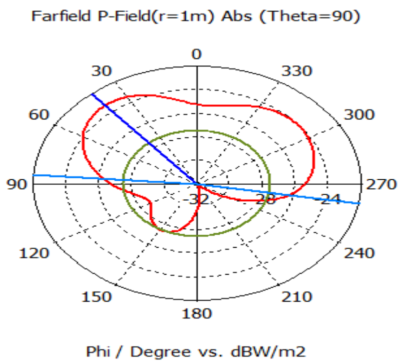
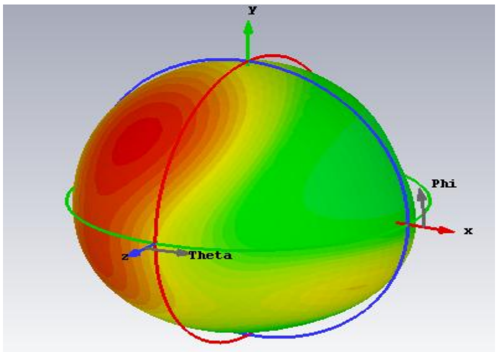


(f)

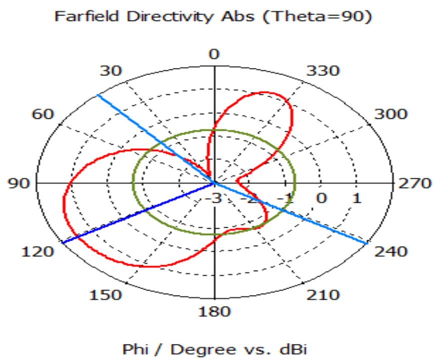
Figure 5.15: Radiation pattern at 2.45 GHz for Wi-Fi of port 4.
(a) 3d view (b) Directivity (c) Gain, (d) E-field, (e) H-field, and (f) Power Pattern

5.8.3 Radiation Pattern for Port 2

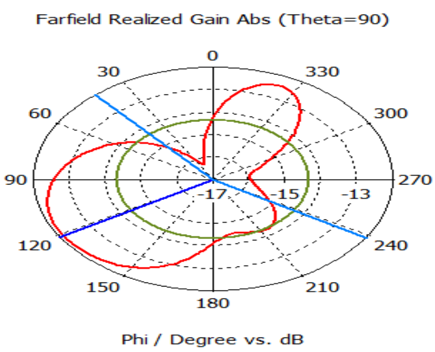
From the analysis of far-field pattern, it has been demonstrated that, it is a directive antenna and its directivity is 1.5 dBi at 2.6 GHz that operates WiMAX application of port-2 in Fig. 5.16. The main lobe direction is 121^0 degree, angular bandwidth at 3dB point is 195^0 degree and side lobe level is -2.2 dB. It covers the region of about 44^0 to 239^0. The e-field for main lobe magnitude is 2.61 dBV/m, h-field for main lobe magnitude is -48.9 dBA/m and power of the pattern is -23.1 dBW/m^2. The gain of the radiation pattern is -12.2 dB for main lobe magnitude.



(a)



(b)



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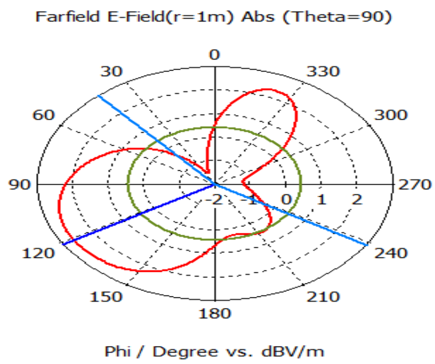

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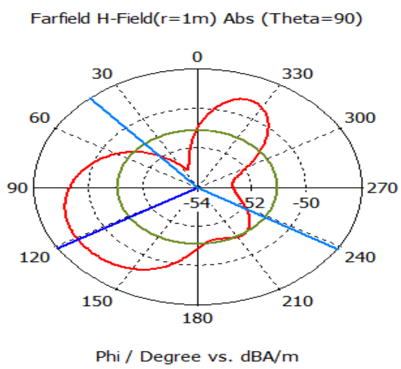
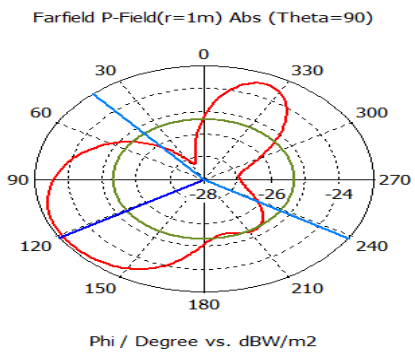


(e)



(f)

Figure 5.16: Radiation pattern at 2.6 GHz for WiMAX port 2

(a) 3d view, (b) Directivity, (c) Gain, (d) E-field, (e) H-field, and (f) Power Pattern

5.8.4 Radiation Pattern for Port 3

For WiMAX application of port-3 at 2.6 GHz, the antenna is a directive antenna and its directivity is 1.5 dBi from the analysis of far-field radiation pattern shown in Fig. 5.17. Main lobe direction is 301^0 degrees, angular bandwidth at 3dB point is 195^0 degree and side lobe level is -2.2 dB. It covers the region of another half of about 59^0 to 224^0, so both ports: port-2 and port-3 covers the region of 360^0. The e-field for main lobe magnitude is 2.61 dBV/m, h-field for main lobe magnitude is -48.9 dBA/m and power of the pattern is -23.1 dBW/m^2. The gain of the radiation pattern is -12.2 dB for main lobe magnitude.

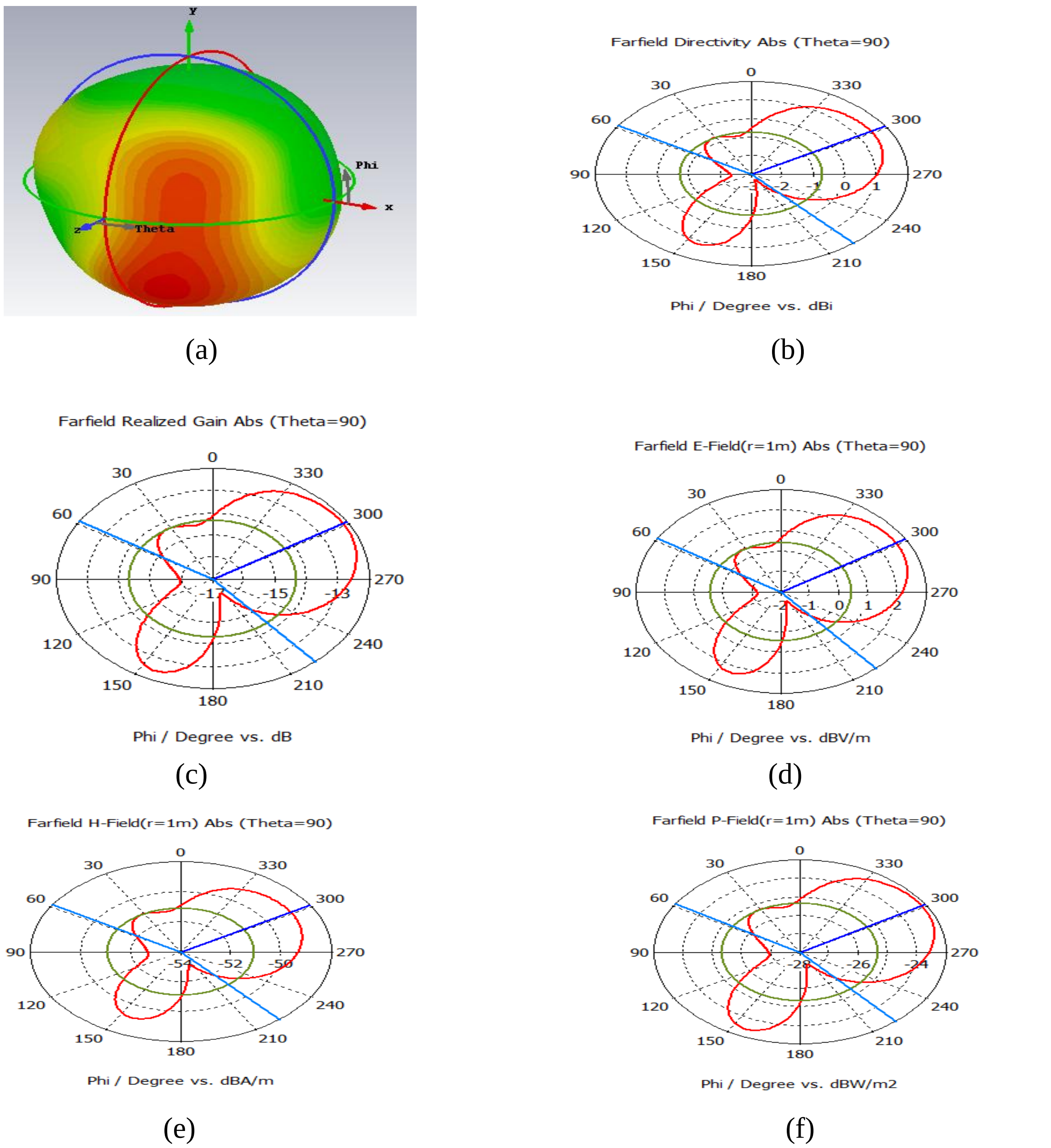


Figure 5.17: Radiation pattern at 2.6 GHz for WiMAX port-3

(a) 3d view, (b) Directivity, (c) Gain, (d) E-field, (e) H-field, and (f) Power Pattern

Table 5.6: Analysis of radiation pattern for 4-port antenna

Port	System	Frequency (GHz)	Directivity (dBi)	Gain (dB)	E-Field (dBV/m)	H-Field (dBA/m)	Power Pattern (dBW/m^2)	Angular BW 3dB (Degree)
Port 1	Wi-Fi	2.45	2	-4.1	2.44	-49.1	-23.3	185
Port 4	Wi-Fi	2.45	2	-4.1	2.44	-49.1	-23.3	185
Port 2	WiMAX	2.6	1.5	-12.2	2.61	-48.9	-23.1	195
Port 3	WiMAX	2.6	1.5	-12.2	2.61	-48.9	-23.1	195

CHAPTER VI

Conclusions and Future Works

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Conclusions and Future Works

6.1 Introduction

This research presents a simple technique to achieve pattern reconfigurable antenna, with a fixed resonant frequency, that operates within a Wi-Fi frequency band. This compact method for pattern reconfigurable antenna design is introduced as a simpler structure of patch. The waveguide of patch is also simpler in form, that is able to fascinated for designing a Wi-Fi base station.

6.2 Comparison between result of proposed antenna and some recent years works

Table 6.1 shows a summarized result of comparison between proposed antenna and related other antenna those are developed in recent year.

Table 6.1: Comparison between result of proposed antenna and some recent years works

Researcher, Year [Ref.]	**Application**	**Bandwidth MHz**	**Return Loss(dB)**	**Used Technology**	**Frequency GHz**
D. C Chang, 2009 [13]	Wi-Fi System	170	22	Dipole Array	2.4
Nan Liu, 2010 [25]	Wi-Fi System	233	>-35	Switching Technology	5.77
M. AA-Dahab, 2015 [12]	Wi-Fi System	400	-17	Array Technology	5.8
Proposed 2-Port Antenna	Wi-Fi Technology	455	-24.5	Only Ports	2.4
Proposed 4-Port Antenna	Wi-Fi Technology, WiMAX	21, 51	-49	Only Ports	2.45, 2.6

6.3 Conclusion

The above result indicates that the proposed design of antenna for Wi-Fi base station is better option due to its directivity. It has been shown that, this beam switching antenna is able to reconfigure pattern at a given operating frequency. It is also showed that there is no need to use any type of switching element in this reconfigurable patch antenna. This research work demonstrated that the antenna has preferable directivity and gain (-4.73dB) for wireless technology. The simulated and measured results prove that the proposed antenna is good for wireless communication. The proposed antenna also showed its VSWR is about 1.12 that expectable value for a perfect antenna designation. This antenna is capable to offer above 450 MHz bandwidth that said to be high speed technology for one channel base station.

6.4 Future Work

The designed antenna is now ready to implement in practical field with supporting hardware. This cannot be able to fully reconfigure the radiation energy. But the research is still proceeding.

Publications

Published

- Atik Mahabub, Md Nazmul Islam and Md. Mostafizur Rahman, "An Advanced Design of Pattern Reconfigurable Antenna for Wi-Fi and WiMAX Base Station", *IEEE 4th International Conference on Advances in Electrical Engineering (ICAEE*), 28-30 September, 2017, Dhaka, Bangladesh.

- Md Nazmul Islam, Md Masud Rana and Md. Mostafizur Rahman, "An Effective Pattern Reconfigurable Antenna Without Using Switching Technology", *3rd International Conference on Inventive Computation Technologies (ICICT),* 15-16 November, 2018, Tamil Nadu, India.

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APPENDIX

Software

In this thesis only one software is used. This is CST (Computer Simulation Technology) STUDIO 2015.

CST Microwave STUDIO Software

CST Microwave STUDIO provides a variety of tools for each stage of the antenna design flow to study and improve the design. By using this software different types of microstrip patch antennas can be designed and their performance can be analyzed.

Designing procedure

Designing procedure of microstrip patch antenna by using CST Microwave STUDIO software is given below:

At the beginning choose **File-> New** to create a new project

↓

Choose **CST MICROWAVE STUDIO** in the project window

↓

Choose the template **Antenna(Planar)** in the project template window

Choose vacuum as background material in the project **Background Properties** window

↓

Confirm all the units in the **Units** window

↓

Choose the brick option and press **Esc** key in the keyboard

↓

In the **Brick** window define all the dimensions in mm

↓

Choose the material from material library

↓

Write a name of the structure

↓

Press **OK** and the structure will be drawn

↓

Pick face and align WCS with the selected face

↓

Draw another structure on the selected face by using the **Brick** option

↓

Draw “Ground plane”, “Substrate”, “Patch” and “Microstrip Feed line” in this process

↓

Perform a **Boolean add** to add the “Microstrip Feed line” with the “Patch”

↓

Pick the edge of the “Microstrip Feed line” and align WCS with the selected face

↓

Choose the **Waveguide Port** and define all the parameters in this window

↓

Press **OK** and the port will be created

↓

Set the frequency range

↓

Add **Field Monitors** and define E-field, H-field and Farfield/RCS at the operating frequency

↓

Define the **Boundary Conditions** and the **Symmetry Planes**

↓

Choose the **Transient Solver** and define the **Normalize to fixed impedance** as 50 ohms

↓

Press **Start** and the solver will be run

↓

When the simulation is finished all the simulation results will be saved in **1D Results** and **2D/3D Results** in the navigation tree

↓

Choose the **S-Parameters** in the **1D Results** in the navigation tree

↓

Make the **VSWR Calculations** pressing the right button of the mouse

↓

Choose the **Farfields** in the navigation tree which represents the radiation pattern

↓

Make the Polar, 2D and 3D plots by choosing the **Plot properties** option

↓

The file is then saved

↓

The graphs of S-parameter Vs Frequency, Directivity Vs Angle and VSWR Vs Frequency for the designed structures are observed