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DESIGN OF 2.4 GHZ PATCH AND PRINTED MONOPOLE ANTENNAS

A Dissertation Submitted to the Faculty of Engineering, University of Zawya in Fulfillment of the Requirements for Degree of Master of Science in the Department of Electrical and Electronic Engineering

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First, I am grateful for God for providing me with the knowledge and tools in order to complete my master's degree. Second, I would like to thank Dr. Ali Alamory for his advice, guidance . A special thanks also to my husband Husayn Albasheer for His contribution in order to complete my Thesis. My utmost thanks also go to my family for their support through my academic years, for their continual support and encouragement.

ABSTRACT

Nowadays, wireless Local Area Network (WLAN) applications have become more popular. Since it allows users to access network services without tethering to a wired infrastructure. Bluetooth communication brings a crucial responsibility to antennas that expected to provide the wireless transmission between those devices. In high performance, Bluetooth applications where size, weight, cost, performance, ease of installation are constraints, and low profile antenna is very much required. To meet these requirements, micro-strip and Patch antennas preferred. Micro-strip and Patch antennas are currently the fastest growing segments in the telecommunications industry and promise to become the preferred medium of telecommunications in the future.

Although these antennas have several advantages, it also has several disadvantages in terms of the size and weight. This Thesis describes the design of monopole antenna and micro-strip patch antenna with operating frequency 2.4GHz for Bluetooth applications. The dimensions of the single micro-strip patch antenna were calculated using transmission line method: Aperture line was used to feed the single element. Monopole antenna and micro-strip patch antenna were based on quarter-wave impedance matching , have been designed and simulated. Analysis showed that the antennas provide better return loss and small bandwidth .

الملخص

أصبح تطبيق شبكة المنطقة المحلية اللاسلكية (WLAN) أكثر شيوعاً في الوقت الحاضر، نظراً لآنه يتيح للمستخدمين الوصول الى خدمات الشبكة دون التقيد بالبنية التحتية السلكية. فللبلوتوث (Bluetooth) أهمية كبيرة وذلك بتوفير الأرسال اللاسلكي بين الأجهزة عالية الأداء، من حيث الحجم والوزن والتكلفة والأداء وسهولة التركيب، مما يجعله أكثر استخداماً. ولتلبية هذه المتطلبات يفضل استخدام هوائي أحادي القطب (Monopole) وهوائي تصحيح الشريحة (Micro-strip)، حيث تعتبر هذه القطاعات الأسرع نمواً في صناعة الاتصالات، ومن المتوقع أن تصبح الوسيلة المفضلة في المستقل. وعلى الرغم من المزايا العديدة للهوائيات، إلا أن لها أيضا عيوباً متمثلة في الحجم والوزن. ترتكز فكرة البحث على تصميم هوائي أحادي القطب وهوائي التصحيح بتردد (2.4 GHZ) لتطبيقات البلوتوث وثم حساب أبعاد هوائي التصحيح أحادي الشريحة (single micro-strip) باستخدام طريقة خط النقل (transmission line); ثم استخدام خط الفتحة (aperture line) لتغذية العنصر الفردي، ثم تصميم ومحاكاة الهوائي أحادي القطب وهوائي الشريحة على أساس مطابقة مقاومة ربع الموجة (quarter-wave impedance matching). أظهرت نتائج البحث أن الهوائيات توفر أفضل فاقد عودة وعرض نطاق ترددي (Bandwidth) صغير.

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LIST OF ABBREVIATIONS

WLAN	-	Wireless Local Area Network
IEEE	-	Institute of Electrical and Electronic Engineers
HFSS	-	High Frequency Structure Simulator
MIC	-	Microwave Integrated Circuits
UMTS	-	Universal Mobile Telecommunication System
PCB	-	Prented Circuit Board
TLM	-	Transmission Line method
PIFA	-	Plan Inverted F Antenna
DCS	-	Digital Communication System
PMA	-	Printed Monopole Antenna
FR4	-	Fire Retardant Type 4
PCS	-	Personal Communication System
PCB	-	Printed Circuit Board
EM	-	Electromagnetic
TE	-	Transverse Electric
CPW	-	Coplanar Waveguide
TM	-	Transverse Magnetic
SAR	-	Specific Absorpation Rate
US	-	United States
GSM	-	Global System for Mobile Communication

LIST OF SYMBOLS

Z0	-	Characteristic impedance
ZL	-	Load impedance
Z_{in}	-	Input impedance
M	-	Impedance Mismatch
D	-	Directivity
CP	-	Circular Polarization
Pin	-	Input power
RL	-	Return loss
f	-	Frequency
f_r	-	Resonant frequency
fc	-	Cut off frequency
G	-	Gain
Q	-	Antenna quality factor
C	-	The light velocity
ϵ_{reff}	-	Effective dielectric constant
ϵ_r	-	Dielectric constant
U_{max}	-	$maximum\ radiation\ intensity$
U_0	-	$average\ radiation\ intensity$
λ	-	Wave length
λ_0	-	Free space wave length
h	-	Substrate height
tan δ	-	Dielectric loss tangent
RI	-	Input resistance
θ	-	Elevation angle

CHAPTER 1

INTRODUCTION

1.1 General Background.

The rapid increase of communication standards leads to a great demand in developing multi-band internal antennas for handset devices and with the rapid growth of wireless communications there is a growing demand for mobile phones that are small, attractive, lightweight, and curvy. This has resulted in the proliferation of handsets with antennas that are internal or hidden within the device. An internal antenna makes the handset look much nicer and compact. The size and weight of mobile handsets have been rapidly reduced, due to the development of modern integrated circuit technology and the requirements of the users. For example, Conventional monopole-like antennas have remained relatively large compared to handset itself. Thus, built-in antennas are becoming very promising candidates for applications in mobile handsets.

Design an internal antenna for a mobile phone is difficult especially when dual or Multi-band operation is required. Although obtaining dual-frequency resonance is straightforward, satisfying the bandwidth requirement for the respective communication bands is difficult. Further complications arise when the antenna has to operate in close proximity to objects like shielding cans, screws, battery, and various other metallic objects.

Currently, many mobile phones use one or more of the following frequency bands: The GSM (Global System for Mobile Communication) band centered at 900 MHz, the DCS (Digital Communication System) band, centered at 1800 MHz, the PCS (Personal Communication System) band, centered at 1900 MHz, Triple and built-in antennas to operate at GSM900, DCS1800, and PCS1900 bands demonstrated in [1].

1.2 Literature review

There are many studies were done in this area of research. In Body-centric wireless communications are a hot topic nowadays. These systems employ antennas in the vicinity of the human body, and cover a wide range of applications, In light of that, this dissertation focuses on the construction of a microstrip dual-band patch antenna, that works in the ISM bands of 2.45 and 5.8 GHz, and is quasiimmune to frequency detuning and performance degraحdation, when in presence of human body tissues [2].

Bhattacharjee (2016) focused in his dissertation on the development of analytical framework for investigation of Printed Monopole Antennas [3]. Noor (2012), designed micro-trip antennas at 5.8 GHz which devoted to short-range communication (DSRC) band [4]. And Lei Jie, (2018) designed and tested low profile 2.4G Wi-Fi micro-strip patch antenna for IoT devices, the design includes stacked micro-strip antenna and a meta-material patch antenna that achieves the 2.4 GHz [5]. Civerolo and Arakaki (2011) have focused on analytical methods and design improvements without identifying parametric tra-deoffs or design methods. Hence, this paper presents theoretically and parametrically identified critical antenna dimensions and performance effects, and a design procedure to convert desired performance requirements into operational prototypes [6]. Also, Christopher (2014), presented an aperture-coupled micro-strip patch antenna with an operation frequency range of 4.8 - 5.2 GHz [7]. Kandasamy (2011) designed a micro-strip antenna using micro-strip line feed model a IE3D software [8]. Werfelli et al. (2016), designed a micro-strip rectangular antenna in Advance Design System Momentum (ADS). The resonant frequency of this antenna is 4.1GHz [9].

In this thesis, it is focused on the design single band antennas. These antennas will be able to operate at 2.4GHz band for Bluetooth and WLAN that are candidates for future mobile handset.

1.3 Antenna Parameters

To describe the performance of an antenna, definitions of various parameters are necessary. Some of the parameters are interrelated and not all of them need to be specified for complete description of the antenna performance [10] .

1.3.1 Bandwidth

Antenna bandwidth is “the range of frequencies within which the performance of the antenna, with respect to some characteristic, conforms to a specified standard" [11].

The bandwidth can be viewed as the frequencies left and right of the center frequency (usually the resonant frequency) in which the antenna performance meets the specified values. The bandwidth of an antenna is commonly agreed upon as the power delivered to the antenna greater than or equal to 90% of the available power [12] .

1.3.2 Polarization

The polarization of an antenna is the polarization of the radiated fields produced by an antenna, evaluated in the far field area. Antennas are often classified as "Linearly Polarized" or "Circularly Polarized", which means the E-field of microwave radiated by antenna varies linearly or circularly along its transmission direction.

Horizontal polarization and vertical polarization are the two mostly often used Linear polarizations. And for circular polarization, it includes Left-Hand and Right-Hand Circular Polarizations (LHCP & RHCP). Due to the reciprocity theorem, antennas transmit and receive in exactly the same manner. Hence, a vertically polarized antenna transmits and receives vertically polarized fields. Consequently, if a horizontally polarized antenna is trying to communicate with a vertically polarized antenna, there will be no reception [13] .

1.3.3 Directivity

Directivity (D) is an important parameter to evaluate the directional of antennas, it indicates the disruption of power intensity of given direction. For example, the directivity equal to 1 if an antenna may transmit power through all direction. The higher directivity represents power intensity of this antenna may more focus on certain direction rather than all direction or multiple directions. The directivity of common antennas arranges from low to high is dipole antennas, microstrip antennas, horn antennas, dish antennas.

$$Directivity = \frac{maximum\ radiation\ intensity}{average\ radiation\ intensity} = \frac{U_{max}}{U_O} \qquad (1-1)$$

Directivity and gain differ only by the efficiency, but directivity is easily estimated from patterns [14].

1.3.4 Gain

As noted, directivity is solely determined by the radiation pattern of an antenna. When an antenna is used in a system it is important how efficiently the antenna transforms available power at its input terminals into radiated power, as well as its directive properties.

To quantify this, gain is defined as 4π times the ratio of the maximum radiation intensity to the net power accepted by the antenna from the connected transmitter, or

$$G = \frac{4\pi}{P_m} U_{\max} \qquad (1-2)$$

This is a power quantity and is sometimes referred to as power gain. This definition does not include losses due to mismatches of impedance or polarization [15] .

1.3.5 Return loss

Return loss is an important parameter when connecting an antenna. It is related to impedance matching and the maximum transfer of power theory. It is also a measure of the effectiveness of an antenna to deliver power from the source to the antenna. The return loss (RL) is defined by the ratio of the incident power of the antenna P_{in} to the power reflected back from the antenna of the source P_{ref} [15] .

the mathematical expression is :

$$RL = 10log_{10}\frac{P_{in}}{P_{ref}}(db) \qquad (1-3)$$

For good power transfer, the ratio P_{in} / P_{ref} shall be high. If we have low RL there is a risk that and it will up end in a frequency there will occur standing wave phenomena’s (resonances) ripple of gain . In most practical circuits a RL value of 10 dB is good enough [16] .

1.3.6 Radiation Pattern

An antenna radiation pattern or antenna pattern is defined as “a mathematical function or a graphical representation of the radiation properties of the antenna as a function of space coordinates. In most cases, the radiation pattern is determined in the far field region and is represented as a function of the directional coordinates. Radiation properties include power flux density, radiation intensity, field strength, directivity, phase or polarization". The radiation property of most concern is the two- or three-dimensional spatial distribution of radiated energy as a function of the observer’s position along a path or surface of constant radius [10] .

1.4 Problem Statement

- The sizes and weights of mobile handsets have rapidly been reduced due to the development of modern integrated circuit technology and the requirements of the users.
- The built-in antennas are becoming very promising candidates for applications in mobile handsets. Conventional monopole antennas are simple, Omni-directional pattern and gain that is suited for mobile application.

  But they have remained relatively large compared to the handset itself, and they have lack of shielding mechanisms, to direct any radiating waves away from user‘s body which causes potential harm to the user‘s health.

1.5 Objective of the thesis

The main objective of this research thesis is to design single band antennas, these antennas will be able to operate at 2.4 GHz band for Bluetooth and WLAN which is become more candidates for feature mobile handset.

1.6 Scope of the thesis

In order to achieve the objectives, the research scope includes:

- A comprehensive literature review is required to obtain an antenna that is needed.
- Propose a novel type of antenna with good parameters requirement.
- Design an antenna using the electromagnetic simulation software namely, High Frequency Structure Simulator (HFSS)
- Optimize the antenna design parameters to satisfy the best return loss and radiation pattern in frequency bands.
- A prototype of the designed antenna will be validated by fabricating the design and compared with simulation results.

1.7 Methodology of the Thesis

In order to achieve the first objective as set out above, a comprehensive literature review is required to obtain an antenna that requires minimal modification to suit the requirements of this design.

As the process of optimizing an antenna's dimensions to meet a set of specifications is highly rigorous. Verify the operations of the antenna at the prescribed frequency in terms of input impedance and field patterns, using electromagnetic simulation software High Frequency Structure Simulator (HFSS).

Compere its performance of the antenna between simulated and measured results. Where an interactive theoretical and experimental design approach will be utilized to optimize the structure of the antenna, the research methodology to simplify the design and the development procedures in this research Thesis includes:

1- Pre. Design Stage

- Literature review.
- Problem statement.

2- Design and Simulation Stage

- Design the optimum antenna that met specification requirement.
- Antenna input impedance optimization.

3- Prototype Stage

- Antenna fabrication.

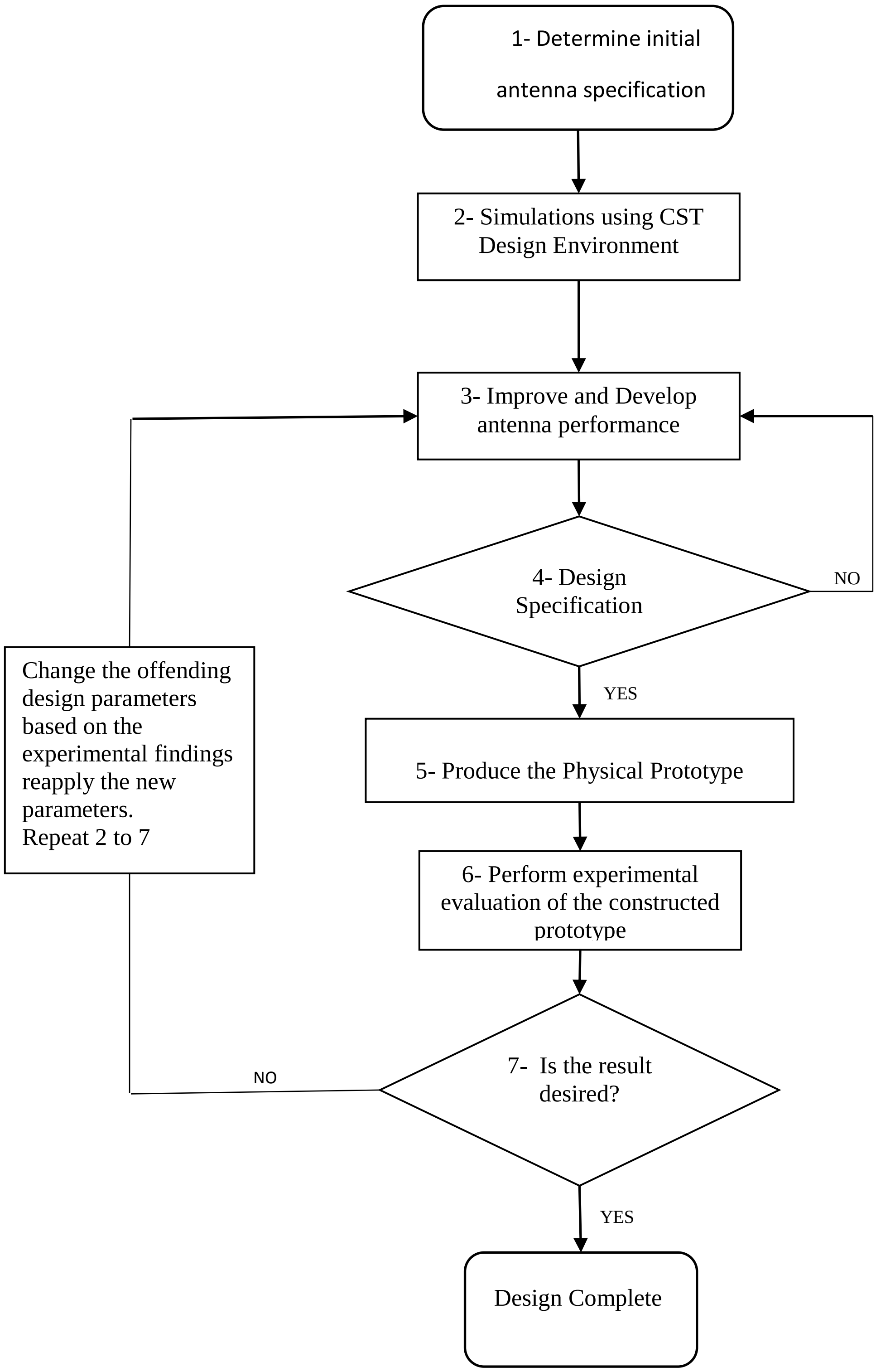
4- Measurement Stage

- Return loss and pattern loss at multi-bands range.

5- Analysis Stage

- The measurement and simulation results comparison.

The flowchart of the thesis is as shown in fig (1-1)



1.8 Thesis Outline

This thesis focuses on designing a single band antenna that operates at 2.4 GHz for mobile application and wireless communication. This can be achieved by understanding the micro-strip antenna and go to the Monopole antenna. Those antennas are the best candidates for future applications. Thesis will be as follows:

Chapter one: concerns with the introduction of the study in hand, that starts with a brief introduction, and continues stating the problem, the objectives, the scope of the study and finally the methodology to carry out in this work.

Chapter two: is the chapter of monopole antenna reveiew , some general antennas types used in mobiles .

Chapter three: discusses the concept of the microstrip antennas and the basic formula to start designing the micro-strip antenna, as well as focusing on the techniques that were used which makes the antenna adequate for applications with good efficiency**.**

Chapter four: illustrates the design and simulation results of Patch antenna , achieved by the software.

Chapter five: presents conclusions and recommendations suggested by the researcher**.**

CHAPTER 2

MONOPLE ANTENNA REVIEW

2.1 Introduction

A **monopole antenna** is a class of radio antenna consisting of a straight rod-shaped conductor, often mounted perpendicularly over some type of conductive surface, called a ground plane. The driving signal from the transmitter is applied, or for receiving antennas, the output signal to the receiver is taken, between the lower end of the monopole and the ground plane [17] .

One side of the antenna feed line is attached to the lower end of the monopole, and the other side is attached to the ground plane, which is often the Earth [18] .

This contrasts with a dipole antenna which consists of two identical rod conductors, with the signal from the transmitter applied between the two halves of the antenna.

The monopole is a resonant antenna; the rod functions as an open resonator for radio waves, oscillating with standing waves of voltage and current along its length. Therefore, the length of the antenna is determined by the wavelength of the radio waves it is used with. The most common form is the **quarter-wave monopole**, in which the antenna is approximately one quarter of the wavelength of the radio waves [19] .

However in broadcasting monopole antennas 5/8 = 0.625 wavelength long are also popular, because at this length a monopole radiates a maximum amount of its power in horizontal directions. Common types of monopole antenna are the whip, rubber ducky, helical, random wire, umbrella, inverted-L and T-antenna, inverted-F, mast radiator, and ground plane antennas [20] .

2.2 Historical Review

The monopole antenna was invented in 1895 and patented 1896 . by radio oneer Guglielmo Marconi during his historic first experiments in radio communication [21].

He began by using dipole antennas invented by Heinrich Hertz consisting of two identical horizontal wires ending in metal plates [22].

He found by experiment that if instead of the dipole, one side of the transmitter and receiver was connected to a wire suspended overhead, and the other side was connected to the Earth, he could transmit for longer distances [23].

For this reason the monopole is also called a Marconi antenna , although Alexander Popov independently invented it at about the same time [22] **.**

2.2.1 Mobile Communication and Wireless Revolution

Mobile communication "one of the fastest growing and consider as the most important telecommunication application" it is the most powerful catalyst for change in lifestyle of the people. The mobile communication was used in limited applications due to costly analogue technologies and restricted service (only phone calls were possible), the tiny high technologies are now become a necessary need of every individuals life.

The wireless revolution is creating a flood of new wireless devices that dramatically increase the availability of voice and data nearly anywhere in the world. While this revolution is significantly expanding the opportunity for new, smaller and better wireless communication terminals. Traditionally most mobile phones and handset have been equipped with the monopole antenna. Whereas the monopole antenna are very simple in design and construction and are well suited to mobile communication application. The most ¼ monopole antenna is the wipe antenna, which can operate at range of frequencies and deal with most environmental conditions better than other monopole antennas.

However, the monopole antenna possesses a number of drawbacks. Monopole antennas are relatively large in size and protrude from the handset case in an awkward way. This problem with the monopole's obstructive and space demanding structure also complicate any efforts taken to equip a handset with several antennas to enable multilane operation. Monopole antennas also lack any built-in shielding mechanisms, to direct any radiating waves away from user's body, thus increasing the potential risk of producing cancerous tumors growth in the user's head and reducing the antenna efficiency. In recent years, the demand for compact handheld communication devices has grown significantly. Devices smaller than palm size have appeared in the market antenna size is a major factor that limits device miniaturization.

In addition to solve the problem of broadening the antenna bandwidth to the required specification of the system, one has to worry about developing new structure for devices that require more than one frequency band of operation.

2.2.2 GSM (Global System for Mobile)

GSM stands for Global System for Mobiles. This is a world-wide standard for digital cellular telephony, or as most people know them Digital Mobile Telephones. GSM was created by the Europeans, and originally meant "Group Special Mobile", but this didn't translate well, so the now common more globally appealing name was adopted.

2.2.3 UMTS (Universal Mobile Telecommunications System)

Standing for "Universal Mobile Telecommunications System", UMTS represents an evolution in terms of capacity, data speeds and new service capabilities from second generation mobile networks.

2.3 Antennas for Mobile Phones

Antennas refer to gateways of wireless communications interfacing the free-space medium and the RF electronics of transceiver systems. In wireless communication applications, the operational push and the design pull considerations direct the choice of antennas. The overall perspective of wireless communication systems plus the pertinent details on the state-of-the-art aspects of associated technology show that, in the modern deployment profile the manufacture of mobile phone antennas pose multidisciplinary considerations . A variety of antenna structures – small and large – have been conceived and adopted in modern mobile communication systems .

In general, the antennas used in mobile phones are expected to have certain characteristics :

1. Minimum occupied volume with regard to portability and overall size minimization of the mobile terminal and shape .
2. Light weight .
3. Conformability to mounting hosts .
4. Multi-band operation for different communication standards .
5. Adequate bandwidth covering the frequency range used by the system, including a safety margin for production tolerances .
6. Isotropic radiation characteristics (omnidirectional) .
7. Negligible human body effect .
8. Low fabrication costs since it is a mass produced consumer item .

2.3.1 External Antennas

The most common handheld phone antenna is a whip, whose length is typically λ/8 or λ/2 (where λ is the wavelength). A whip antenna is cheap and easy to manufacture . It has a wide bandwidth and a suitable radiation pattern for mobile phone use .

The current distribution of the antenna changes so that the current maximum moves from the base of the antenna towards the center point of the antenna when the antenna is made longer .

The current maximum of a λ/4 antenna is located closest to the user's head . Relatively strong electrical currents may also be induced on the casing of the phone because the casing acts as a ground plane for the antenna . In the case of λ/8 and λ/2 antennas the currents are weaker, and the current maximum of the antenna is located farther away from the user's head. In addition to whip antennas helical antennas are also used in handheld phones.

A helical antenna consists of a wire that is wound in the shape of a helix. The advantage of the helical design is its small size . The height of a whip antenna for 900 MHz is 100 mm whereas the height of a λ/4 helical antenna is only 26 mm . However, the whip and helical antennas will break easily if the phone is mishandled by dropping it .

Fig (2-1): Examples of Whip Antennas Commonly Used in Hand-Held Devices

2.3.2 Internal Antennas

The structure of an internal mobile antenna is as shown below. The user holds the device at the lower end and the antenna is installed at the upper end of the device on the backside in order to prevent direct radiations towards the user . The antenna and the user are now separated by the Printed Circuit Board (PCB) which acts as a ground plane for the antenna.

The ground plane now can reflect most of the back radiations of the antenna that is directed towards the user, thus lower the SAR value to very much below acceptable limits .

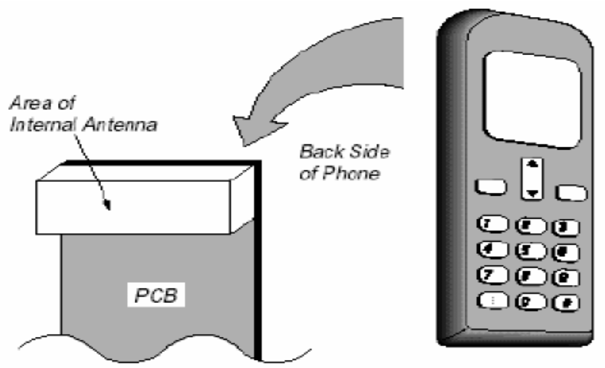


Fig (2-2) : Internal Antenna behind the PCB Board

Once such antenna that suits this kind of installation is the microstrip antenna, which is a conducting patch printed on a grounded microwave substrate. It has thin profile, light weight, compact size and volume, conformability to mounting hosts and low fabrication costs as its attractive features .

A particular subclass of microstrip antennas that is gaining more and more popularity recently is the Planar-Inverted-F Antenna (PIFA) .

Numerous research articles have been published related to PIFA ever since the concept of dual-band and tri-band phones (with an arbitrary separation of bands) came into existence. PIFA renders itself capable of operating in two or more discrete frequency bands usually using the concept of excitation and modification of natural modes in the same structure .

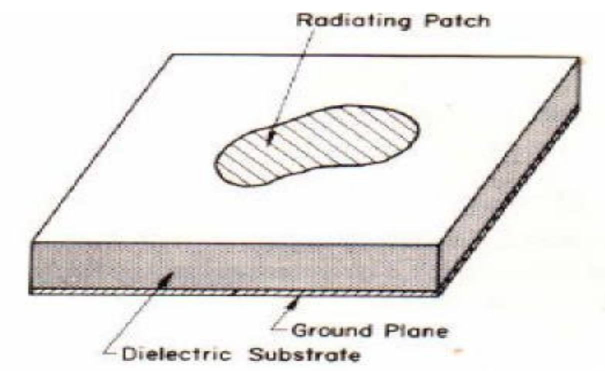
CHAPTER 3

METHODS OF ANTENNA DESIGN AND BROADBAND TECHNIQUES

3.1 Introduction

In today's applications where the antenna's size, weight, cost, performance, ease of installation and aerodynamic profile are of utmost consideration, the low-profile microstrip antenna is preferred over conventional antennas. The term 'microstrip' actually refers to any type of open wave guiding structure which is not only a transmission line but also used together with other circuit components like filters, couplers, resonators, etc. In fact, microstrip antennas are an extension of the microstrip transmission line. Microstrip antennas can be flush-mounted to metal or other existing surfaces, and they only require space for the feed line, which is usually placed behind the ground plane. As for its disadvantages, microstrip antennas are inefficient and possess very narrow frequency bandwidth, typically only a fraction of a percent or at most a few percent.

A microstrip antenna in its simplest configuration consists of a radiating patch on one side of a dielectric substrate, which has a ground plane on the other side. The patch conductors usually made of copper or gold, and can be virtually assumed to be of any shape. However, conventional shapes are normally used to simplify analysis and performance prediction. The radiating elements and the feed lines are usually photo-etched on the dielectric substrate.



Fig(3-1) : Basic Configuration of Microstrip Antenna

As has been shown in figure (3-1) is the basic configuration of a simple microstrip antenna. The upper surface of the dielectric substrate supports the printed conducting strip while the conducting ground plane backs the entire lower surface of the substrate. The radiating patch may be square, rectangular, circular, and elliptical or any other configurations. Square, rectangular and circular shapes are the most common because of the ease of analysis and fabrication. As for the feed line, it is also a conducting strip, normally of a smaller width. Coaxial-line feeds, where the inner conductor of the coax is attached to the radiating patch, are also widely used. Sometimes, microstrip antennas are also referred as printed antennas[24].

3.2 Radiated Fields of Microstrip Antenna

The field structure within the substrate and between the radiating element and the ground plane is shown in figures 3-2 (a) and 3-2 (b). The electromagnetic wave traveling along the microstrip feed line spreads out under the patch. Hence, the resulting reflections at the open circuit set a standing-wave pattern. From figure 3-2 (b), it can be clearly seen that the radiated fields undergo a phase reversal along the length of the structure, but is approximately uniform along the width of the structure.

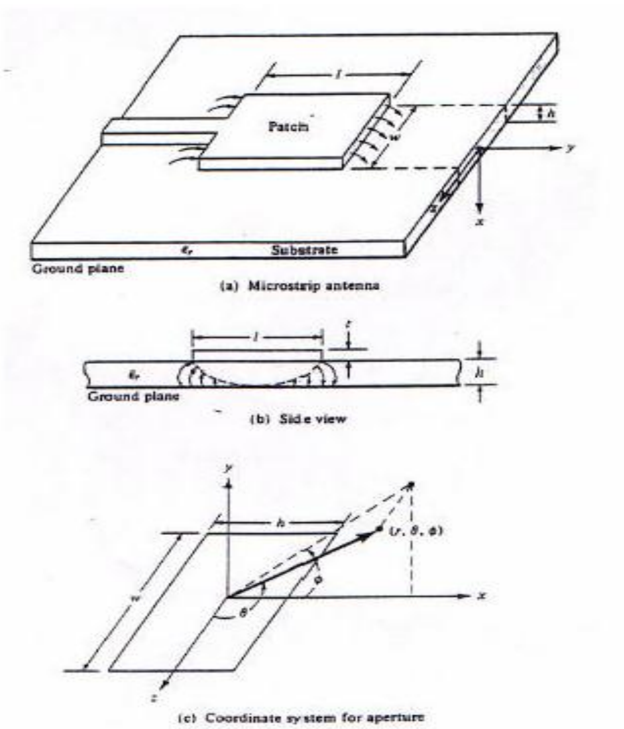


Fig (3-2) : Microstrip Antenna and Coordinate System

The antenna consists of two slots, separated by a very low impedance parallel-plate transmission line which acts as a transformer [25] .

The length of the transmission line has to be approximately λg/2 in order for the fields at the aperture of the two slots to have opposite polarization. The components of the field from each slot add in phase and provide a maximum radiation normal to the element.

As for the electric field at the aperture of each slot, it can be categorized into x and y components, as shown in figure 3.2(c).

The y components are out of phase and hence, their contributions will cancel out each other.

Due to the fact that the thickness of the microstrip is normally very small, the electromagnetic waves generated within the dielectric substrate (between the patch and the ground plane) undergo considerable reflections when they arrive at the edge of the strip. Hence, only a small fraction of the incident energy is radiated. As a result, the antenna is considered to be very inefficient and it behaves more like a cavity instead of a radiator [25].

3.3 Characteristics of Microstrip antennas

The microstrip antenna has proved to be an excellent radiator for many applications because of its several advantages, but it also has some disadvantages. The advantages and disadvantages of the microstrip antenna are given in Sections **3.2.1** and **3.2.2.**[11] .

3.3.1: Advantages:

Microstrip antennas have several advantages compared to the conventional microwave antennas. The main advantages of Microstrip antennas are listed as follows:

1-They are lightweight and have a small volume and a low-profile planar configuration.

2-They can be made conformal to the host surface.

3-Their ease of mass production using printed-circuit technology leads to a low fabrication cost.

4- They allow both linear polarization and Circular Polarization .

5-They can be made compact for use in personal mobile communication.

6-They allow for dual- and triple-frequency operations [26] .

3.3.2 Disadvantages:

Microstrip antennas suffer from some disadvantages as compared to conventional microwave antennas. They are the following:

1- Narrow BW.

2- Lower gain.

3- Low power-handling capability.

4- Large ohmic loss in large feed network.

5- Radiation from feeds contributes to the radiation pattern.

6- Excitation of surface waves [26] .

3.3.3 Applications

Most of the rapid advances in microstrip antenna and arrays took place in the 1980s. Firstly, These were driven by defense and space application. Then this technology is growing rapidly in the commercial sector. Specification for defense and space application anntenna typically emphasize maximum perfomance with little constraint on cost [26] .

On the other hand, commercial applications demand low cost components, oftenat the xpense of reduced electrical performance . Thus, microstrip antennas for commercial systems reguire low – cost materials, simple and inexpensive fabrication technigues. Some of the commercial systeme that presently use microstrip antenna are listed in the Table(3- 1) :

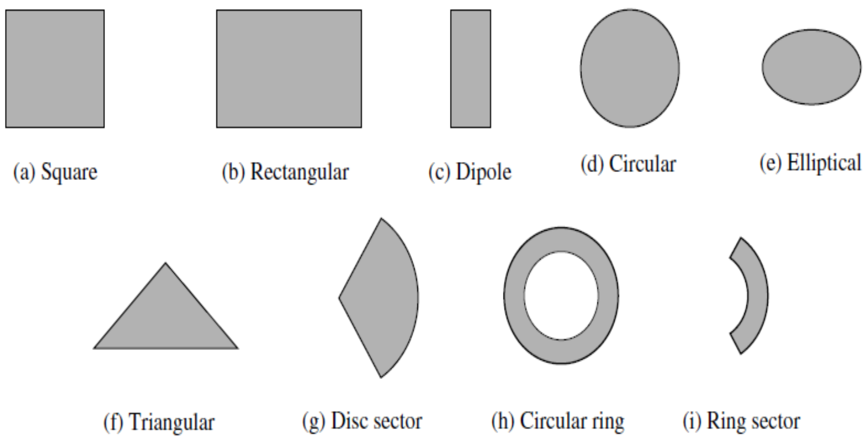
Table(3-1) : microstrip antenna applications

Application	**Freguency**
Global Positioning Satellite	1575 MHZ and 1227 MHZ
GSM	915-890 MHZ and 960-935MHZ
Wireless Local AreaNetworks	2.4-2.48 GHZ and 5.4 GHZ
Cellular Video	28GHZ
Direct Broadcast Satellite	11,7-12.5 GHZ
Automatic Toll Satellite	905 MHZ and 5-6 GHZ
Collision Avoidance Radar	60 GHZ,77 GHZ,and 94 GHZ
Wide Area Computer Networkes	60 GHZ

3.4 Types of Microstrip Antennas

Often microstrip antennas are also referred to as patch antennas. The radiating elements and the feed lines are usually photo etched on the dielectric substrate. The radiating patch may be square, rectangular, thin strip (dipole), circular, elliptical, triangular, or any other configuration [10].

These and others are illustrated in Figure (3-3) .



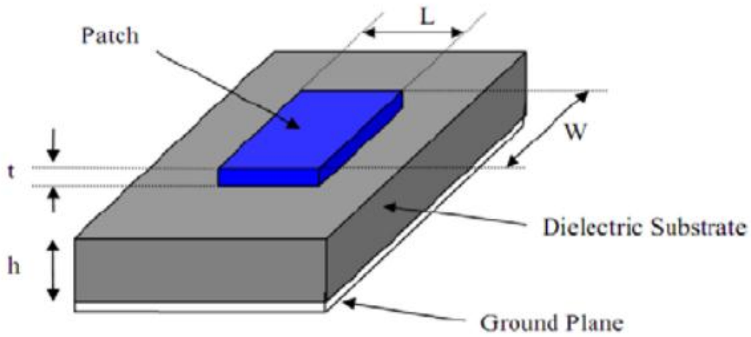
Fig(3-3) : Representative shapes of microstrip patch elements

3.4.1 Rectangular Microstrip Patch Antenna

Although design equations will be given for single-layer rectangular patch, serious design work should use one of the excellent available commercial design codes. Their use reduces the need to modify the final dimensions using a knife to remove metal or metal tape to increase the patch.

Antennas can be built with tuning tabs, but the labor to trim these increases cost. Tuning tabs are unsuitable for arrays when the input port to individual antennas cannot be accessed. As we add layers to increase bandwidth, a cut-and-try method becomes extremely difficult, and numerical methods are a necessity [27] .

Rectangular patch antennas can be designed by using a transmission-line model. It is suitable for moderate bandwidth antennas. Patches with bandwidths of less than 1% or greater than 4% require a cavity analysis for accurate results, but the transmission line model covers most designs [27] .



Fig(3-4) : Rectangular microstrip patch

3.5 Feed Techniques and Modeling of Microstrip Antennas

Microstrip patch antenna has various methods of feeding techniques. As these antennas having dielectric substrate on one side and the radiating element on the other. These feed techniques or methods are being put as two different categories **contacting and non-contacting.**

Contacting feed technique is the one where the power is being fed directly to radiating patch through the connecting element. through the Microstrip line.

Non-contacting technique is the one where an electromagnetic magnetic coupling is done to transfer the power between the Microstrip line and the radiating patch. Even though there are many new methods of feed techniques the most popular or commonly used techniques are:

1- Coaxial probe

2- Microstrip line

- Edge feed
- Inset feed

3- Co planar wave guide feed

4- Aperture coupling

1 and 2 being the contacting feed techniques and 3, 4 being non- contacting feed techniques . There are few factors which lead or involve in the selection of a particular type of feed technique. The first and the foremost factor is the efficient power transfer between the radiating structure and the feed structure. the impedance that is matching between the radiating structure and the feed structure.

The minimization of the radiation and the effect of it's on the radiation pattern is one of the most important aspect for the evaluation of feed. However, those techniques will be discussed[28] .

3.5.1 Coaxial Probe Feed

The Coaxial feed or probe feed is avery common technique used for feeding Microstrip Patch antennas.The inner conductor of the coaxial connector extends through the dielectric up to the patch .

, while the outer conductor is connected to the ground plane. Figure (3-5) shows amicrostrip antenna with coaxial feeding .

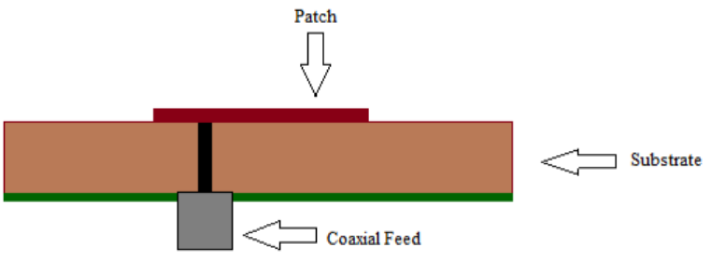


Fig (3-5) : Coaxial Feeding of Microstrip Antenna

The main advantage of this type of feeding scheme is that the feed can be placed at any location in side the patch in order to match with its input impedance. This feed method is easy to fabricate and has low spurious radiation.

However, a major disadvantage is that it provides narrow band width and is defficult to model since a hole has to be drilled in the substrate and the connector protrudes outside the ground plane [29] .

3.5.2 Microstrip line feed

Microstrip Line Feed Microstrip Feed Line is depending on the conducting strip. In this technique a conducting strip directly connected to the patch which is smaller in dimension as compare to patch. It is very easy to fabricate, very simple in modeling and match with characteristic impedance 50Ω or 75Ω. This can achieve by properly controlling the inset position[29].

A model of Microstrip Line Feed shown in the figure (3-6) .

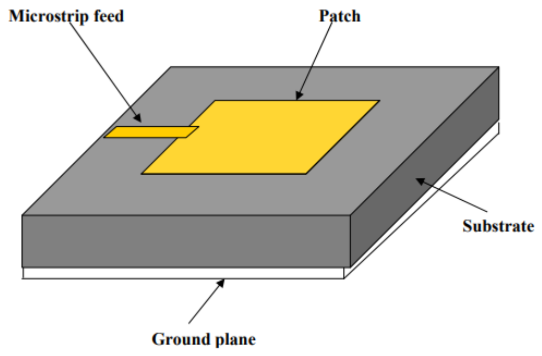


Fig (3-6) : Microstrip Feed Line

3.5.3 coplanar waveguide

A Principle of coplanar waveguide feed As shown in Figure (3-7) , the coplanar aveguide omposed of dielectric substrate and three conduction band. Three metal etching conduction bands are in the same side of the dielectric substrate. The signal is in the between of the two ground part on the one side of the dielectric substrate, the other side is nothing. Coplanar waveguide structure generally adopts the high dielectric constant substrate, and the wavelength is less thanλ_0 inside the waveguide, therefore the electromagnetic field is concentrated in the medium and the air interface.

Alternating electromagnetic field generated between the metal conduction bands and the ground conduction band, can produce longitudinal and transverse alternating electromagnetic field [29].

Coplanar waveguide is used as transmission line to conduction TEM wave, as constraint conditions:

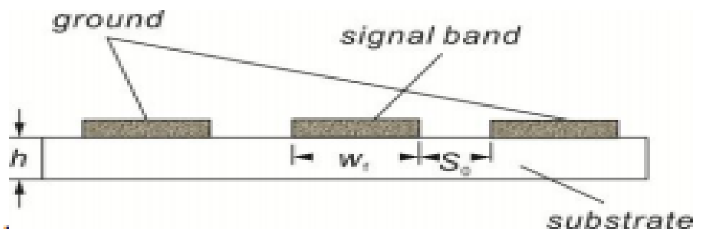


Fig (3-7) : The structure of coplanar waveguide

3.5.4 Aperture Couple Feed Technique

Aperture coupled microstrip patch antennas have become a viable option for wireless and telecommunication systems over traditional microstrip patch antennas. Research and development in the 1980s contributed to the discovery of the aperture-coupled microstrip patch antenna . David Pozar is credited as being one the main pioneers in the development of the aperture coupled microstrip patch antenna. The fundamental structural difference between the microstrip patch and aperture coupled microstrip patch antenna is the feed method used to excite the patch. While the microstrip patch antenna uses direct feed in order to excite the patch, the aperture coupled microstrip patch antenna uses non-contact feed lines which is accurately described as the magnetic equivalent of the edge-fed procedure in [30] .

The non-contact feed is also capacitive in nature which counteracts with the natural high inductance of the excitation. Having indirect feed contact allowed for the aperture coupled microstrip patch antenna to achieve low current discontinuity which is fundamental for achieving good impedance and radiation performance. Since its introduction, aperture coupled microstrip antennas have continually been used in numerous applications requiring a wideband frequency range. This includes, but is not limited to, global positioning satellites, cellular phones, personal communications systems, GSM, wireless local area networks, cellular video, direct broadcast satellites, automatic toll collections, collision avoidance radar, and wide area computer networks [31] .

This type of feed technique comes under the non-contacting feed techniques and here the radiating patch and the micro strip feed line are being divided by the ground plane. The main features in this particular feed technique is that it has a wider bandwidth and the shielding of the radiating patch from the radiation gets from the structure.

Fig (3-8) shows an overview of a microstrip patch antenna design with aperture coupled technique. In this figure two substrates; one for feed line and another for patch are formed.

A slot is formed at center of ground and feed line is below the second substrate as shown in Fig (3-8) These types of antennas are more popular, because of the patches and slots can be any shape and this gives the improvement in the performance of microstrip patch antennas.

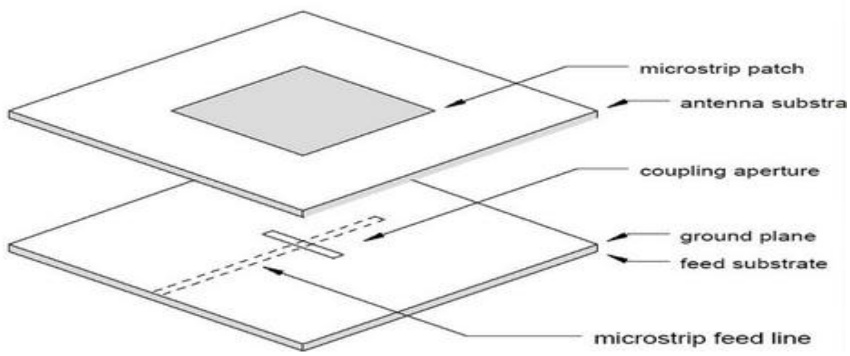


Fig (3-8) : Aperture- couple feed technique general view

It can be seen that the configuration of this feed and as said above the radiating patch and Microstrip feed line are separated by the ground plane. The coupling between the patch and the feed line is trough aperture in the ground plane the line feed on the lower substrate of coupled electromagnetically to the patch through the aperture. The amount of coupling depends on the size, shape and also the location of the aperture. There is minimization of the spurious radiation as the ground plane separates the feed line and the patch; this can be achieved when there is a usage of thin, high dielectric material for the lower substrate and thick, low dielectric constant material for the upper substrate. The aperture slot can be of any size shape and these design parameters drive the bandwidth.

The lower and the upper substrate parameters are chosen separately to improve the bandwidth and for the optimization of the feed and radiation separately.

So as said the patch's substrate is of thick and lower dielectric const and for the feed line it's thin & has a high dielectric const. In this feed technique there is a feature of improving the polarization purity. The black lobe radiation from the slot is typically 15 to 20db below the main beam of the coupling slot, is non resonant. The position of the coupling slot is almost centered with respect to patch where there is a maximum magnetic field of patch to improve the magnetic coupling between the magnetic field of the patch and the magnetic current near the slot [32] .

3.6 Comparison of Different Feed Methods

The Comparison of Different Feed Techniques shown in Table (3-2):

Characteristics	**Micro strip line**	**Coaxial Probe**	**Aperture Coupling**	**Proximity Coupling**
Return loss	Less	More	Less	More
Spurious Feed Radiation	More	More	Less	Minimum
Ease of Fabrication	Simple	Soldering and Drilling needed	Alignment Required	Alignment Required
Polarization Purity	Poor	Poor	Excellent	Poor
Band Width	2-3 %	2-3 %	21 %	13 %

3.7 Substrate Materials

The choice of dielectric substrate plays an important role in the design and simulation of the microstrip transmission line as well as any other antennas. Some important dimensions of the dielectric substrate are:

- The dielectric constant.
- The dielectric loss tangent that sets the dielectric loss.
- The thermal expansion and conductivity.
- The cost.
- The manufacturability.
- The thickness of the copper surface.

There are numerous types of substrates that can be used for the design of antennas. They often have different characteristics and their dielectric constants normally range from $2.2 \leq \varepsilon_r \leq 12$. Thick substrates with low relative dielectric constants are often used as they provide better efficiency and a wider bandwidth.

However, using thin substrates with high dielectric constant would result in smaller antenna size. But this also results negatively on the efficiency and bandwidth. Therefore, there must be a design trade-off between antenna size and good antenna performance [33] .

Table (3-3) : Properties of Microwave Dielectric Substrates

Material	Dielectric Constant, ε_r	Loss Tangent
Reinforced PTFE, RT Duriod 5880	2.20 (1.5 %)	0.0009
Fused Quartz	3.78	0.0001
96% Alumina	9.40 (5 %)	0.001
99.5 % Alumina	9.8 (5 %)	0.0001
Sapphire	9.4, 1.6	0.0001
Semi-Isulating GaAs	12.9	0.002
GIL Copper clad	3.2	0.003
Rogers 4003 C	3.55	0.0021
FR-4	4.4	0.019

Following are the consideration of choosing the substrate in this project:

- Mechanically stability up to high temperatures (soldering, deposition of components in thick film technique) .
- Resistance to chemicals (photolithography process, etching, resist removal) .
- Material hardness (cutting and drilling of holes) .
- Low cost .
- Guaranteed availability of the material .

3.8 Design Specifications

A traditional microstrip patch antenna consists of a microstrip line fed directly to a patch resting on a single layer dielectric substrate. A ground substrate is also added to the lower dielectric substrate which serves as a path for return currents. The microstrip patch is considered a resonant type radiator meaning that its feed length is pproximately half of the guided wavelength .

Figure (3-9) shows the basic schematic diagram of an edge-fed microstrip antenna.

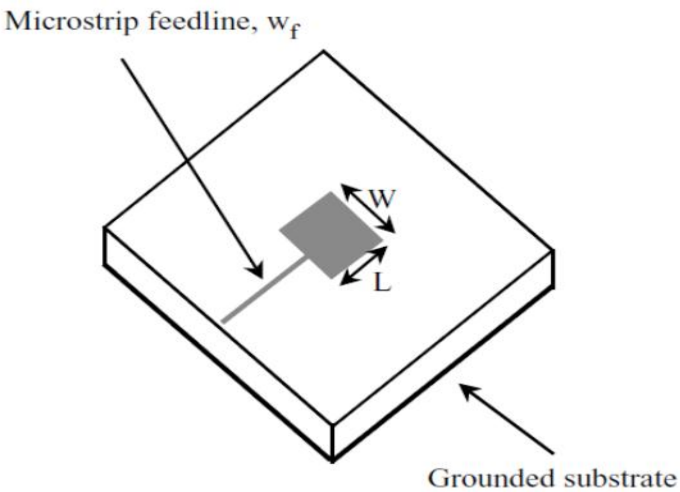


Fig (3-9) : Schematic diagram of a microstrip patch antenna

The microstrip transmission line is designed to transmit electromagnetic energy to the radiating patch.

Figure (3-10) shows the schematic diagram of a traditional microstrip transmission line[33].

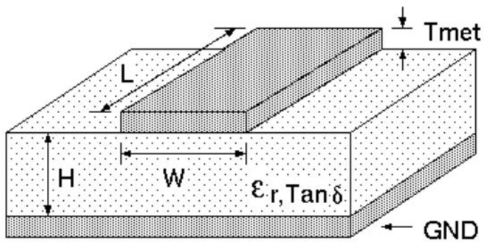


Fig (3-10) : Schematic diagram of a microstrip transmission line.

3.8.1 Effective Dielectric Constant

One might think that the effective dielectric constant, $\varepsilon_{r,eff}$, is the same as the dielectric constant, ε_r, of the substrate. This appears to be true only for a homogeneous structure and not for a non-homogeneous structure. For microstrip structures, we are able to calculate the effective dielectric constant that comes in two different cases. These two cases are illustrated in figure (3-11) whereby the top diagram shows a microstrip with width, w, greater than the thickness, h. The opposite can be said about the bottom diagram [34] .

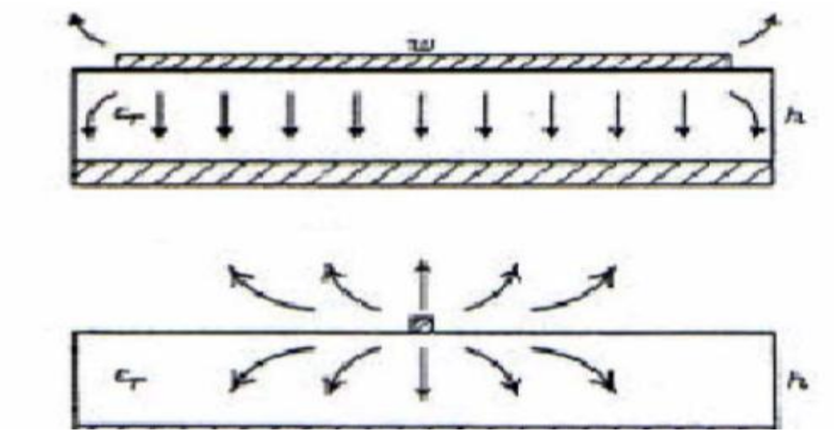


Fig (3-11) : Wide and Narrow Microstrip Line

By looking at the diagram, we can conclude that the circuit performs similar to having two parallel planes as most of the fields as kept under the wide microstrip width. Thus, $\varepsilon_{r,eff}$ is approximately equivalent to ε_r. half of the fields will be in air with ε_r= 1, while the other half of the fields will be confined to the substrate with $\varepsilon_{r,eff}$= ½(ε_r + 1).

Therefore, the range of a dielectric constant can be said to be [34]:

$$\frac{1}{2}(\varepsilon_r + 1) \leq \varepsilon_{r,eff} \leq \varepsilon_r \qquad (3 - 1)$$

$$\varepsilon_{r,eff} = \frac{\varepsilon_r+1}{2} + \frac{\varepsilon_r-1}{2}\left[\left(1+\frac{12}{\frac{w}{h}}\right)^{\frac{-1}{2}} + 0.04\left(1-\frac{w}{h}\right)^2\right] \text{for } \frac{w}{h} < 1 \qquad (3-2)$$

$$\varepsilon_{r,eff} = \frac{\varepsilon_r+1}{2} + \frac{\varepsilon_r-1}{2}\left[\left(1+\frac{12}{\frac{w}{h}}\right)^{\frac{-1}{2}}\right] \text{for } \frac{w}{h} \geq 1 \qquad (3-3)$$

3.8.2 Wavelength

For a propagating wave in free space, the wavelength of that medium is equal to the speed of light divided by its operating frequency. To obtain the wavelength of a given wave-guide or antenna, the free space wavelength is simply divided by the square root of the effective dielectric constant of the wave-guide. These are shown in equations (3.4) and (3.5) [34] .

$$\lambda_o = \frac{c}{f_o} \qquad (3 - 4)$$

$$\lambda_g = \frac{\lambda_o}{\sqrt{\varepsilon_{r,eff}}} \qquad (3 - 5)$$

Where c = speed of light, f_0= operating frequency, λ_0= free space wavelength and λ_g= the guide wavelength.

3.8.3 Characteristic Impedance

The characteristic impedance, Z_0, of any line is the function of its geometry and dielectric constant. For a microstrip transmission line, the characteristic impedance is defined as the ratio of voltage and current of a travelling wave. For a microstrip line with width, w, we are able to calculate the characteristic impedance through the following two equations [34] :

$$Z_o = \frac{60}{\sqrt{\varepsilon_{r,eff}}} \ln\left(\frac{8}{\frac{w}{h}} + 0.25\frac{w}{h}\right) for \frac{w}{h} \leq 1 \qquad (3-6)$$

$$Z_o = \frac{\frac{120\pi}{\sqrt{\varepsilon_{r,eff}}}}{\frac{w}{h} + 1.393 + 0.667\ln\left(\frac{w}{h} + 1.444\right)} for \frac{w}{h} \geq 1 \qquad (3-7)$$

3.9 Design procedure

Based on the simplified formulation that has been described, a design procedure is outlined which leads to practical designs of rectangular microstrip antennas. The procedure assumes that the specified information includes the dielectric constant of the substrate (ε_r) the resonant frequency f_r, and the height of the substrate h. The procedure is as follows [35] :

1. For an efficient radiator, a practical width that leads to good radiation efficiencies is

$$W = \frac{c}{2f_r}\sqrt{\frac{2}{\varepsilon_r + 1}} \qquad (3-8)$$

2. Determine the effective dielectric constant ($\in_{reff}$) of the microstrip antenna using :

$$\in_{reff} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2} \times \frac{1}{\sqrt{1 + 12\frac{h}{w}}} \qquad (3-9)$$

3. Once W is found using (3-1), determine the extension of the incremental length ΔL using:

$$\Delta L = \text{h} \times 0.412 \frac{(\epsilon_{reff}+0.3)(\frac{W}{h}+0.264)}{(\epsilon_{reff}-0.258)(\frac{W}{h}+0.8)} \qquad (3-10)$$

4. The actual length of the patch can now be determined by [35] .

$$L = \frac{c}{2f_r\sqrt{\epsilon_{reff}}} - 2\Delta L \quad = \frac{c}{2f_r}\sqrt{\frac{2}{\varepsilon_r+1}} \qquad (3-11)$$

Chapter 4

Design and Simulation results Of Patch Antenna

4.1 Introduction

The design parameters and obtained results are presented in this chapter. The designs of monopole antenna and Patch aperture Coupleing Microstrip Patch Antenna are illustrated respectively. In addition, the simulations results for both antennas designs are shown analyzed.

4.2 Monopole Antenna Structure

The Monopole antenna was designed and simulated by using HFSS Design Environment. using rectangular Printed Monopole Antenna on FR4 substrate (ε_r=4.4) having thickness 1.6 mm with loss tangent of 0.02 fed by a 50 Ω microstrip line . The geometry of the antenna shown in fig (4-1) . The detailed dimensions of the rectangular printed monopole antenna shown in fig (4-1) are listed below in Table (4-1) .

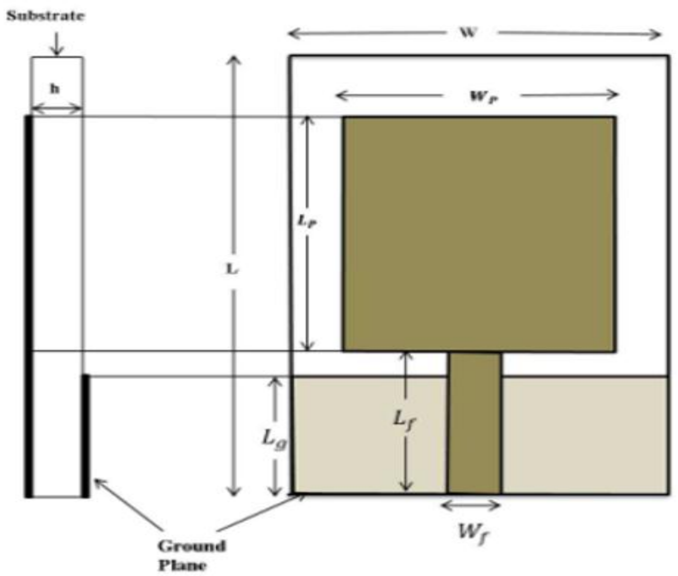


Fig (4-1) : Geometry of arectangular printed monople antenna

Table (4-1) : Detail dimensions of rectangular PMA.

Parameter	Dimension of Rectangular PMA							
	L_P	W_P	L_f	W_f	L_g	L	W	h
Units(in mm)	10	23.6	17.8	2.96	15	50	30	1.6

4.3 Simulation Results

HFSS software was applied to carry out the design simulations. Due to some difficulties, the hard ware design was not completed; such these problems the unavailability of some materials and spare parts.

Furthermore, the simulation results for these antennas as well.

4.3.1 Return Loss

The return loss less than -10 dB is very acceptable for WLAN and Bluetooth applications. The graph in figure (4-2) shows the simulation result for the monopole antenna.

As shown in this graph, it can be seen that at the resonant frequency 2.44 GHz the Return loss (RL) is -37.329 dB.The antenna bandwidth extended from 2.3563 GHz to 2.5234 GHz at -10 dB return loss is found to be 6.5 % and the return loss at 2.45 GHz is -28.6dB.

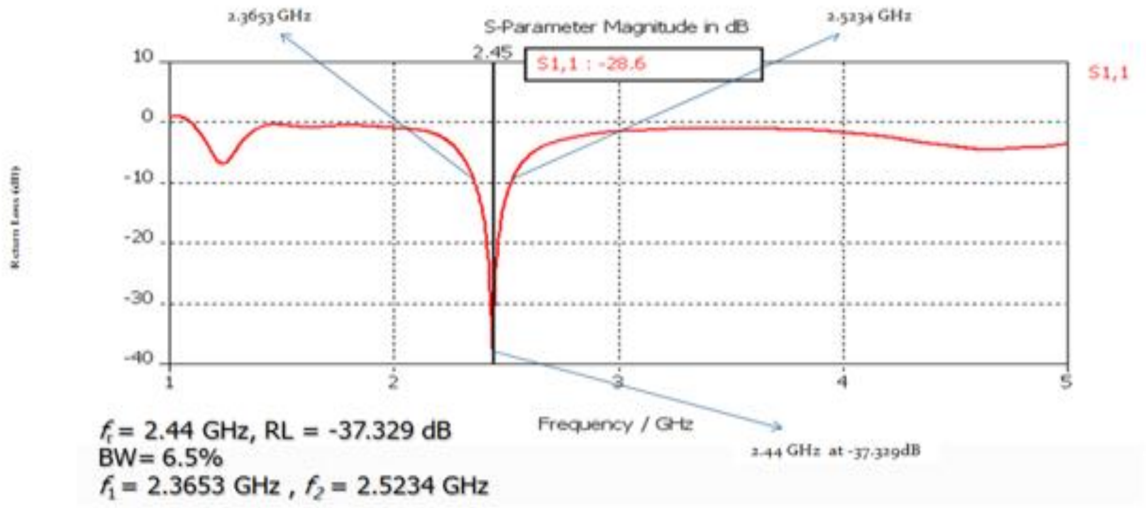


Fig (4-2) : Return Loss Simulated Result of Monopole antenna

4.3.2 Radiation Pattern

The figure (4-3) , (4-4) shows the simulated E-and H-field radiation patterns of the proposed antenna at a frequency of 2.4 GHz. Radiation pattern refers to the direction of the electromagnetic waves radiates away from the antenna. It is a graphical representation of radiation properties of the monopole antenna as the function of space co-ordinate. The realized gain is calculated by taking the ratio of the power radiated to the power into the antenna. As shown in the figure 4-3, the maximum realized gain is 2.4 dB at 2.4 GHz.

A monopole antenna radiates normally to its patch surface. The radiation patterns of the antenna is omnidirectional and with this, the radiation is omnidirectional which is desirable for such application.

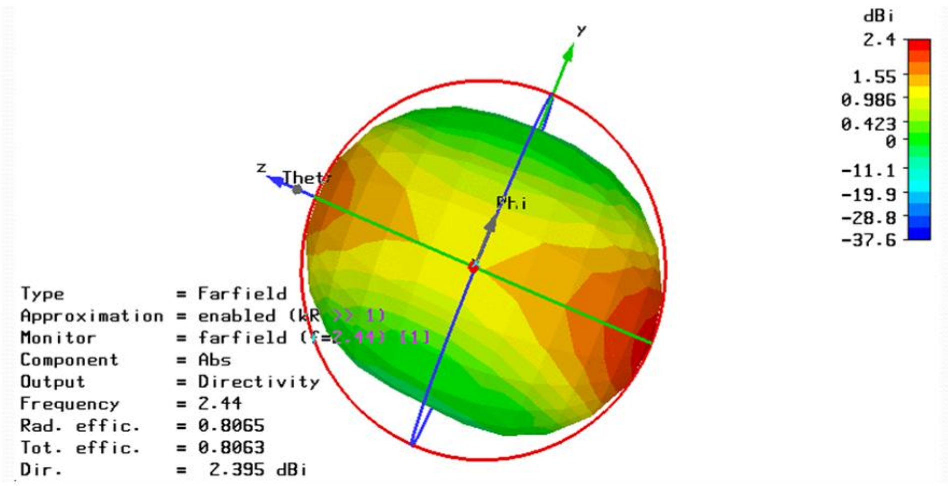


Fig (4-3) : The 3D Far Field Radiation Pattern of Monopole antenna

The results obtained from the Figure 4-4 are listed :-

1. Frequency 2.44 GHz.
2. Main lobe magnitude = 2.4 dBi.
3. Main lobe direction = 175.0 deg.

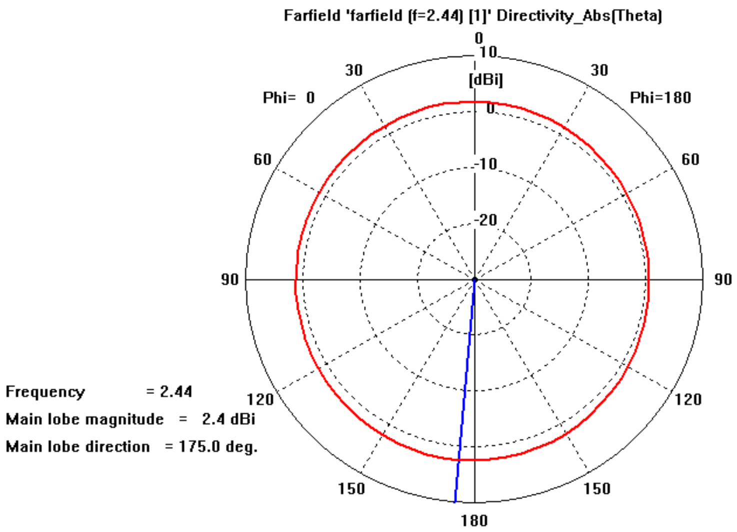


Fig (4-4) : E- plane radiation pattern result of monopole antenna

4.4 Patch Antenna Structure

Similarly a side view of the antenna is shown in the figure (4-5) to get a clear idea of the antenna feeding .

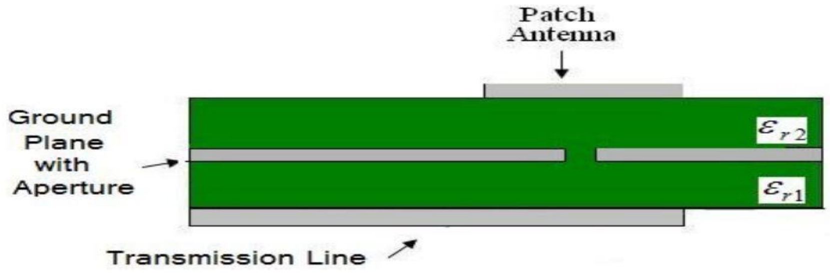


Fig (4-5) : Side view of the antenna

The driven patch (23.5 × 23.5)mm^2 is designed to operate at in the frequency band of 2.34 -2.46 GHz and is fed by a 50 Ohm microstrip line through an aperture (21.4 × 1.4)mm^2

etched on the center of the common ground plane. The feed layer (90 × 90 × 0.508) mm^3 and patch layer (90 × 90 × 8)mm^3 are built respectively by using the substrate Rogers

4003 C (ε_r = 3.55, tan δ = 0.0021).

4.5 Aperture Coupled Microstrip Patch Antenna

4-5-1 Design Specifications

An aperture coupled microstrip patch antenna was created and simulated in HFSS.
Figure (4-6) shows the 3-D schematic of the proposed aperture coupled microstrip patch antenna.

Table(4-2) shows the design parameters used for the aperture coupled microstrip patch antenna.

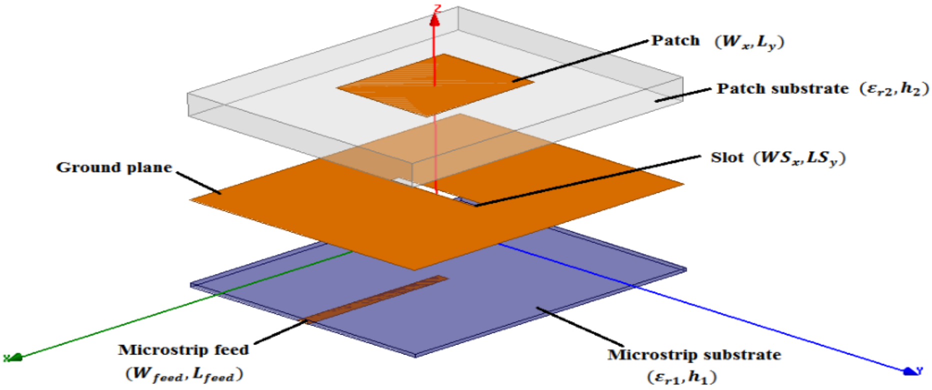


Fig (4-6) : 3-D schematic diagram of aperture coupled microstrip antenna.

Table (4-2) : Design parameters for aperture coupled microstrip patch antenna

Design Parameters		**Value (in mm)**
Microstrip Substrate Thickness (Rogers 400C)	h_1	0.508
Patch Substrate Thickness (Rogers 400 C)	h_2	8
Patch Length	L_y	23.5
Patch Width	W_x	23.5
Slot Length	LS_y	21.4
Slot Width	WS_x	1.4
Stup Length	l_{stub}	4.35
Microstrip Feed Length	L_{feed}	50
Microstrip Feed Width	W_{feed}	1.13

4.6 Simulation Results

The figures shows the simulation result for aperture coupled microstrip antenna design by using the (HFSS). And the practical experiment has been done to obtain the following parameters Return Loss and Radiation Pattern.

4.6.1 Return Loss

From the below Figure (4-7), it can be seen that at the resonant frequency 2.39 GHz the return loss (RL) is -20.24 dB.The antenna bandwidth extended from 2.34 GHz to 2. 46 GHz is found to be 4.9 % and the return loss at 2.39 GHz is -20.24 dB.

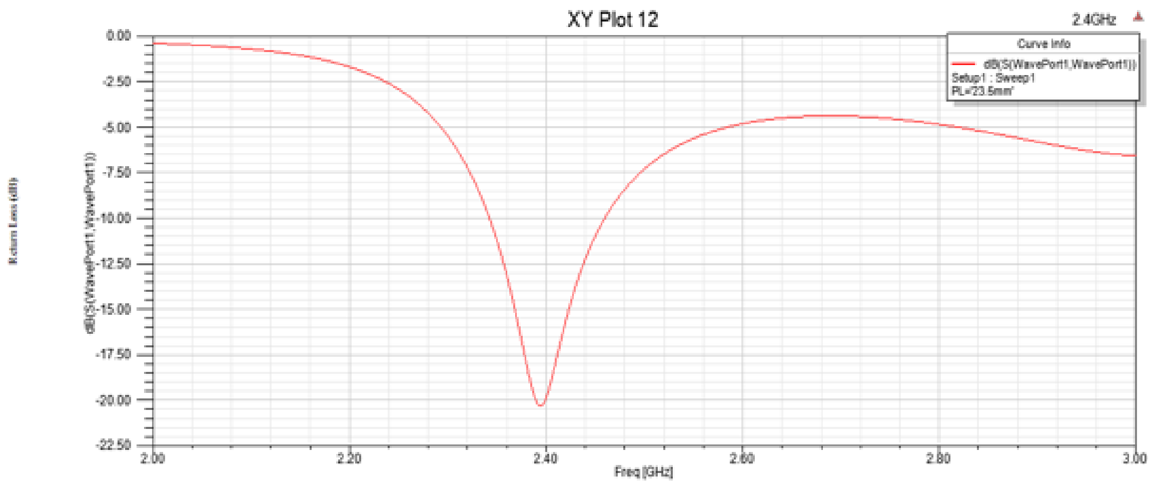


Fig (4-7) : Return Loss Simulated Result of aperture coupled microstrip Antenna.

4.6.2 Radiation Pattern

The realized gain represents the gain that includes the reflection losses at the input of the antenna. The realized gain is calculated by taking the ratio of the power radiated to the power into the antenna. As shown in the figure (4-8) , the maximum realized gain is 6.8 dB at 2.39 GHz.

Fig (4-8) : The 3D Far Field Radiation Pattern of aperture coupled microstrip Antenna

The results obtained from the Figure (4-9) are listed :-

1- Frequency 2.39 GHz.
2- Main lobe magnitude = 6.749 dBi.
3- Main lobe direction = 0 deg.

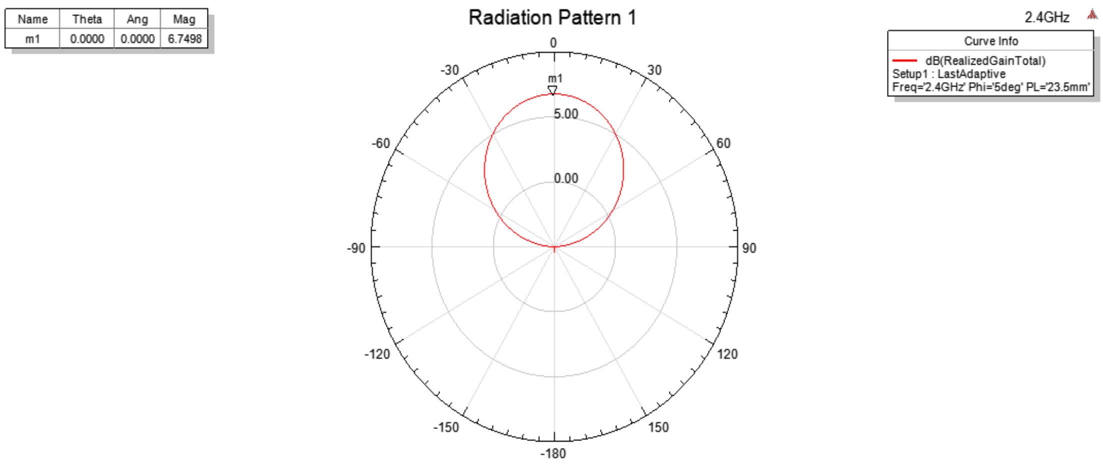


Fig (4-9) : E- plane radiation pattern result of aperture coupled microstrip antenna

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

The goal of this Thesis was to design a low cost, highly directional antenna that was low profile and easy to manufacture. Current high gain antennas on the market that meet these specifications are expensive. The development of a lower cost supplement with similar performance would attract consumers.

This Thesis focuses on the design of Monopole antenna operating and aperture coupled microstrip patch antenna at 2.4 GHz.

Monopole antenna has been presented. The antenna is capable of operation in the 2.44 GHz rang. **The simulated** result show a good return loss more than -37.329 dB.

An aperture coupled microstrip patch antenna has been presented. The antenna is capable of operating in the 2.39 GHz rang .**The simulated** result show a good return loss more than -20.24 dB. These indicate a good impedance matching is achieved in designing the patches and feeds.

5.2 Recommendations

work can be carried out to improve or extend the research further. Below are some recommendations that can be carried out:

- Optimize the current design to achieve the Dual-Band operation frequencies 2.4 and 5.8 GHZ.

- Different type of monopole antenna can be designed and studied, so that a comparisons can be made to the antennas.
- Study and see the effects of using different dielectric substrate.
- Decreasing the size would allow for the antenna to be implemented in more

wireless mobile applications where board space is limited. These applications include, but are not limited to, cellular phones, WiFi / WiMAX routers, gaming consoles, weather radars, WiFi-enabled televisions.

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APPENDIX

Show the steps of HFSS

ANSYS HFSS is an industry standard tool for simulation 3-D full- wave electromagnetic fields.

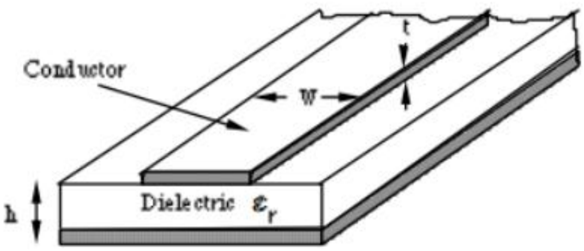
Getting Started

1- Name Project

2- New HFSS as shown below

Creating the Microstrip

We are going to make the substrate (dielectric layer), ground plane, and copper trace (conductor) for a microstrip line .

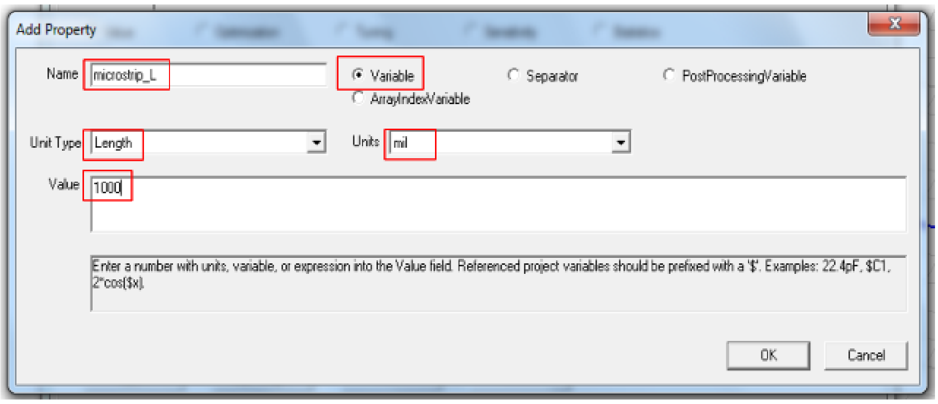


To do this, we will make three "boxes" in HFSS, and then designate the appropriate dimensions and material for each box [37].

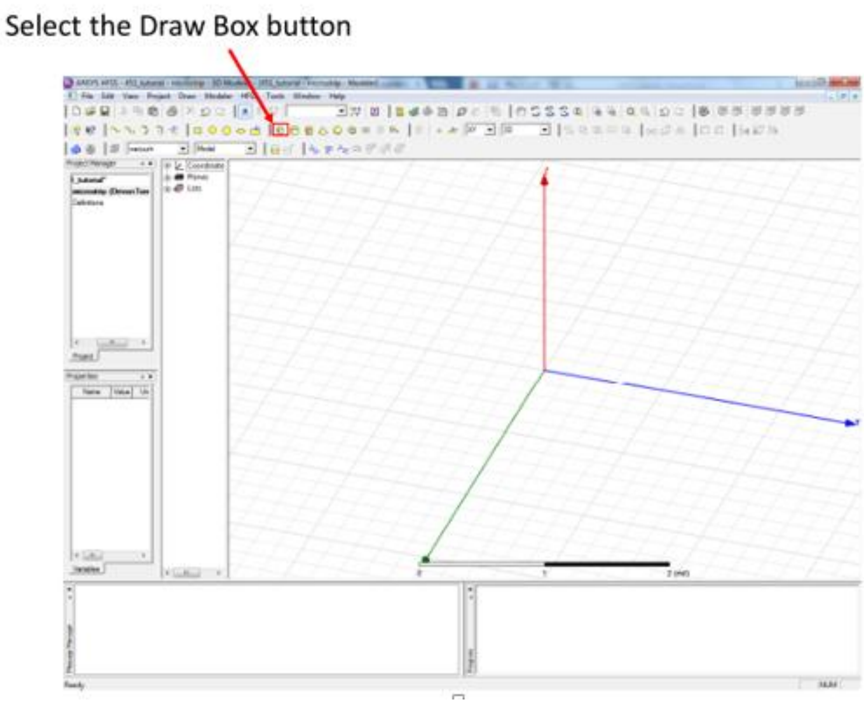
First we are going to define several variables for the dimensions of our substrate, ground plane, and copper trace

- Select HFSS ,Design Properties ,Add

- Fill in the properties as shown below



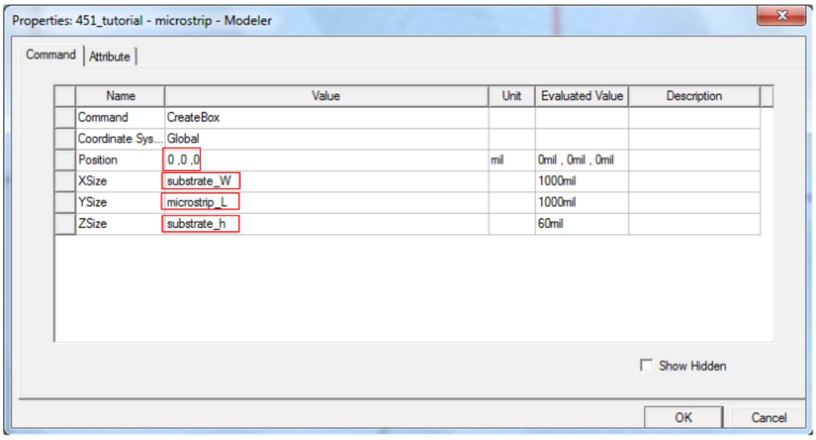
Creating the microstrip Substrate: (1)



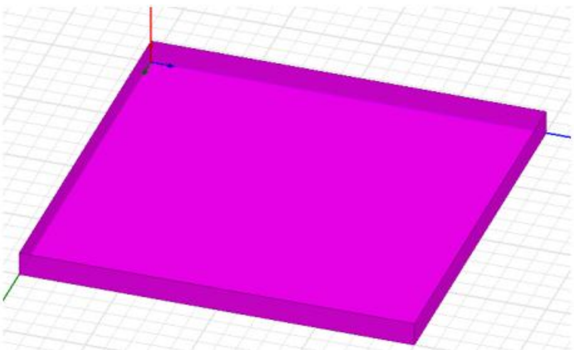
- created an arbitrary sized box.

A window will pop up in which you can define the dimensions and location of the box.

- Fill in the location and dimension as shown below.



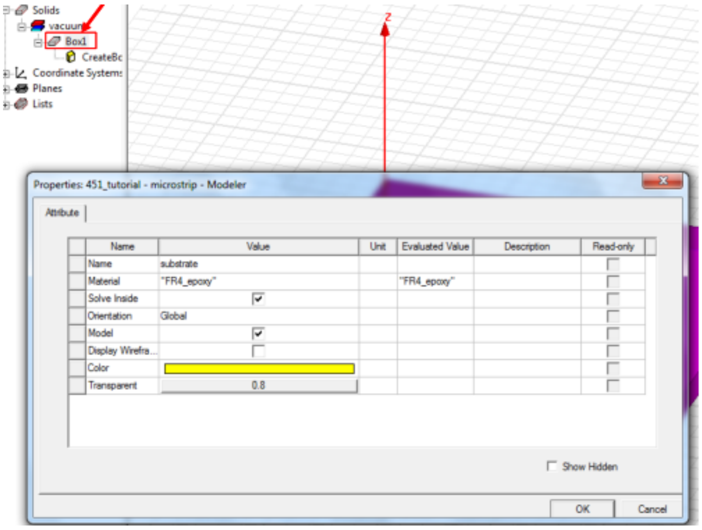
A box similar to this is created .



This box now has the dimensions that we want for our substrate. The next step is to define the material of our substrate.

- Fill in the properties as shown below

- Details on next slide .



- Change the name from Box1 to substrate.
- Change the material .
- Change the color to whatever you want .

We repeat the same previous steps for drawing the Gnd Plane and path

Creating the Air Box

HFSS treats the space around design that hasn't been designated as a specific material .

Because of this, we need to define an airbox around our design .

And Validation Check and Analyze to get the best gain [38] .