Mohamed Khider University of Biskra
Faculty of Sciences and Technology
Department of Electrical engineering

MASTER THESIS

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Design Circular Patch Antenna with Coaxial Feed using HFSS

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الجمهورية الجزائرية الديمقراطية الشعبية

People's Democratic Republic of Algeria

وزارة التعليم العالي و البحث العلمي

Ministry Of Higher Education and Scientific Research

Mohamed Khider Biskra University
Faculty of Sciences and Technology
Electrical Engineering Department
Field: Telecommunication
Option: Networks and Telecommunication

A Dissertation for the Fulfillment of the Requirement of a

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Design Circular Patch Antenna with Coaxial Feed using HFSS

Presented by: **Favorable opinion of the supervisor:**

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Ms. Abida TOUMI

Stamp and signature

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Proposed by: Rahma FORTAS

Directed by: Mr. Sofiane AMEID

Summarize (English and Arabic)

This work talks about the design of microstrip patch antenna that can achieved dual band and multiband. for this purpose we study to enhancement techniques for microstrip antenna,Two techniques are introduced DGS and circular slots for enhancing the return loss and the bandwidth,. Interesting results are obtained for specific band which are WLAN and mobile applications. The simulation and extracting parameters are by using of HFSS.

Keyword: DGS, slot, WLAN, mobile applications, microstrip patch antenna.

يتحدث هذا العمل عن تصميم هوائي مطبوع والذي يمكن أن يحقق النطاق المزدوج والنطاق المتعدد، و لهذا الغرض قمنا بدراسة تقنيات التحسين للهوائي المطبوع، حيث تم إدخال تقنيتين DGS وفتحات دائرية لتعزيز خسارة العودة وعرض النطاق الترددي. يتم الحصول على نتائج مثيرة للاهتمام لنطاقات محددة مثل WLAN وتطبيقات الهاتف المحمول. المحاكاة والمعلمات المستخرجة باستخدام HFSS.

الكلمات الرئيسية: DGS ، فتحة، WLAN، تطبيقات الهاتف المحمول، الهوائي المطبوع.

Dedication

I dedicate this project to God

Almighty, my Creator, my strong pillar, my source of inspiration,

and then to my dear parents and to all my family.

Acknowledgments

Thank God, the Lord of the Worlds, and the prayer and peace be upon our Lord Muhammad and his companions

First of all, I would like to express my sincere thanks to my great supervisor, Teacher AMIED Sofiane, who has kindly supervised this thesis and for his valuable scientific efforts, guidance and support.

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Finally, I thank all my family and especially my parents, their support, their prayers, they gave me all that they had just to see me a successful daughter, and now I'm trying to give them back a little piece of what they gave.

Contents

CHAPTER III : DESIGN AND SIMULATION

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List of abbreviation:

3D: Three Dimensional.

3G: 3rd Generation.

3GPP: 3rd Generation Partnership Project.

4G: Fourth Generation.

AR: Axial Ratio.

CM: Cavity Method.

DGS: Defected Ground Structure.

EDGE: Enhanced Data rates for GSM Evolution.

FDD: Frequency Division Duplexing.

FEM: Finite Element Method.

GSM: Global System for Mobile Communications.

HFSS: High Frequency Structure Simulator.

HSxPA: High-Speed Packet Access.

IEEE: Institute of Electrical and Electronics Engineers.

LTE: Long Term Evolution.

MAC: Medium Access Control.

MPA: Microstrip Patch Antenna.

OFDM: Orthogonal Frequency Division Multiplexing.

PCB: Printed Circuit Board.

PHY: physical layer.

QoS: Quality Of-Service.

RFID: Radio-Frequency IDentification

SC-FDMA: Single Carrier Frequency Division Multiple Access.

TDD: Time-Division Duplexing.

TEM: Transverse Electric Magnetic.

TLM: Transmission-Line Method.

UMTS: Universal Mobile Telecommunications System.

VSWR: Voltage Standing Wave Ratio.

WIMAX: Worldwide Interoperability for Microwave Access.

WLAN: Wireless Local Area Network.

WMAN: Wireless Metropolitan Area Network.

GENERAL INTRODUCTION

Iintroduction:

Man began to communicate since his creation, and he has used several methods for that throughout the ages. Human voices were used first, and then sounds such as drums or conch shell horns, and then smoke from signal fires were used, this technique was used in wars. After the appearance of the writing, people used homing pigeon to communicate with each other.

In 1938 Samuel Morse invented the telegraph, and it was the first electrical communication system developed for commercial use. Then, inventions continued until the advent of wireless communication. Where it was sent Signaling and audio communication using electromagnetic radiation. Transmitting information wirelessly was a sciatic curios-it.

Wireless Communication is the fastest growing and most vibrant technological areas in the communication field. Wireless Communication is a method of transmitting information from one point to other, without using any connection like wires, cables or any physical medium. Therefore, it allowed to the devices like smart phones, laptops and tablets to move around freely within the area of network.

The development of wireless technology is due to the development of antennas. The antenna is a necessary component in each wireless communication system, its provides a means of transmitting and receiving electromagnetic waves,

The first antennas were built in 1888 by German physicist Heinrich Hertz in his pioneering experiments to prove the existence of waves predicted by the electromagnetic theory of James Clerk Maxwell. Starting in 1895, Guglielmo Marconi began development of the antennas, this development continued until the antenna became an indispensable part of our daily life. They are present on satellites, planes, radars, in our telephones, at different frequencies, and different geometries.

microstrip antennas are the most common types of antennas it was first introduced in the 1950s. However, this concept had to wait for about 20 years to be realized after the development of the printed circuit board (PCB) technology in the 1970s. After that, microstrip patch antenna got more interest from the researchers due to its advantages over the wireless system.

The project's objectives:

The objective of this thesis is to design a microstrip patch antenna that can achieve both, the multiband and dual band, also, to address and improve the microstrip antenna parameters based on specific methods and techniques. With taking into account the simplicity and the efficacy of the design. All of this study and design is with the use of the 3D design program and electromagnetic simulator, which is the High Frequency Structure Simulator (HFSS) Version 15.

Work and Study plan:

This thesis is divided into three chapters organized as follows:

First chapter: an introduction about the wireless communications technologies and their frequency bands. Then, we introduce an definition of the antenna, mechanism of radiation, types, we finish the chapter with the parameters.

Second chapter: introduces the fundamentals of the microstrip patch antennas. We will present its characteristics, advantages and disadvantages, feeding methods, applications, and others. We finish with an overview of multiband antenna.

The third chapter: in this chapter three design models will be modeled and simulated.

The first one is for single band application. The second and third models are for the dual band and multiband respectively with the use of two techniques: patch antenna with defected ground structure and patch antenna with circular slots. For enhancements of antenna parameters. After that, we extract the obtaining results and discuss them for each design.

Our work is finish with conclusion and proposing perspectives as a future works.

CHAPTER I

ANTENNA FUNDAMENTALS

I.1 introduction

The wireless communication was first introduced in the 19th century by Guglielmo Marconi, and it's the fastest growing field of technology which has captured the attention of social life in the present century. And for this it became wireless communication technology has become an essential part of various types of wireless communication devices, this technology is mainly based on the transfer of information from one device to other through the air without requiring any cable or wires or other electronic conductors, That is, through electromagnetic waves, so we can say that the antenna is the most important part in wireless communication systems because it uses such kind of waves.

This chapter is divided into two parts, in the first part we will talk about different communication technologies like WLAN, LTE, and WIMAX. In the second one we will see an overview about antenna such definition, types, parameters, etc.

I.2 first part: wireless communication

I.2.1 IEEE 802.11 WLAN

A wireless local area network (WLAN) is an information system intended to offer diverse location-independent network service access to portable wireless devices using radio waves instead of wired infrastructure. Among existing system architectures, the IEEE 802.11 family is the most popular as the name suggests, it belongs to the group of popular IEEE 802.x standards and it's the accepted standard concerning medium access control (MAC) and physical (PHY) layers in WLANs.

In 1997, IEEE (Institute of Electrical and Electronics Engineers) released the 802.11 Wireless Local Area Network (WLAN) standard. In September 1999 the IEEE 802.11a amendment to the original standard was ratified. Basically, it utilizes the same core protocol as the original standard, operates in the 5-GHz band, and uses a 52-subcarrier OFDM with a maximum raw data rate of 54 Mbps, it is not interoperable with 802.11b, except if using equipment that implements both standards. Due to the fact that the 2.4-GHz frequency band has been heavily deployed, operating in the 5-GHz band gives 802.11a the advantage of less interference. In June 2003, a third modulation standard was ratified: 802.11 g. This extension exploits the 2.4-GHz frequency band (similar to 802.11b) but operates at a maximum raw data rate of 54 Mbps, or about 24.7 Mbps net throughput, similar to 802.11a. IEEE 802.11 g hardware is compatible with its 802.11b counterpart. The modulation scheme used in 802.11 g is OFDM. The maximum range of 802.11 g devices is slightly greater than that of 802.11b devices, but the range in which a client can achieve the full 54-Mbps data rate is much shorter than that which a802.11b client can reach, 11 Mbps [1], [2].

I.2.2 LTE

In 2004, LTE (Long Term Evolution) was first proposed by Japanese operator NTT DoCoMo [3]. The Long-Term Evolution (LTE) is the next evolutionary step beyond 3G for mobile wireless communication. LTE brings together many technological innovations from different areas of research, and it has been introduced by the Third Generation Partnership Project (3GPP) due to high demand for higher data rate and quality of service (QoS).

LTE is a latest standard in the mobile network technology tree that previously realized the GSM/EDGE and UMTS/HSxPA network technologies. The objective of LTE development is to build a system that meets demand for a high data rate, low latency, and optimization for packet switched traffic. The LTE is expected to provide peak data rates of at least100 Mbps in downlink and 50 Mbps in uplink. A major difference of LTE to other technologies is the radio interface where in LTE, Orthogonal Frequency Division Multiplexing (OFDM) and Single Carrier Frequency Domain Multiple Access (SC-FDMA) are used as radio access schemes for downlink and uplink respectively [4]. This technology has two duplex modes (time division duplex and frequency division duplex). In Time Division Duplex (TDD), the transmission direction is separated in the time domain while the uplink and downlink utilize the same frequency. This results in each call direction being allotted distinct timeslots. For Frequency Division Duplex (FDD), transmission in uplink and downlink utilized different frequencies [5].

I.2.3 WIMAX

In 1998, the Institute of Electrical and Electronics Engineers (IEEE) formed a group called 802.16 to develop a standard for what was called a wireless metropolitan area network (WMAN). The group first produced a standard for fixed wireless applications in 2001 and later enhanced it to support mobility. in the same year The industry consortium called Worldwide Interoperability for Microwave Access (WiMAX) Forum was formed develop, perform interoperability and conformance testing, and certify end-to-end wireless systems based on the IEEE 802.16 air-interface standards, WiMAX operates in a mixture of licensed and unlicensed bands. The unlicensed bands are typically the 2.4 GHz and 5.8 GHz bands. Licensed spectrum provides operators control over the usage of the band, allowing them to build a high-quality network. The unlicensed band, on the other hand, allows independents to provide backhaul services for hotspots. In 2005, the revised standard, called IEEE 802.16e, was completed and is often referred to as Mobile WiMAX. That operates in licensed frequency bands in the range of 2 to 6 MHz [6],[7].

The IEEE 802.16 standard supports frequency division duplexing (FDD) and time division duplexing (TDD). For the most part, FDD has been used in cell phone technology. The reason that TDD is also used is that it can dynamically allocate upstream and downstream bandwidth depending on traffic requirements [1].

I.3 second part: antenna

I.3.1 definition

Antennas are essential parts in communication systems. and it's a device that is used to transfer guided electromagnetic waves (signals) to radiating waves in an unbounded medium, usually free space, and vice versa. Antennas are frequency-dependent devices. Each antenna is designed for a certain frequency band. Beyond the operating band, the antenna rejects the signal. Therefore, we might look at the antenna as a band pass filter and a transducer [8].

I.3.2 how an antenna radiate

In order to know how an antenna radiates, let us first consider how radiation occurs A conducting wire radiates mainly because of time-varying current or an acceleration (or deceleration) of charge. The radiation from an antenna can be explained with the help of **Figure I.1** which shows a voltage source connected to a two conductor transmission line. An electric field is created which is sinusoidal in nature when a sinusoidal voltage is applied across the transmission line and this results in the creation of electric lines of force which are tangential to the electric field. The free electrons on the conductors are forcibly displaced by the electric lines of force and the movement of these charges causes the flow of current which in turn leads to the creation of a magnetic field [9].

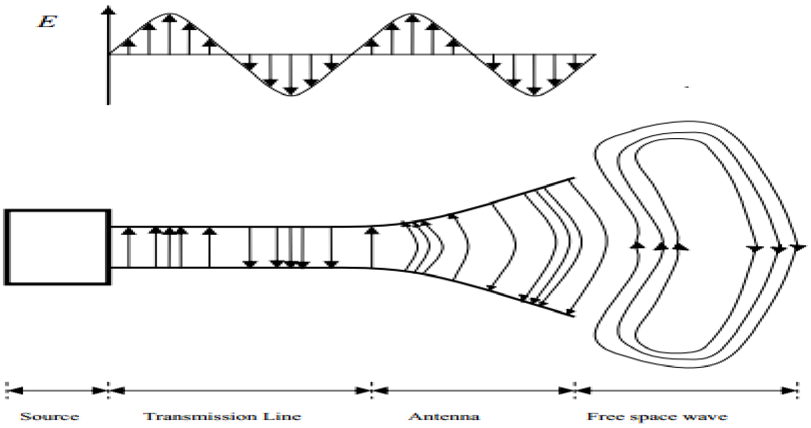


Figure I.1: Radiation of antenna [9].

I.3.3 types of antenna

Below we will introduce and briefly discuss some forms of the various antenna types like wire, aperture, microstrip antenna.

a) Wire antenna:

Wire antennas are familiar to the layman because they are seen virtually everywhere on automobiles, buildings, ships, aircraft, spacecraft, and so on. There are various shapes of wire antennas such as a straight wire (dipole), loop, and helix. Circular loop is the most common because of its simplicity in construction. Loop antennas can take other forms. They may take the form of a rectangle, square, ellipse, or any other configuration [10].

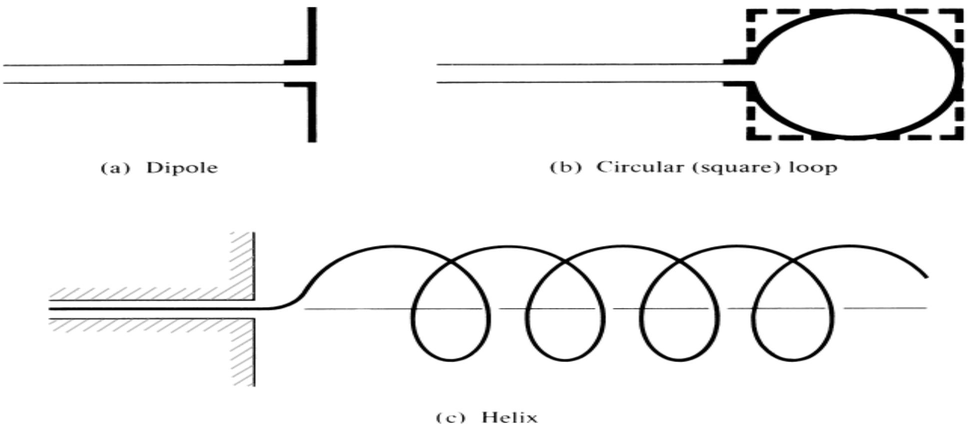


Figure I.2: Wire antenna examples [10].

b) Aperture antenna:

Aperture antennas are very popular for aircraft applications because it can be flush mounted onto the surface and the aperture opening can he covered with a radome to protect the antenna from the environmental conditions. This is implemented to maintain the aerodynamic profile of high-speed aircraft. Aperture antennas are used at microwave and the millimeter wave frequencies. There are a large number of categories for which the radiated electromagnetic fields can be considered to emanate from a plane aperture. This includes reflector antennas, lenses and horn antennas. The geometry of the aperture may he any shape [11].

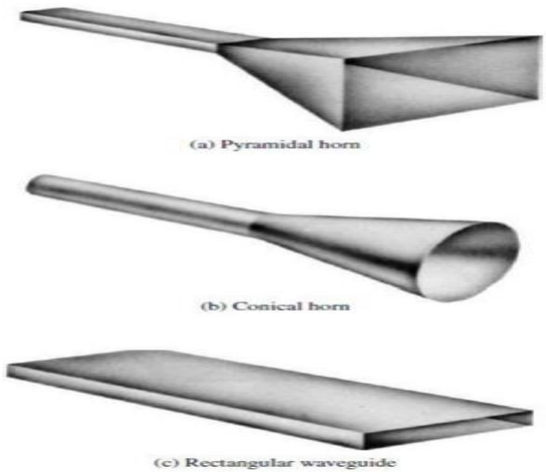


Figure I.3: Aperture antenna configuration [10].

c) Microstrip antenna:

Microstrip is the most successful and revolutionary antenna technology ever. Its success comes from very well-known advantages. And it also has some limitations, the most well-known being the inherent narrow bandwidth, narrow impedance, low axial ratio (AR), small gain, lower power handling capacity and low efficiency. These antennas consist of a metallic patch on a grounded substrate the metallic patch can take many different configurations. However, the rectangular and circular patches are the most popular. Microstrip patch antennas can operate in dual-band and multi-band application either dual or circular polarization. Microstrip is considered the most successful and revolutionary antenna technology ever.

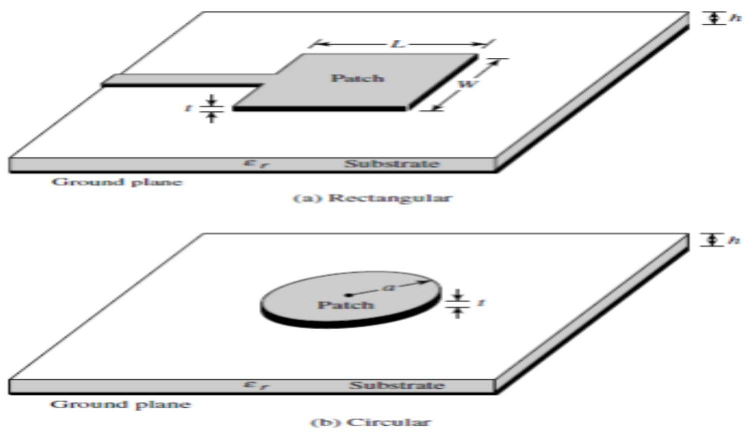


Figure I.4: Patch antennas [10].

Microstrip patch antennas are more popularly used now a days due to its various advantages such as light weight, low volume, easy to install on the rigid surface and low cost. These antennas can be mounted on the surface of high-performance aircraft, spacecraft, satellites, missiles, cars, and even handheld mobile telephones [10], [12], [13].

d) Array antenna:

Multielement antennas are widely used for years in wireless communications because of their potentialities in terms of high gain beam scanning and complex beam shaping. Most of applications of radiating arrays concerns very large panel (more than 20 wavelength side) with several hundreds or thousands of elements. In an array antenna, the fields from the individual elements interfere constructively in some directions and cancel in others. Usually, arrays consist of identical elements, although it is possible to create an array of dissimilar radiating elements.

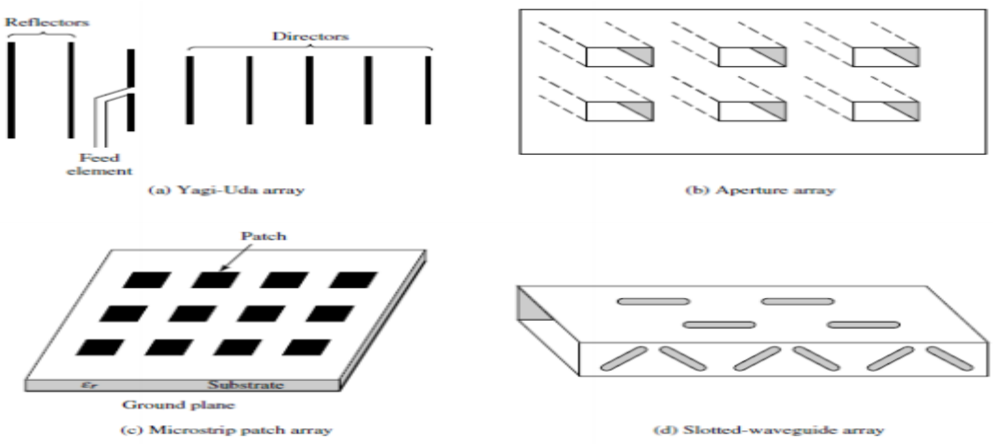


Figure I.5: Array antenna configuration [10].

Arrays offer the unique capability of electronic scanning of the main beam by changing the phase of the excitation current of each array element. There are many main control mechanisms that affect the overall performance of an array antenna, such as the array geometry (linear, circular, planar, etc.), the distance of separation between adjacent elements, and the radiation pattern of each individual element [14],[15].

I.3.4 antenna parameters

During the design process of an antenna, Consideration should be given to the effect of some basic parameters on the antenna efficiency such as radiation pattern, return loss, bandwidth, and others. Some of the antenna parameters are described below.

a) Radiation pattern:

The radiation pattern is defined as the spatial distribution of a quantity that characterizes the electromagnetic field generated by an antenna [15]. 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 [16].

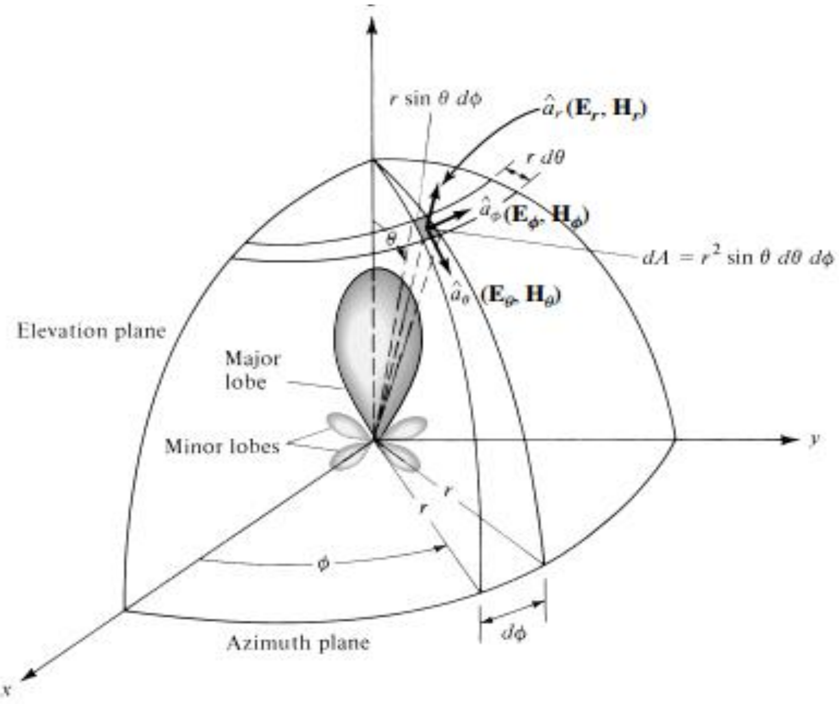


Figure I.6: Radiation pattern [16].

b) Return loss:

Return Loss (RL). This was first used in the telephone industry to measure the "echo" on the various bidirectional circuits and lines. Return loss is a measure of the effectiveness of power delivery from a transmission line to a load such as an antenna. It is simply the logarithmic ratio of relative magnitudes of input power and reflected power expressed in dB. The following expression represents the return loss:

$$\mathbf{RL = 10\ log10\ \frac{Pin}{Pref}} \quad \textbf{(I.1)}$$

Where:

- RL= Return Loss
- P_{in} = input power
- P_{ref} = reflected power

Reflected power cannot exceed input power. Thus Pref < Pin and RL is a positive number. Negative return loss is possible with active devices [17],[18].

c) Bandwidth:

Bandwidth is a fundamental antenna parameter. Is defined as the range of frequencies within which the performance of the antenna conforms to a specified standard. Bandwidth describes the range of frequencies over where the antenna parameters, is within an acceptable value from those at the center frequency. As shown in the following expression:

$$\mathbf{BW = \frac{F_H}{F_L}} \quad \textbf{(I.2)}$$

For narrowband antennas, the bandwidth is expressed as a percentage of the frequency difference (upper minus lower (F_L)) over the center frequency (F_C) of the bandwidth **(I.3)** represent that [19],[20]:

$$\mathbf{BW = 100} \times \mathbf{\frac{F_H - F_L}{F_C}}\ [\%] \quad \textbf{(I.3)}$$

Where:

- BW = bandwidth

• F_H = highest frequency

• F_L = lowest frequency

• F_C = frequency of the center

d) Directivity:

Often a principal goal in antenna design is to establish a specified radiation pattern. Directivity of an antenna is defined as the ratio of the radiation intensity in a given direction from the antenna to the radiation intensity averaged over all directions. The following equation represents it:

$$\boldsymbol{D} = \frac{\mathbf{U}}{\mathbf{U0}} \quad \textbf{(I.4)}$$

We also can define the directivity as the average radiation intensity: total power radiated by the antenna divided by 4π [21],[22].

$$\boldsymbol{D} = \frac{\mathbf{4\pi U}}{\mathbf{P_{rad}}} \quad \textbf{(I.5)}$$

Where**:**

• D = directivity

• U = radiation intensity (W/sr)

• U0 = radiation intensity of isotropic source (W/sr)

• P_{rad} = total radiated power (W).

e) Gain:

Gain is the most important performance parameter of an antenna. The gain of the antenna is closely related to the directivity. But the difference between them is that the gain takes into account the efficiency and directivity of antenna together. Hence the gain given by:

$$\mathbf{G} = \boldsymbol{e}_{\mathbf{t}}\ \mathbf{D} \quad \textbf{(I.6)}$$

Also can define as the ratio of the radiation intensity in a given direction from the antenna to the total input power delivered to the antenna port divided by 4π. It is expressed as [23],[16]:

$$\mathbf{G} = \mathbf{4\pi} \times \frac{\mathbf{U}}{\mathbf{P_{in}}} \quad \textbf{(I.7)}$$

Where:

- G = gain
- e_t = total efficiency
- D = directivity
- U = radiation intensity
- P_{in} = total radiated power

f) input impedance:

The input impedance of an antenna is the impedance presented by an antenna at its terminals. The antenna impedance Z_A can be expressed as :

$$\mathbf{Z_A} = \boldsymbol{R_A} + \boldsymbol{j}\mathbf{X_A} \quad \textbf{(I.8)}$$

The radiation resistance is associated with the radiation of real power. For a lossless antenna, with [15]:

$$\mathbf{R_A} = \boldsymbol{R_r} + \mathbf{R_L} \quad \textbf{(I.9)}$$

j) Polarization:

Polarization is defined as the curve traced by the end point of the arrow (vector) representing the instantaneous electric field. The field must be observed along the direction of propagation. There are two types of polarization, circular and linear polarization [24].

j.1) linear polarization:

The polarization of an antenna is determined by the direction of the electric field.In linear polarization the electric field vector changes in magnitude only. Polarization mismatch occurs when the polarization of the receiving antenna is not equal to the polarization of the incoming wave [25] .

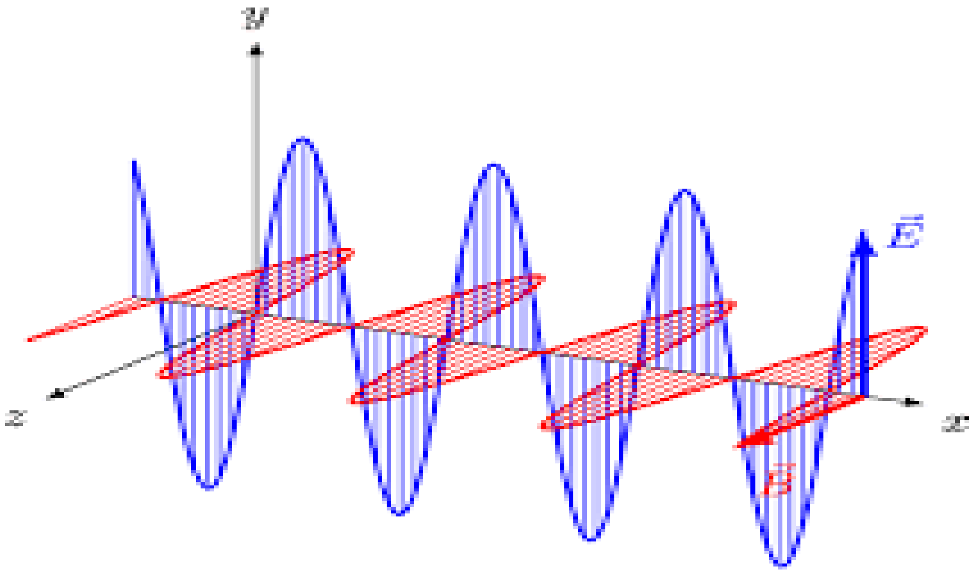


Figure I.7: Linear polarization [26].

j.2) circular polarization:

In circular polarization, the electric field at that point traces a circle as a function of time and it only can be achieved when the magnitude of two components are same . Axial ratio can used to determine the quality of the circular polarization. Circular polarized antenna can be achieved by using slot, truncated corner, nearly square patch, double layer, and others [27].

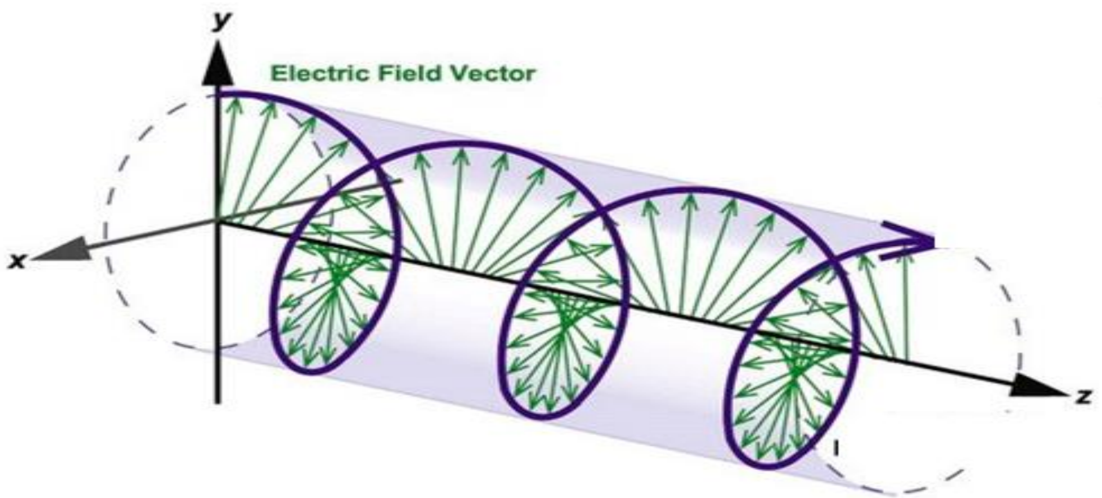


Figure I.8: Circular polarization [28].

I.4 Conclusion:

In this chapter, we presented an overview on some famous wireless communications technologies like WLAN, LTE, WiMAX. Because of the need and the importance for wireless communication for present. we also seen a definition and types of the antenna, Which is one of the most important elements of wireless communication, then we presented the main characteristic parameters that used in telecommunication networks such radiation pattern, return loss, bandwidth, directivity ,input impedance, etc.

These parameters considered as the main factors for designing a perfect antenna.

CHAPTER II

MICROSTRIP PATCH ANTENNA

II.1 Introduction

The field of information science and technology incorporates several devices, including antennas, which can be used to transmit, collect and transfer information. Understanding how these antennas work and how they can be utilized at different frequencies ranging from radio to terahertz requires knowledge of the basic parameters for their operation. Microstrip patch antennas are the important device in wireless communication systems due to their light weight, low profile, high gain, and simple structure antennas, and high efficiency characteristics.

In this chapter, we will present theoretical analysis of microstrip patch antenna, we will see its characteristics, advantages and disadvantages, feeding methods, application, and others.

II.2 Circular Microstrip Patch antennas

Microstrip antennas or printed circuit board received considerable attention starting in the 1970s but he idea was be traced to a 1953. A Microstrip patch antenna consists of a radiating patch on one side of a dielectric substrate which has a ground plane on the other side .The patch is generally made of conducting material such as copper or gold. The MPA shape are shown in **Figure II.1** However, other shapes, such as the square, circular, triangular, semicircular, annular and square ring shapes shown in **Figure II.2** are also used [29],[9]

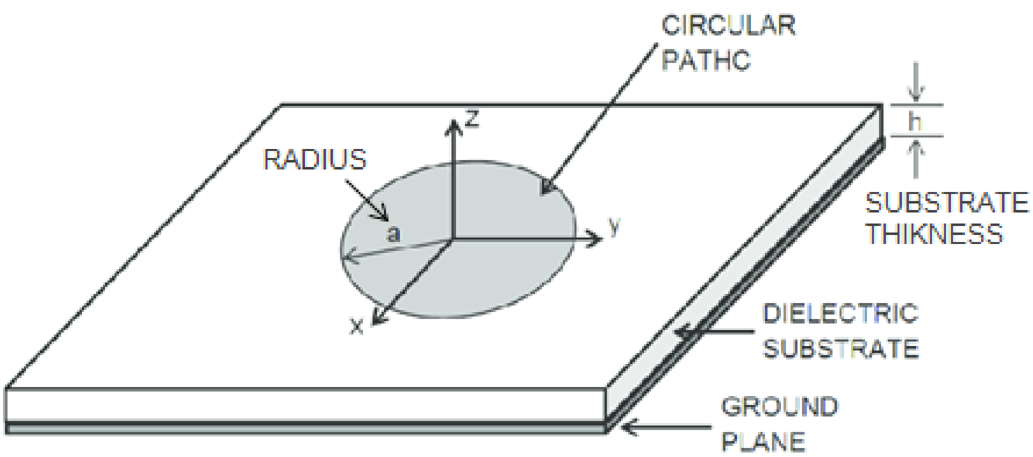


Figure II.1: Circular Microstrip Patch antenna [30].

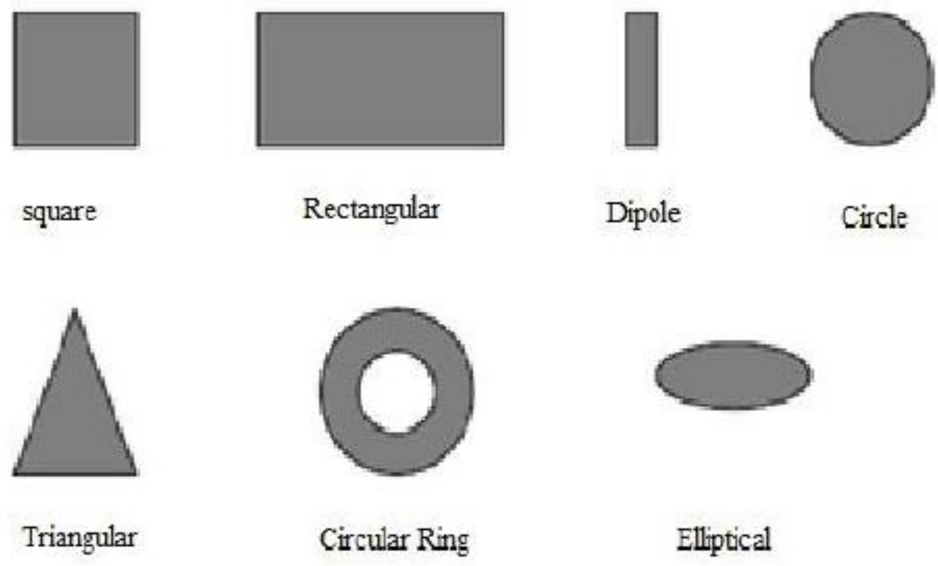


Figure II.2: Different shape of patch antenna [31].

II.3 Basic principles of operation

The basic principles are illustrated here for a circular patch, but the principles apply similarly for other patch shapes. The electric field is zero at the center of the patch, maximum (positive) at one side, and minimum (negative) on the opposite side. It should be mentioned that the minimum and maximum continuously change side according to the instantaneous phase of the applied signal. The electric field does not stop abruptly at the patch's periphery as in a cavity, rather, the fields extend the outer periphery to some degree. These field extensions are known as fringing fields and cause the patch to radiate [19]

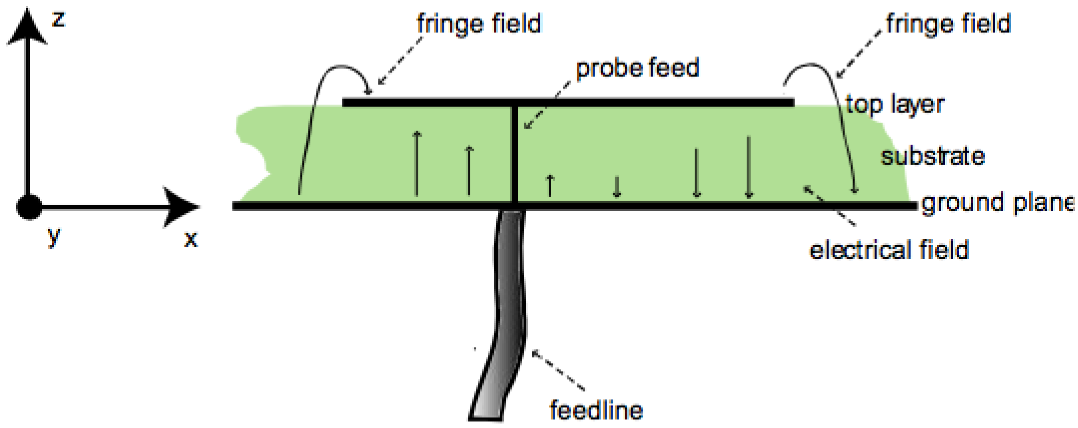


Figure II.3: Cross section of a patch antenna in its basic form [32].

II.4 Feed techniques

Microstrip line, Coaxial, Aperture and proximity feed are the four-methods considered as the most popular techniques.

II.4.1 Microstrip line feed

In this kind of technique, the microstrip patch is directly connected with the conducting microstrip feed line. The dimensions of the feed line are different than microstrip patch. It is the most easier technique in fabrication compared to the three other methods [33].

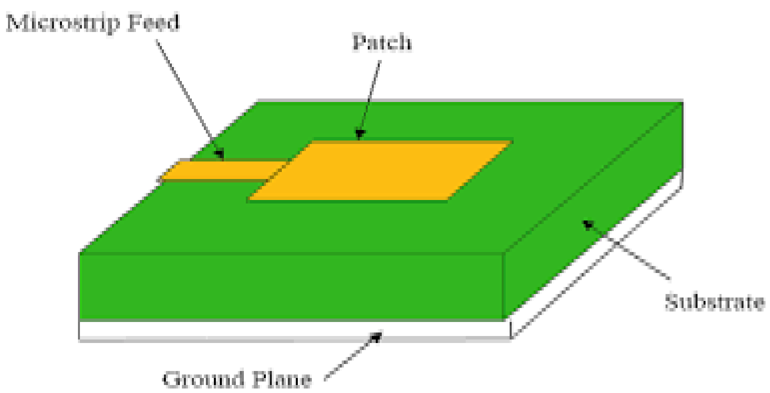


Figure II.4: Microstrip line feed [34].

II.4.2 Coaxial feed

In this feeding method, inner conductor of coaxial cable is connected to the microstrip patch of an antenna and outer one is connected with ground plane . Mostly, the feed networks are isolated from the microstrip patch, but in this mechanism, it is not like that .Spurious radiation minimization, easy fabrication and efficient feeding are the advantages of coaxial feeding method [33].

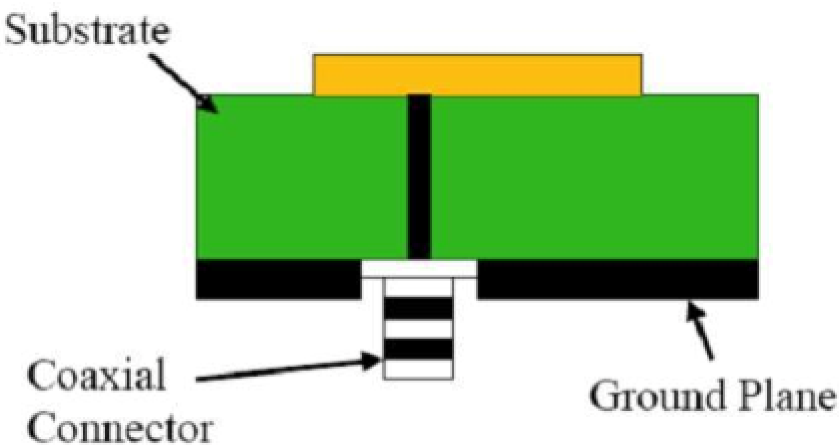


Figure II.5: Coaxial line feed [34].

II.4.3 Aperture coupled feed

In this technique, the radiating patch and the microstrip feed line are separated by the ground plane. The patch and the feed line is coupled through a slot in the ground plane. The coupling slot is centered below the patch, leading to low cross polarization. Since the ground plane separates the patch and the feed line, spurious radiation is minimized. The main disadvantage of this feed technique is that it is difficult to fabricate due to multiple layers, which also increases the antenna thickness [35].

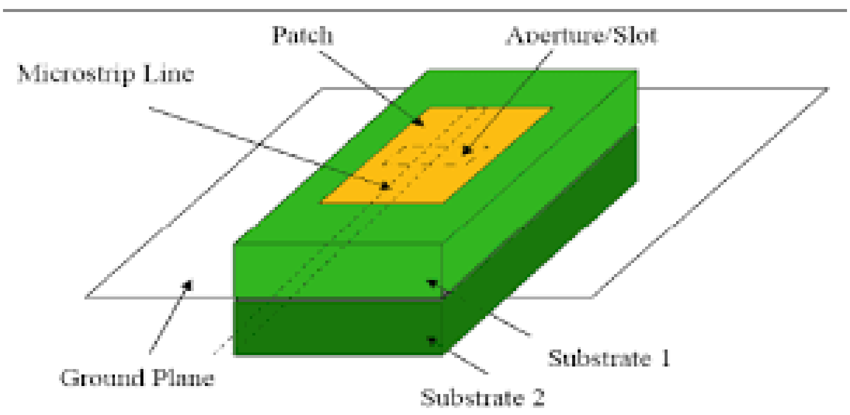


Figure II.6: Aperture coupled feed [36].

II.4.4 Proximity coupled feed

Proximity Coupled Feed: In this type of feed two dielectric substrates are used such that the feed line is between the two substrates (**Figure II.33**). The radiating patch is on top of the upper substrate. The main advantage of this feed technique is to provide very high bandwidth and eliminates spurious feed radiation. This feeding technique poses drawbacks as it is fabrication is tough due to presence of two dielectric layers requires desired alignment. Also, the overall increment in the antenna thickness is a major concern.

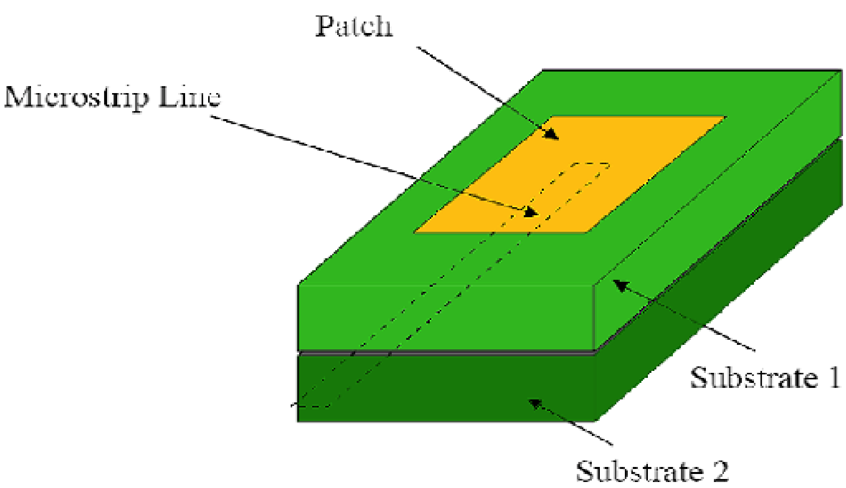


Figure II.7: Proximity coupled feed [37].

Matching can be achieved by controlling the length of the feed line and the width to- line ratio of the patch [38],[39].

II.5 Advantage and disadvantage of MSA:

Microstrip patch antennas have many advantages due to their importance, and among these advantages we mention the following [40],[41],[29]:

- Light in weight.
- Easy to feed and fabricate.
- They have lower fabrication cost
- They allow for dual- and triple-frequency operations.
- They can be made compact for use in personal mobile communication.
- They operate at microwave frequencies

Disadvantage of MSA:

The drawbacks of these types of antennas are [42],[43]:

- Low gain, narrow bandwidth.
- Low power handling capacity.
- Dielectric and conductor losses can be large for thin patches, resulting in poor antenna efficiency.
- Sensitivity to environmental factors such as temperature and humidity.

II.6 Microstrip Antenna Applications:

The microstrip patch antennas are famous for their performance and robust design. Microstrip patch antennas have applications in various fields such as in the medical field, satellites and even in the military systems just like in the rockets, aircrafts missiles and many more. . Some of these applications are discussed as below [9]:

- Mobile and satellite communication application.
- Global positioning system applications.
- Radio frequency identification (RFID).
- Interoperability for microwave access (WiMax).
- Radar application.
- Medicinal and Telemedicine applications.

II.7 Physical Models of Analysis

The microstrip patch antennas can be analyzed in various methods, the most popular are:

- Transmission-line method (TLM)
- Cavity method (CM)

II.7.1 Transmission Line Mode

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 – homogenous line of two dielectrics, 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 because the fringing fields around the periphery of the patch are not confined in the dielectric substrate but are also spread in the air [44].

Appropriateness of line model depends on the line length and the highest frequency to be simulated. For “short” or “medium” transmission lines, a simple lumped coupled-ð model, or several in series, may suffice .For longer lines or higher frequencies, Development of presently used transient transmission line models for this case are based on the “traveling wave model”[45].

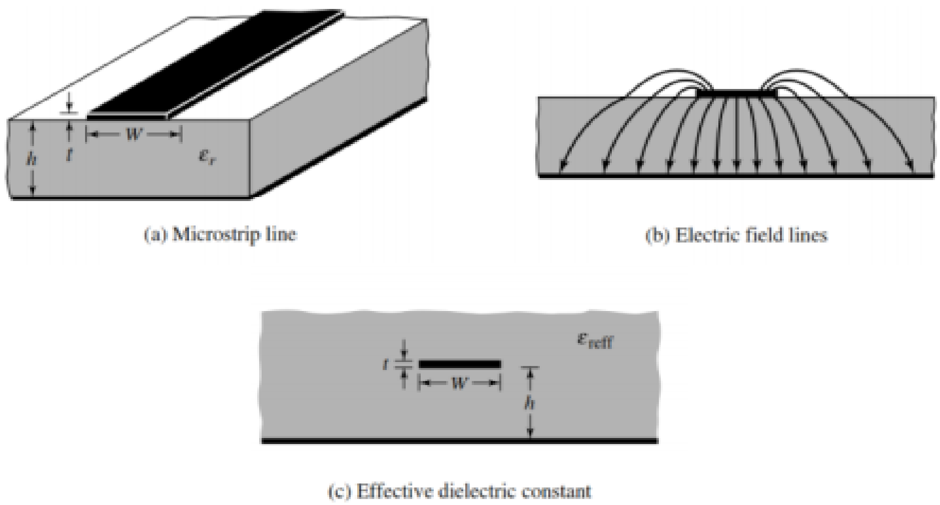


Figure II. 8: Microstrip line and its field lines, and effective dielectric constant Geometry [46] .

II.7.2 cavity Mode

The transmission line model impressive, and its good at usage, robust and easy. cavity model – this is preferred the most to analyze the Microstrip antenna. The structure of the model goes this way – the inner region of the patch is filled as a cavity, bounded by the electric walls on both ways i.e. on top and bottom, it has a magnetic wall thorough the periphery.

We can see the charge distribution on the upper and the lower surfaces of the patch and even at the bottom of the ground plane, this happens when there is a power given to the Microstrip patch [47].

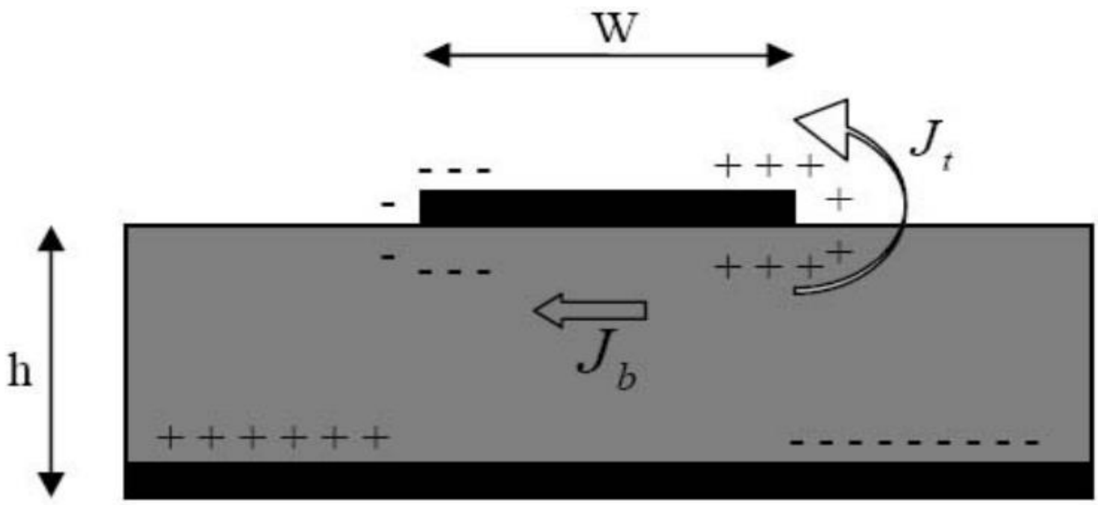


Figure II. 9: Charge distribution and the current density creation on the Microstrip patch [47].

II.8 multi-band antenna:

With the widespread use of the GSM system which employs the dual frequency bands and with the development of 3G and even 4G technologies, multiband and wideband antennas operating at additional frequency bands are required. In order to realize multiband operation, a wide variety of antenna types, which uses different multiband techniques, is used.Higher order resonances, Multiple resonant structure, parasitic resonators, and others.

It is expected, that all the handsets will probably become compatible with multibands in the near future. In such multiband systems, a multiband antenna is definitely one of the key devices since it is compatible with all the frequency bands without resort to multiple antennas [48],[49].

II.9 Conclusion:

The technological advancement of the microstrip antenna is increasing day by day. A lot of research work is going on microstrip antenna for its better utilization in the future. However, its suffer from the narrow band, Low power handling capacity. Fortunately, a lot of methods have been used to enhance the bandwidth of the microstrip patch antenna like using slot, using defected ground structure, etc.

All of these techniques are introduced carefully in the next chapter.

CHAPTER III

DESIGN AND SIMULATION

III.1 Introduction

In this chapter, we will give a design, simulation of circular microstrip patch antenna. This project involves studying the effect of improvement techniques on antenna characteristics (the coefficient of reflection, the resonance frequency and the bandwidth). The simulation is realized by applying computer simulation technology **(HFSS)** software.

Our study is beginning by the first design and the simulation of a basic antenna, the structure consists of a circular patch antenna fed by coaxial feed of 50 **Ω** for impedance matching.

In the second design, we take the same optimal dimensions for previous antenna but alter the ground plan by added two rectangular slots for a dual-band claiming. The design and simulation of the proposed antenna exhibits two narrow band one of which is intended for 3G mobile applications.

In the final design, we will take the circular patch antenna with DGS and we insert two circular slots on the radiating patch to perform the multi- band and with this insertion, we will show the appearance of the new resonance frequency.

III.2 Design and analysis

Ansoft HFSS has evolved over a period of years with input from many users and industries. In industry, it's the tool of choice for high-productivity research, development, and virtual prototyping.

HFSS is a high-performance full-wave electromagnetic (EM) field simulator for arbitrary 3D volumetric passive device modeling that takes advantage of the familiar Microsoft Windows graphical user interface, and it's an interactive simulation system whose basic mesh element is a tetrahedron. This allows you to solve any arbitrary 3D geometry, especially those with complex curves and shapes quickly and accurately. Ansoft pioneered the use of the Finite Element Method (FEM) for EM simulation. Ansoft HFSS can be used to calculate parameters such as S Parameters, Resonant Frequency, and Fields [50].

III.3 first design: simple circular patch antenna

In **Figure III.1** below, we present the architecture and geometry of our simple circular antenna, and the **table III.1** gives its dimension. The antenna is fed with a 50 Ω coaxial.

Parameter	Value
Dimension of ground	(50 × 45)mm^2
Dimension of Substrate	(50 × 45)mm^2
Thickness of Substrate	1.62 mm
Substrate material used	FR4-epoxy
Relative permittivity (ε_r)	4.4
Radius of circular patch (r)	20 mm
Location of feed (XO, YO)	(7.5 , 3)

Table III.1: The parameters of a circular antenna

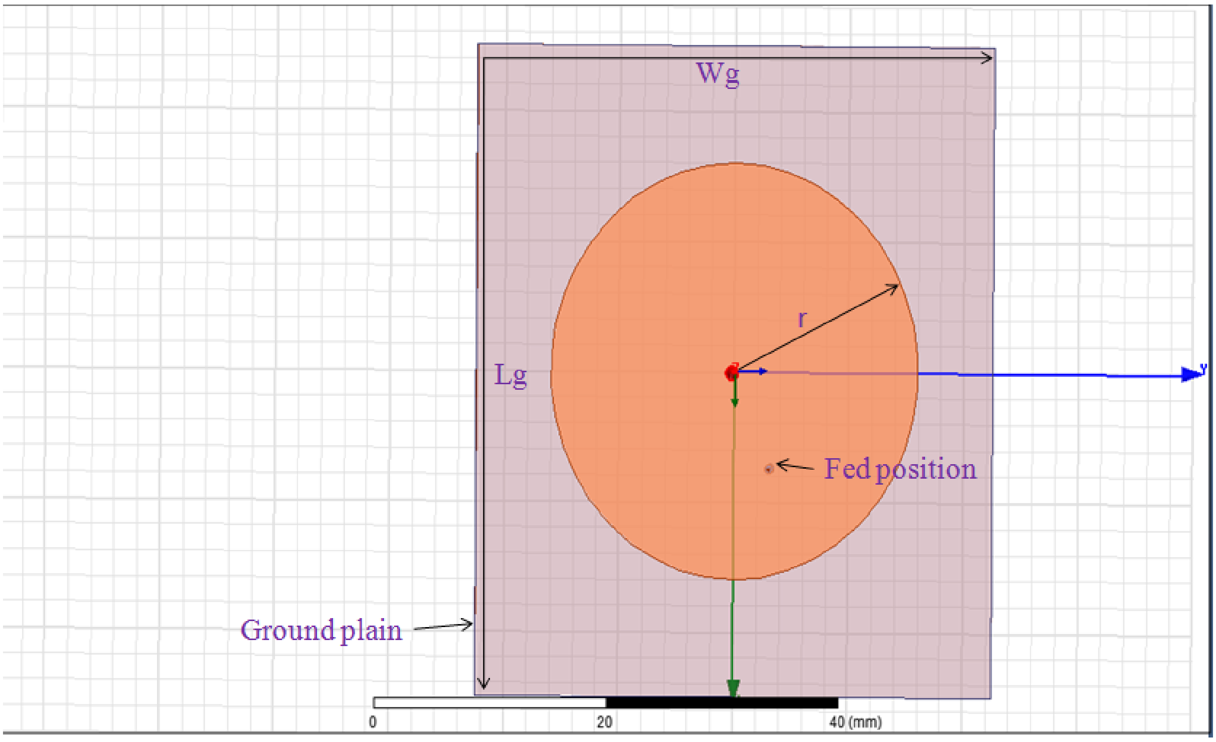


Figure III.1: Structure of a circular antenna.

III.3.1 geometrical study for the antenna

The study of the proposed antenna begins by studying the effect of the geometry parameters. Two parameters will be varied (r) and (Fp), knowing that when we were varied one at a time keeping the other constant.

III.3.2 effect of the radius of circular patch (r)

The **figure III.2** present the return loss for three different values of **r**, with **Fp** value is fixed at (7.5×3) mm. The parameter is varied as we can see in **Table III.2.** The result exhibits that when we increase in **r**, the resonance frequency decrease, and if we decrease **r** the frequency increasing.

r [mm]	f_H [GHz]	f_L [GHz]	f_C [GHz]	S_{11} [dB]
19	2.1423	2.0812	2.1114	-25.8625
20	2.0376	1.9853	2.0129	-38.1074
21	1.9394	1.8939	1.9144	-28.4605

Table III.2: Result of the radius of circular patch (r)

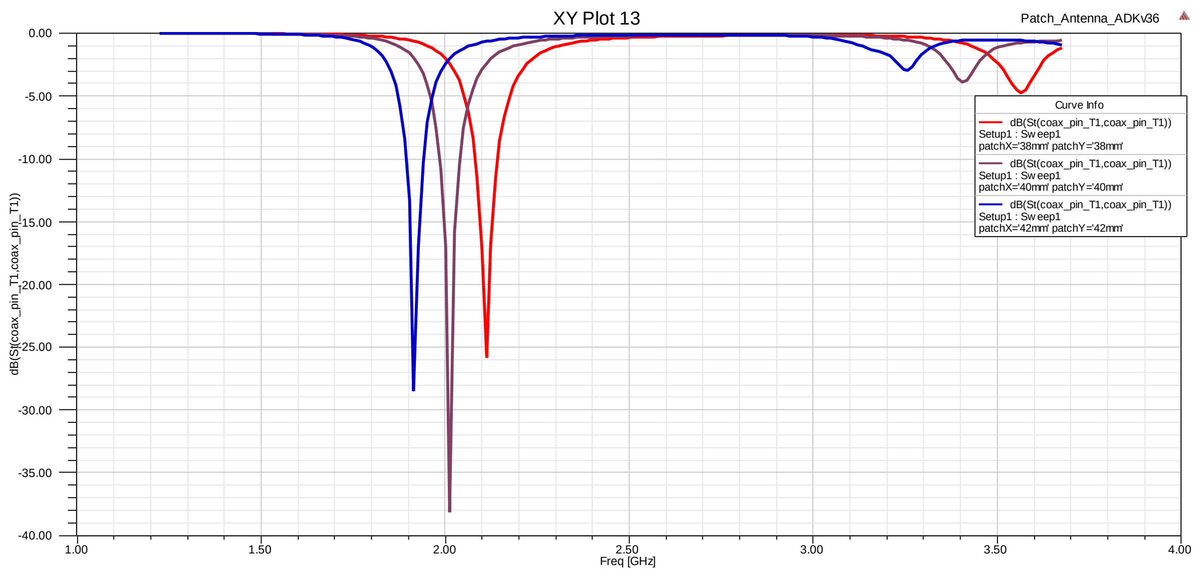


Figure III.2: Effect of variation in (r)

III.3.3 effect of the variation in feed position (Fp)

In this step, we change the position of the coaxial feed (Fp) between (7 x 2.5) mm and (8 x 3.5) mm and we maintain the variable r at 20mm. The results of the variation are listed at the **Table III.**3. The best results when (Fp) is at (7.5 x3) mm as shown in the **Figure III.3**.

Fp [mm]	F_H [GHz]	F_L [GHz]	F_C [GHz]	S_{11} [dB]
(7×2.5)	**2.0319**	**1.9817**	**2.0006**	**-18.6887**
(7.5×3)	**2.0376**	**1.9853**	**2.0129**	**-38.1074**
(8×3.5)	**2.0132**	**1.9603**	**1.9883**	**-27.1291**

Table III.3: Result of the variation in (Fp).

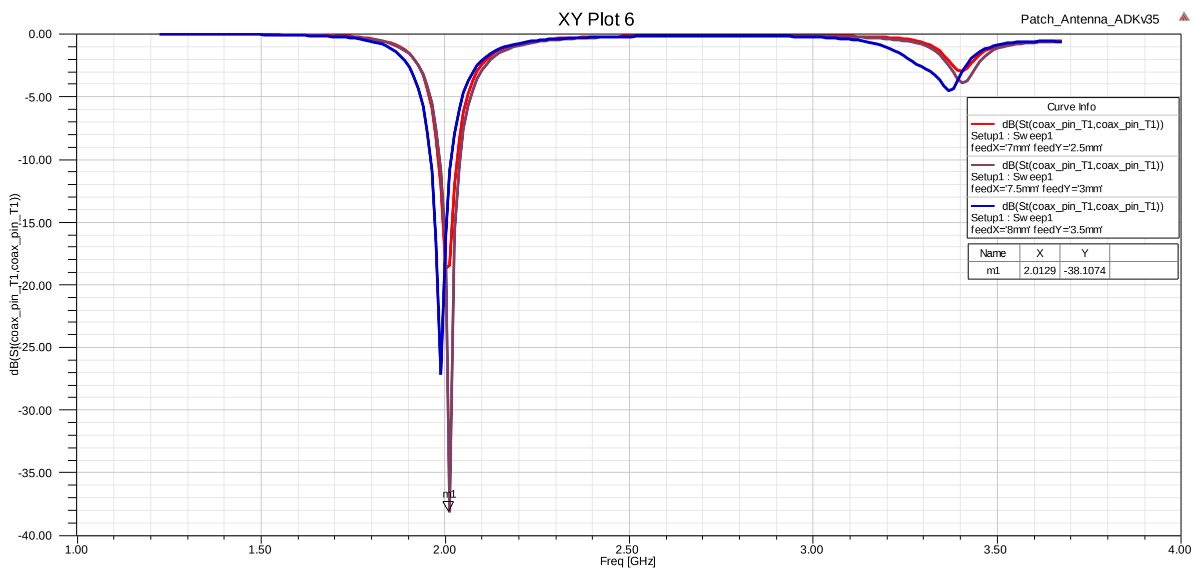


Figure III.3: Effect of variation in (Fp).

Based on the previous results, we can say that the two engineering parameters only affect the operating frequency by decreasing or increasing. **Figure III.4** shows the performance return loss as a result of the two studies above when variables (r) and (Fp) take 20 mm and (7×2.5) mm respectively. The result indicates a very good match,-38dB at 2.01GHz for mobile application. The bandwidth set for -10 dB is 2.6%.

With:

$$\mathbf{BW = f_H - f_L = (2.0376\ - 1.9853\,) = 0.523\ GHz}$$

Or:

$$\mathbf{BW = 100 \times \frac{f_H - f_L}{f_C}\ [\%] = 100 \times \frac{0.0523}{2.0129}[\%] = 2.598\%}$$

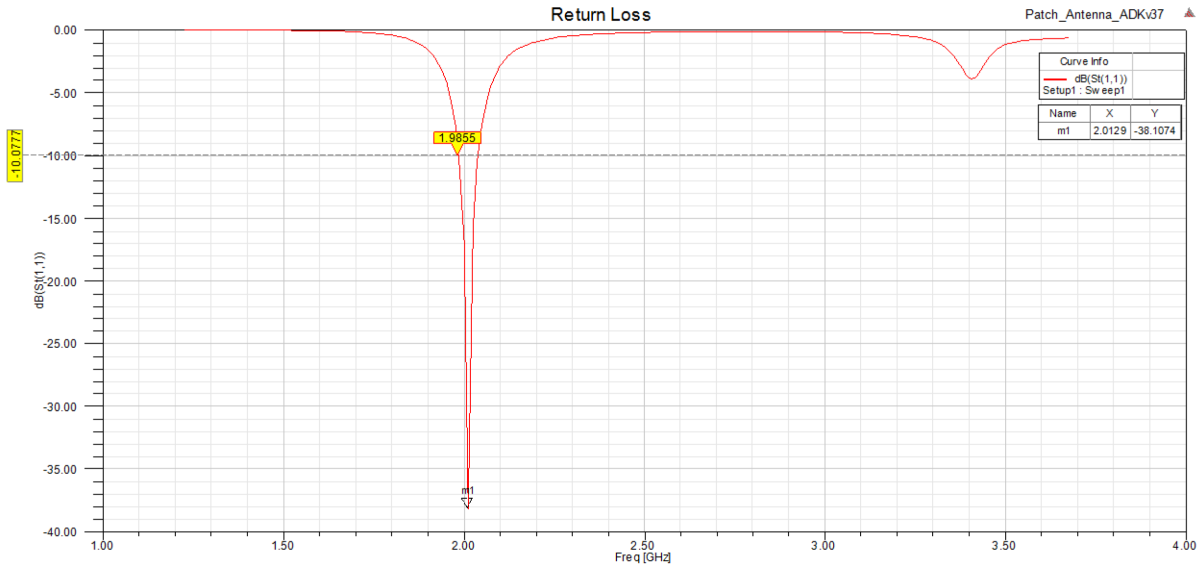


Figure III.4: Return loss for circular antenna.

VSWR:

In **Figure III.5** we see VSWR (voltage standing wave ratio) it expresses the quality of the antenna adaptation. We note that at the frequency 2.01 GHz with VSWR =1.0252, which confirms that our antenna present a good impedance matching at resonant frequency.

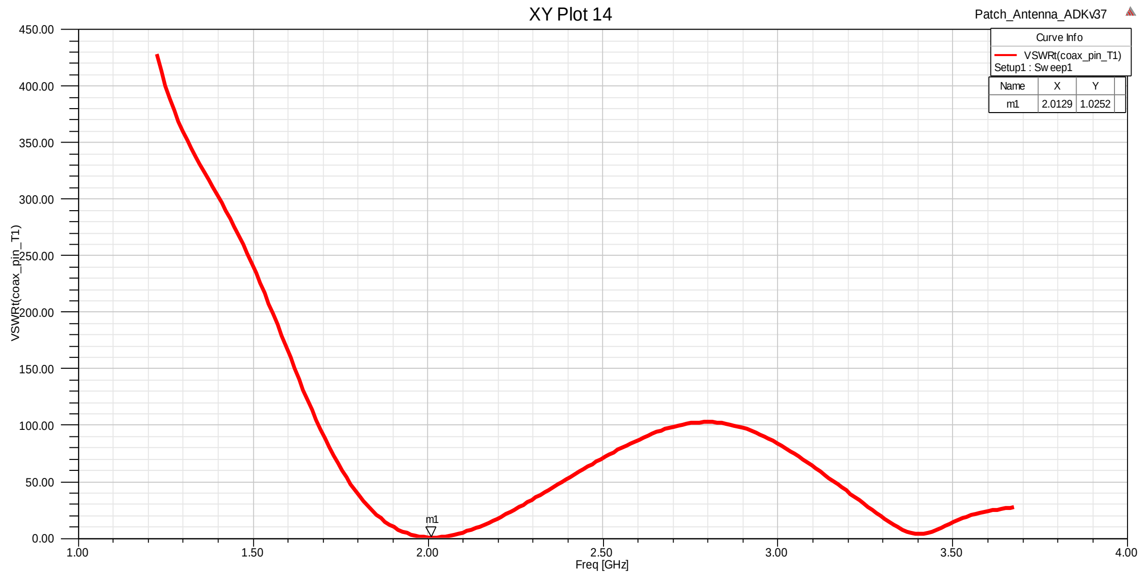


Figure III.5: VSWR of circular antenna.

Smith chart:

Smith chart is an important plot that used in radio frequency. **Figure III.6** shows how is the impedance behavior of the patch antenna with the frequency. The result confirms that the resonance frequency is in very good matching.

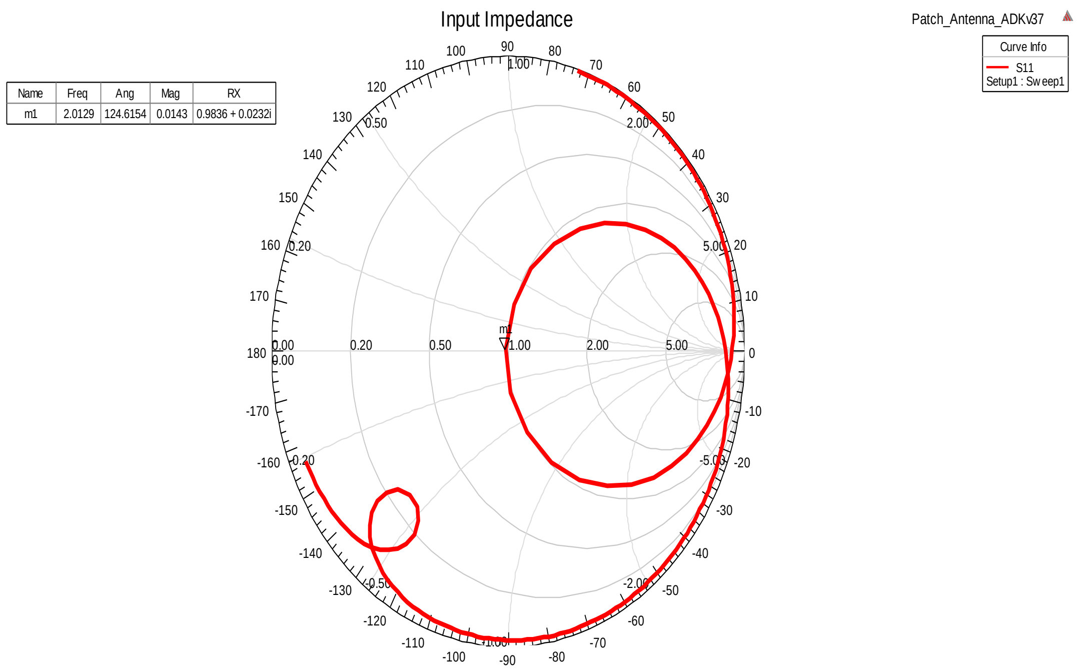


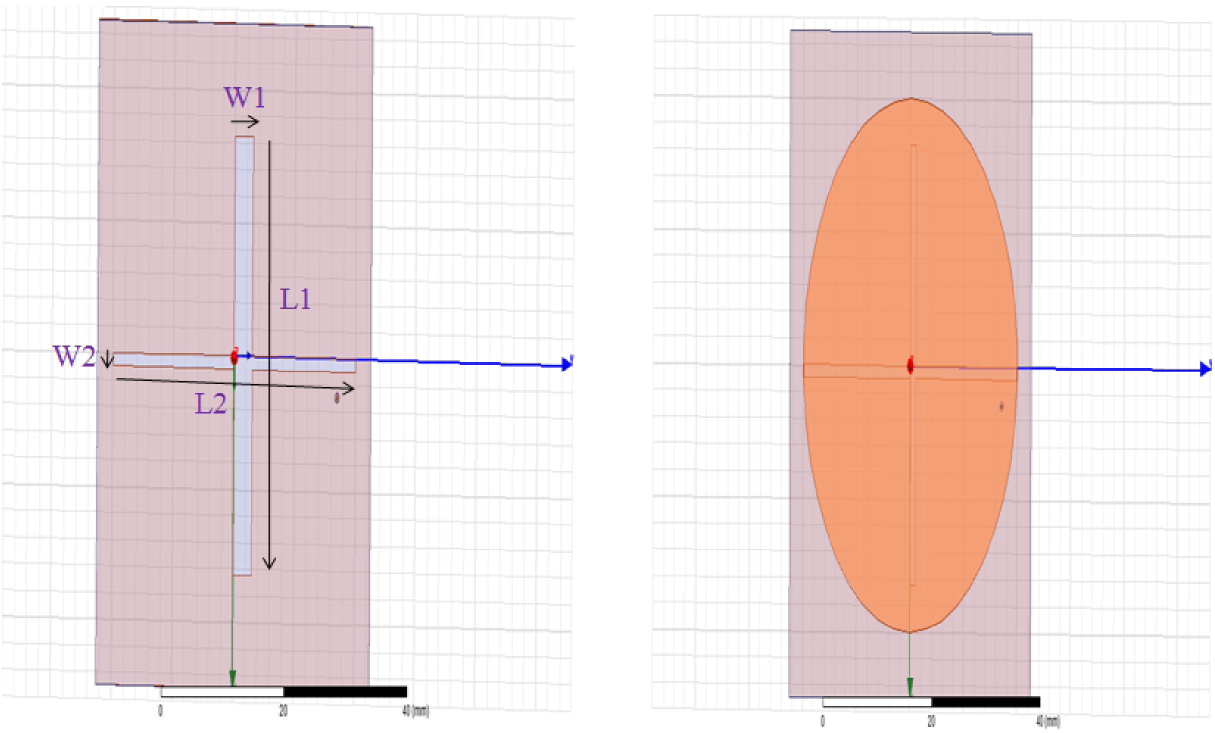
Figure III.6: Smith chart of circular antenna.

III.4 second design: circular patch with DGS

In this second design, we take the optimal geometrical parameters of the previous antenna, but we add two rectangular slots in the ground as it appears in the **figure III.7** (a) and (b). The **table III.4** below depicts the length of the principal parameters of the antenna.

Parameter	Value
Dimension of ground	(50 × 45)mm^2
Dimension of Substrate	(50 × 45)mm^2
Relative permittivity (ε_r)	4.4
Radius of circular patch (r)	20 mm

Table III.4: Dimension of circular patch antenna with DGS.



b) Back view **a) Top view**

Figure III.7: **Top view and back view of circular patch with DGS.**

III.4.1 geometrical study for the antenna

In this step, the variation will be in length (L1) and width (W1) of slot1 in order to get best results, when we vary in parameter the other stay fixed.

III.4.2 effect of variation in (L1)

The **figure III.8** shown the return loss of the variable (L1), variation taken from 31.5 to 34.5mm. We see that when we increase or decrease in (L1) return loss of optimal frequencies (low and high) is decrease. The results are listed in **Table III.5**.

L1	Ƒc(low)	S_{11}	Ƒc(high)	S_{11}
31.5 mm	**2.1484GHz**	**-23.5394dB**	**3.4411GHz**	**-29.0005dB**
33mm	**2.0668GHz**	**-36.9811dB**	**3.4534GHz**	**-36.9136dB**
34.5 mm	**2.0449GHz**	**-34.1997dB**	**3.4534GHz**	**-29.3720dB**

Table III.5: Result of the variation in (L1).

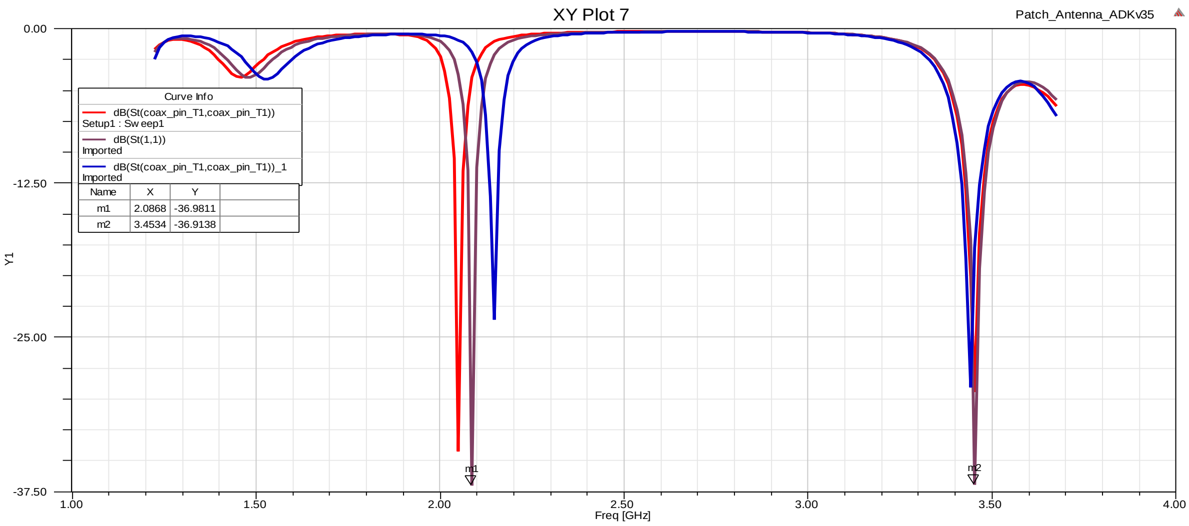


Figure III.8: Effect of varying in (L1).

III.4.3 effect of variation in (W1)

The **figure III.9** shown the return loss of the variable (W1), we take the variation from 0.8 to 1.2 mm with a step of 0.2 mm. We see that the effect of (W1) is the same as effect of (L1). The **table III.6** gives the results.

W1	Ƒc(low)	S_{11}	Ƒc(high)	S_{11}
0.8 mm	2.1361GHz	-20.1234dB	3.4903GHz	-20.6479dB
1mm	2.0668GHz	-36.9811dB	3.4534GHz	-36.9136dB
1.2 mm	2.075GHz	-20.5248dB	3.4165GHz	-18.7335dB

Table III.6: Result of the variation in (W1).

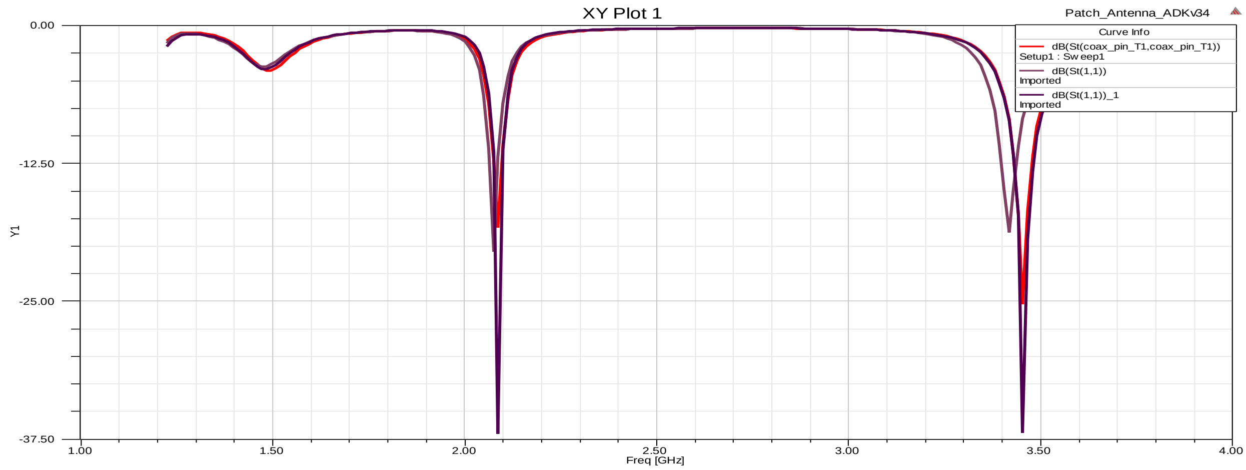


Figure III.9: Effect of varying in (W1).

Figure III.10 present the return loss of our antenna with the optimal size parameters. We can say that the integration of DGS at the ground of our antenna produce a dual-band antenna. Where the S11 results indicates a good matching in both resonance frequencies with-36.98dB.the bandwidth set for -10 dB is 1.38% at 2.08 GHz it's for mobile applications and for the second band retune loss is -36.91dB and BW is 1.97% at 3.45 GHz for WiMAX applications-

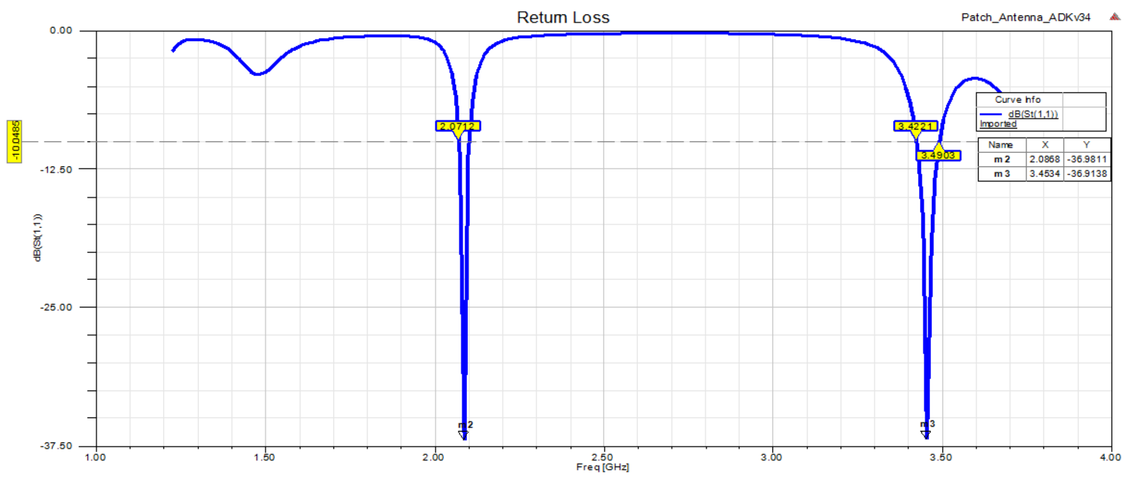


Figure III.10: Return loss for circular antenna with DGS.

III.5 the final design: circular patch with DGS and circular slots

In this step, we designed two slots in the previous antenna with different values on the radiating patch as seen in the **Figure III.11** to improve the bandwidth.

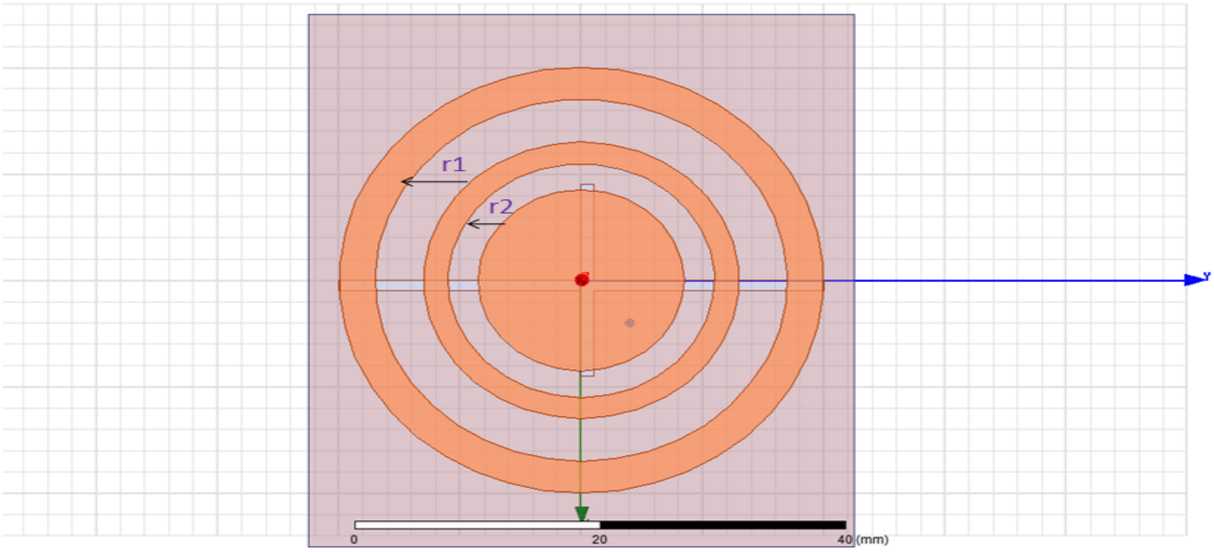


Figure III. 11: circular patch with DGS and circular slots.

III.5.1 geometrical study for the antenna

In this last design, we will vary two parameters (r1) and (r2) respectively. In order to get more optimized results.

III.5.2 effect of variation in (r1)

Figure III.12 shows the effect of variation in (r1) on return loss and bandwidth. The parameter is varied as listed in **Table III.7**. The result exhibits for the first peak that there is an expulsion relationship between R1 and return loss, For the second and the third peak the return loss is decrease When the value of(r1) is higher or lower than the optimum value (3.5 mm), but for the effect of variation in (r1) on bandwidth we see that it's decrease When the value of(r1) is change from the optimum value for the first and the second band. For the last band, BW is increase when the value of (r1) is change.

r 1	F_{C1}[GHz]	BW_1	S_{11}[dB]	F_{C2}[GHz]	BW_2	S_{11}[dB]	F_{C3}[GHz]	BW_3	S_{11}[dB]
3 mm	2.46	0.0312	-18.29	2.55	0.0271	-23.38	3.02	0.1567	-26.45
3.5mm	2.50	0.0252	-21.56	2.55	0.0248	-29.92	3.03	0.1798	-31.31
4mm	2.54	0.0370	-21.70	3.01	0.0579	-24.82	3.26	0.0822	-23.16

Table III.7: Result of the variation in (r1).

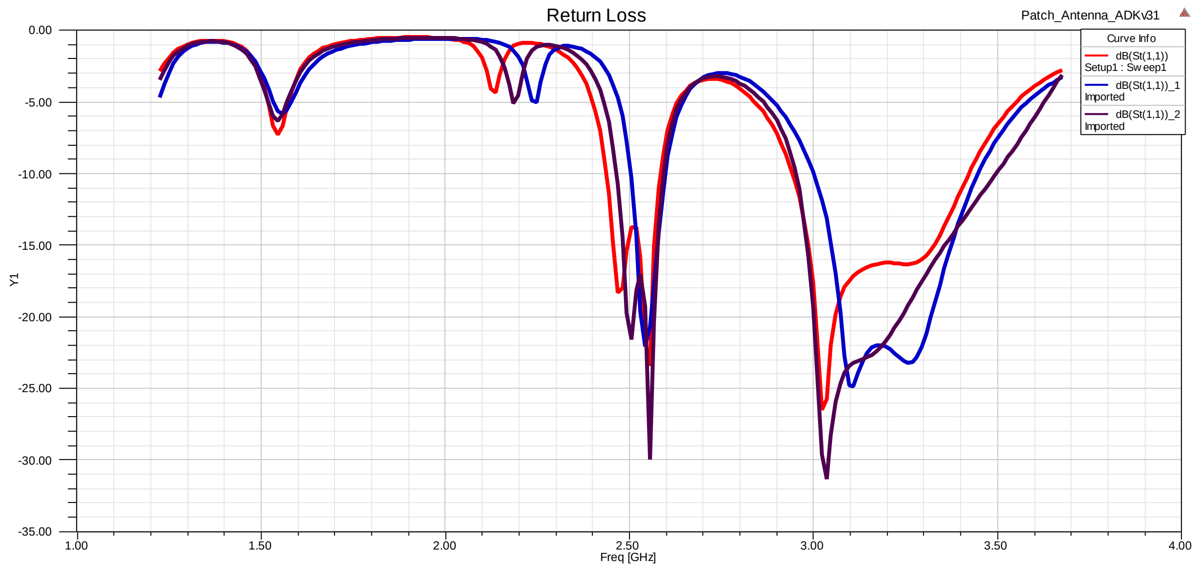


Figure III.12: Result of varying in (r1).

III.5.3 effect of variation in (r2)

The **figure III.13** shown the return loss and bandwidth of the variable (r2), we take the variation from 1.1 to 1.3 mm with a step of 0.1 mm. from the **table III.8** We can say that in the first band, when the value of (r2) is higher or less than (1.2 mm), both parameters are decreasing, but for the second band, the effect of our variable on bandwidth and return loss is the same. We observe that we have good results at (1.2 mm) for the third band.

r 2	F_{C1}[GHz]	BW_1	S_{11}[dB]	F_{C2}[GHz]	BW_2	S_{11}[dB]	F_{C3}[GHz]	BW_3	S_{11}[dB]
1.1mm	2.50	0.0252	-21.56	2.55	0.0248	-29.92	3.03	0.1798	-31.31
1.2mm	2.50	0.0268	-27.54	2.55	0.0229	-21.19	3.05	0.1575	-43.85
1.3mm	2.51	0.0259	-23.88	2.56	0.0233	-24.17	3.23	0.1376	-24.80

Table III.8: Result of the variation in (r2).

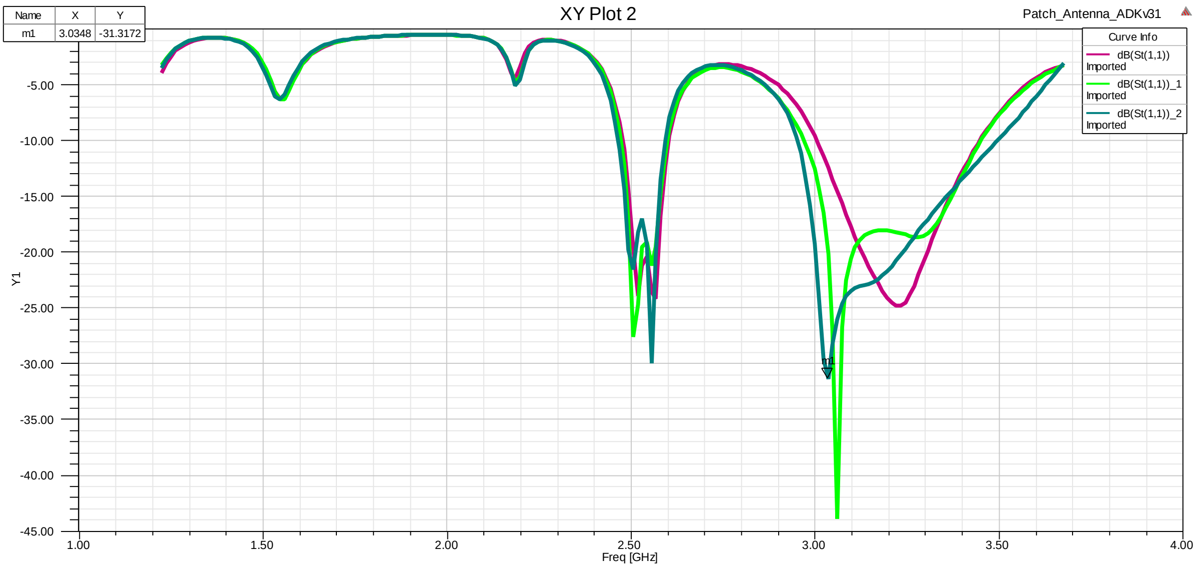


Figure III.13: Result of varying in (r2).

Figure III.14 shows the performance return loss and bandwidth of our last design. We can say that the optimal results as a result of the two studies above when variables (r1) and (r2) take 3.5 mm and 1.2 mm, respectively. It's shown a multiband antenna, the result indicates a good matching (-27.54 dB) at 2.5 GHz with a bandwidth (for -10 dB) of 2.68%, for the second band (-21.19 dB) at 2.55 GHz with BW of 2.29%. We have also a last band with return loss of (-43.85 dB) and BW value of 15.75% .Those frequencies are all for WLAN applications.

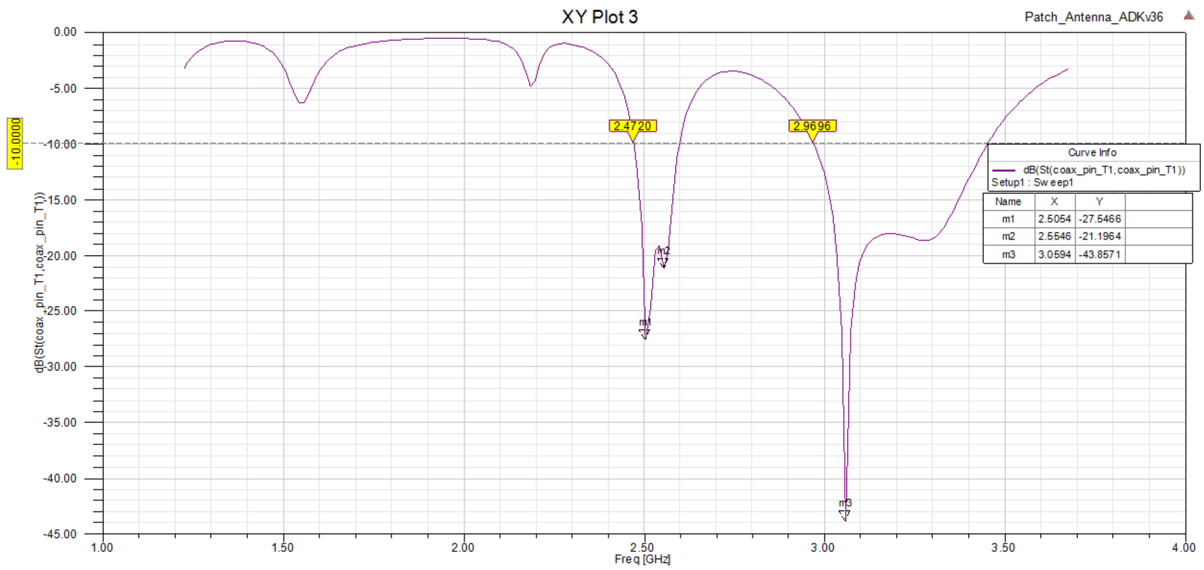


Figure III.14: Return loss of circular patch with DGS and circular slots.

VSWR:

In **Figure III.15** we see VSWR, we note that we have three results, the first at the frequency 2.5 GHz with VSWR =1.0876, the second at the frequency 2.55 GHz and VSWR=1.1120. The last is in 3.05 GHz with VSWR =1.0129. Which confirms that our antenna is very adapted to resonant frequencies.

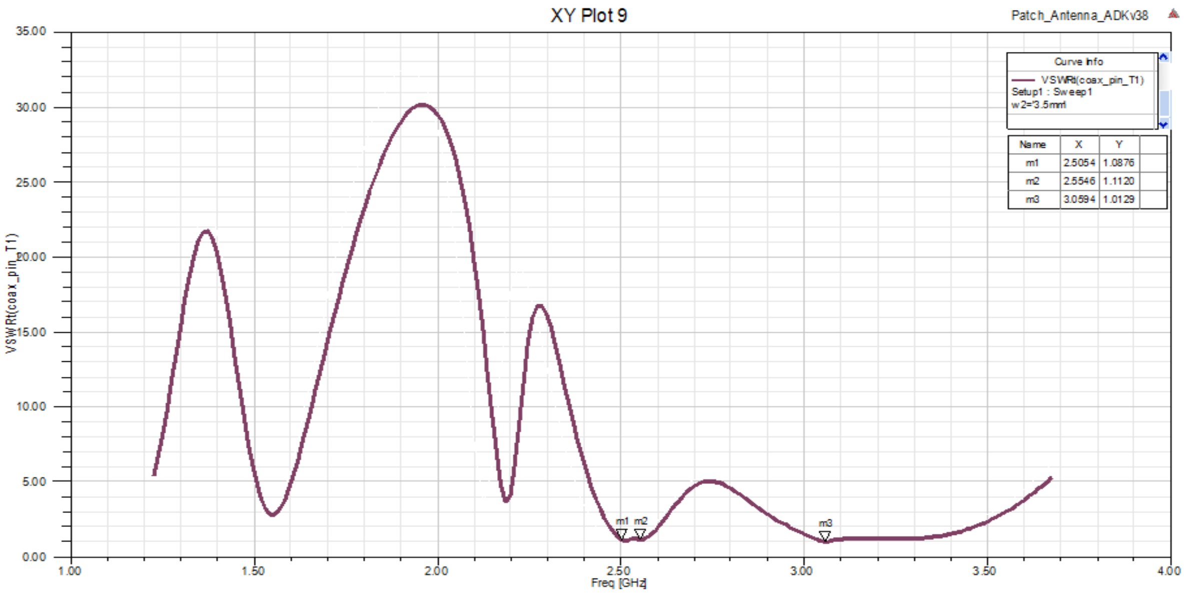


Figure III.15: VSWR of circular patch with DGS and circular slots.

Gain:

The **Figure III.16** represents the 3D radiation diagram (gain) plotted for the entire frequency range. The gain of our antenna of value 3.01 dB. In this representation an almost omni-directional radiation.

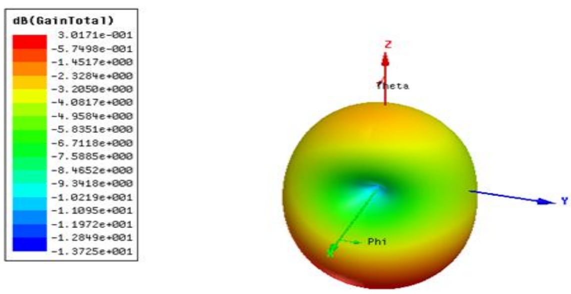


Figure III.16: The 3D gain of circular patch with DGS and circular slots.

Smith chart:

Figure III.17 shows how the impedance behavior of the patch antenna with the frequency is. The result confirms that the resonance frequencies are in good matching.

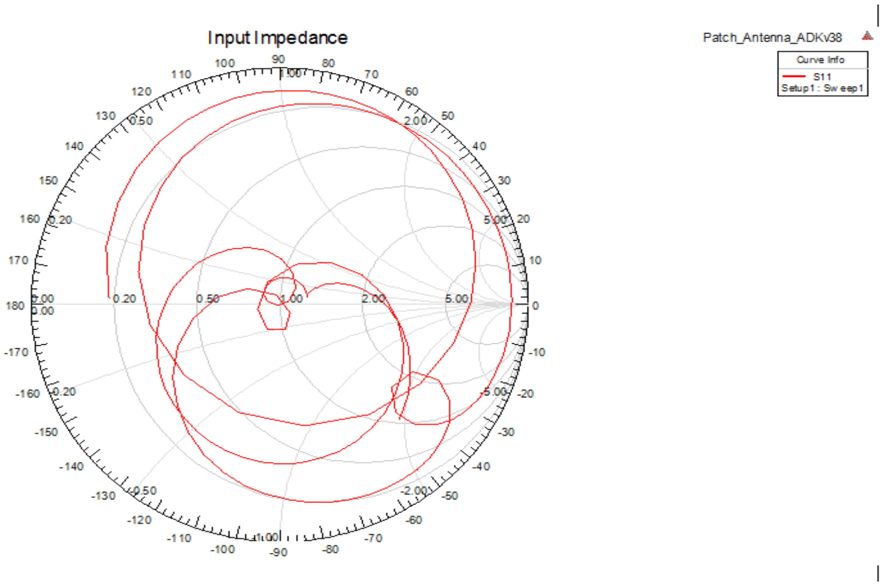


Figure III.17: Smith chart of circular patch with DGS and circular slots.

III.6 conclusion

Three design models for microstrip patch antenna was presents with a parametric study in this chapter, in the objective to designing a dual and multiband antenna.

In the first design, we was presented simple circular patch antenna, its showed one peak at 2.01GHz of mobile applications with a good return loss . In the second design we are add to the structure of the previous antenna two rectangular slots by etching them in ground of the antenna, to obtained a circular patch with DGS. This new design had showed a dual-band with good matching, -36.dB and bandwidth set for -10 dB is 1.38% at 2.08 GHz it's for mobile applications and for the second band BW taken 1.97% at 3.45 GHz for WIMAX applications. The third is circular patch with DGS and slots in the radiation patch. This design had showed a multi-band frequencies with very good matching specially in the last peak due to the variation the (r2), we was obtained an return loss of -43.85dB at 3.05GHz and bandwidth of 15.75% from (2.96-3.45) GHz, this range is intended for WLAN applications.

Finally, we can conclude that we have obtain the main objective of this project, and we propose the following perspectives as a future works:

- Study the possibility of miniaturization of our antenna.
- The using other technics to obtain dual-band or multiband application's.

- Changing the technic of feeding

General Conclusion and Future Scope

General Conclusion and Future Scope:

In this thesis, three designs have been given and studied.

We have been started with fist model it's a simple patch antenna for single operating frequency. In Second design, we applied the antenna enhancement principle that we proposed, on the ground Plan in order to achieve the dual band. In the last design, we applied the second principle of enhancement that is the slots in radiation patch. These steps paid off because it allowed us to improve the performance of the microstrip antenna especially the bandwidth in which we obtained a broadband antenna to response the wireless communications demand.

The Future Scopes of our work are:

Last but not least, we can conclude that we have obtained the main objective of this project, and we propose the following perspectives as a future works:

- Study the possibility of miniaturization of our antenna.
- The using other technics to obtain dual-band or multiband application’s.
- Changing the technic of feeding

Finally, we can say that this study is initial phase of a longer-term project with the goal of improving antenna performance. Significant work remains to be done in order to achieve perfect results for these designs. However, this work has established a solid foundation for future work and despite the problems, we have encountered during the realization of this project, we consider that the work has been done and we have reached some of our objectives what which we have created it.

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