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Design And Enhancing Parameters Of A Patch Antenna For Wireless Application Using HFSS

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Design and enhancing parameters of a patch antenna
for wireless application using HFSS

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Theme:

Design and enhancing parameters of a patch antenna for wireless application using HFSS

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Summarize (English and Arabic)

Nowadays, the wireless communication is in increasing demand. This creates some requirement like broadband, dual band and high data rate. Hence, the microstrip patch antenna is the most appropriate due its various advantages. Our objective is to design a microstrip patch antenna that can achieve broadband, dual band and high data rate. Therefore, the study is based on specific techniques to improve these demands. Two techniques are introduced for enhancing the bandwidth DGS and U-slot, and another technique to achieve the dual band is by modify the shape of the radiator. Interesting results are obtained for specific band which are WiMAX 5.5 GHz and C-band. The simulation and extracting parameters are by using of HFSS.

Keyword: DGS, U-slot, WiMAX, C-band, microstrip patch antenna

في الوقت الحاضر، الاتصال اللاسلكي في اطلب متزايد. هذا يخلق بعض المتطلبات مثل النطاق العريض، مزدوج النطاق ومعدل البيانات العالية. وبالتالي، فإن الهوائي المطبوع هو الأنسب بسبب مزاياها المختلفة. هدفنا هو تصميم الهوائي المطبوع الذي يمكن أن يحقق النطاق العريض، مزدوج النطاق ومعدل البيانات العالية. لذلك، تعتمد الدراسة على تقنيات محددة لتحسين هذه المتطلبات. تم تقديم تقنيتين لتعزيز عرض النطاق الترددي DGS وU-slot، وتقنية أخرى لتحقيق النطاق المزدوج هي عن طريق تعديل شكل الراديتر. تم الحصول على نتائج مثيرة للاهتمام لنطاقات محددة وهي WiMAX 5.5 GHz وC-band. المحاكاة والمعلمات المستخرجة باستخدام HFSS.

كلمات مفتاحية:DGS، U-slot، WiMAX، الهوائي المطبوع

Dedication

This thesis dedicated to:

my great parents, who have loved me unconditionally

my beloved brother and sister

my all family and friends

my country: Algeria

the readers

Acknowledgments

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List of abbreviation

2G : second Generation

3G : Third Generation

3GPP : 3rd Generation Partnership Project

CDMA : Code-Division Multiple Access

DGS : Defected Ground Structure

ETSI : European Telecommunications Standards Institute

FDD : Frequency Division Duplexing

GPS : Global Positioning System

GSM : Global System for Mobile Communications

HFSS : High Frequency Simulator Structure

IEEE : Institute of Electrical and Electronics Engineers

LTE : Long Tearm Evolution

OFDMA : Orthogonal Frequency Division Multiple Access

QoS : Quality Of-Service

SC-FDMA : Single Carrier Frequency Division Multiple Access

TDD : Time-Division Duplexing

TDMA : Time-Division Multiple Access

UMTS : Universal Mobile Telecommunications System

WIFI : Wirelss Fidelity

WiMAX : Worldwide Interoperability For Microwave Access

WLAN : Wireless Local Area Network

WPAN : Wireless Personal Area Network

GENERAL INTRODUCTION

Introduction

What is the wireless communication? From the first centuries ago, people have been cared about the communication and have been invented many ways to do it. Where the soldiers in the Great Wall of China used fire and smoke signal to send attack alert between towers. After the appearance of the writing, people used homing pigeon to transmit the messages over the distance. With the industrial revolution in 19 century, telegraph and phone are invented and still used until Marconi succeeded in transmitting a letter over the electromagnetic waves and overcomes the use of the wire in communication. Nowadays, the revolution of using the wireless communication in the modern world have been appeared in several utilizations, like in the high performance such as spacecraft, aircraft, cellular phone, missile application and satellite [1]. The antennas are inseparable part of this revolution, because they are considered as the most candidates for this development and meeting the requirement for the wireless communications.

The Wireless communication is to send and receive any kind of information without using any electrical conductor. Therefore, it allowed to the devices like smart phones, laptops and tablets to move around freely within the area of network. It also increased larger users because it is not limited by a specific number of connection ports. Recently, the high data rate and coverage become an interesting part in the wireless communication. The WiMAX (worldwide interoperability for microwave access) is an application that can provide a data rate of 70 Mbps and coverage around 50 Km. It is based on WMAN (Wireless Metropolitan Area Network) and with greatly flexibility and freedom. For the big area, satellite is the most appropriate due to the large coverage and the providing bandwidth. Clearly, any wireless communication requires a device with specific criteria such as low profile, low cost, easy to fabricate and low energy consumption. Fortunately, all of these applications and criteria have achieved with the presence of the microstrip patch antenna.

In 1953, Deschamps puts the first outline of the conception of the microstrip patch antenna while, Munson [2] and Howell [3] were developed the first practical antenna in the 1970s. After that, microstrip patch antenna got more interest from the researchers due to its advantages over the wireless like in the WiMAX, radio, Wi-Fi, and its application

such in the smartphone, USB modem, TV, etc. However, the main disadvantages of the microstrip patch antenna that it suffers from: is the narrow band and low gain.

Now, the need for high data rate and multi users lead to have an antenna with broadband. To overcome this problem, some techniques we had applicated to broad the bandwidth of the antenna and enhance the gain. In addition, other requirement is in demand which is the dual band. Designing a wireless phone with two operating frequency becomes an obligation for several reasons. Moreover, the achieving of the broadband and dual band, this is lead to introduce a modification in the microstrip patch antenna itself, either by adding other structure or by reduce the geometry of the antenna. By consequence, new problem appears is the complexity of the antenna design when we modify the geometry.

Recently, several applications and technologies required the broadband antenna. In the commercial application, the rapidly increasing in the use of cellular phone like 2G, 3G and 4G need to have a consider bandwidth. In the WLAN and Bluetooth, sharing: files, resource and information also need for high data rate. Other, dual band also in demand due its benefits on the wireless communication by making the antenna operates in two different resonance frequencies. All this lead to provide study that can make the microstrip patch antenna is more suitable for all application.

Thesis objective:

The objective of this thesis is to design a microstrip patch antenna that can achieve both, the broadband and dual band based on specific methods and techniques, taking into account the simplicity and the efficacity 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.

Thesis outline:

This thesis is divided on three chapters:

first chapter: it provides an introduction about the wireless communications technologies and their frequency bands. Also, we introduce some classical basic theory of the microstrip patch antenna, for example: radiation mechanism, feeding techniques, antenna parameters, etc.

Second chapter: an overview to the broadband and dual band techniques will be given. A 3D reference model for single band microstrip patch antenna will be simulated and extract some interesting results and discuss them.

Last Chapter: in this chapter three design models will be modelled and simulated. The first one is for dual band application. The two second models are for the broadband with the use of two technique: patch antenna with defected ground structure and patch antenna with U-slot. After that, we extract the obtaining results and discuss them for each design.

General conclusion and perspectives: our work finalizes with general conclusion and gives some future scope.

CHAPTER I

INTRODUCTION TO THE WIRELESS TECHNOLOGIES
TECHNOLOGIES
AND MICROSTRIP PATCH ANTENNA

Chapter I

Introduction to The Wireless Communication and Microstrip Patch Antenna

I.1 Introduction:

In 1897, Guglielmo Marconi was the first one who made communication over electromagnetic waves by transmitting three-dot Morse code for the letter "S". After that, wireless communications have been attracting peoples and especially scientists. So, the real meaning of wireless communications is to transfer information without using any wires, and Telecommunication is assisted this transmission of signals or information over a distance. Today, the world uses various types of wireless communication product and different communication technologies.

In this first chapter, a generality will be introduced about some famous wireless technologies such as GSM, WLAN, LTE, etc. We will give their historic development and their operation frequencies. Also, because the microstrip patch antennas becomes a big player in the communication due to its good characteristic, an overview about its basics and parameters will be giving.

I.2 PART ONE: wireless technologies

I.2.1 GSM:

GSM (Global System for Mobile Communications) is a standard developed by the ETSI (European Telecommunications Standards Institute). It Contains the essential functions for the support of personal mobility, especially with regard to user identification and authentication [4]. GSM systems work in various distinctive bearer recurrence ranges (isolated into GSM recurrence ranges for 2G and UMTS recurrence groups for 3G), with most 2G GSM systems working in the 900 MHz or 1800 MHz groups. Where these bands were already allocated, the 850 MHz and 1900 MHz bands were used instead (for example in Canada and the United States). In rare cases the 400 and 450 MHz frequency bands are assigned in some countries because they were previously used for first-generation systems. For comparison most 3G networks in Europe operate in the 2100 MHz frequency band. Regardless of the frequency picked Toward an operator, it is separated into timeslots for Individual phones. This grants eight full-rate on the other

hand sixteen half-rate talk channels for each Radio frequency. These eight radio timeslots gathered into A TDMA frame. Half-rate channels utilize exchange frames in the same timeslot. The channel data Rate for at 8 channels will be 270.833 Kbit/s, and the frame duration is 4. 615 ms. The transmission power in the handset is limited to a maximum of 2 watts in GSM 850/900 and 1 watt in GSM 1800/1900 [5].

I.2.2 IEEE 802.11 WLAN:

IEEE 802.11 work group started its standardization activities in 1991. It published the first standard specification in 1997 and operating at the unlicensed band of 2.4 GHz at speeds of 1 and 2 Mbps. in 1999, the IEEE 802.11a standard was updated and operating on the 5 GHz (5.15-5.35 and 5.725-5.825) and provide a transmission rate up to 54 Mbps. In the same year, the standard was approved that resulted in 802.11b and operating at 2.4 GHz and provides 11 Mbps of data rate. In 2003, the standard 802.11g was recognized because of inconsistency band between 802.11b and 802.11a. More then, another standard IEEE 802.11n, which underpins up to 600 Mbps, is being standardized. IEEE 802.11 WLAN, or WIFI, is likely the most generally broadband wireless, giving the most data rate transmission among standard-based wireless technologies. The most typical applications of the 802.11 WLAN include Internet access of portable devices in various networking environments. [6, 7, 8].

I.2.3 LTE:

In 2004, LTE (Long Term Evolution) was first proposed by Japan's. This new standard is for cellular phone and data terminals devices and it is provided the high-speed wireless communication, and broadband access technology. It established as a reaction to the requirement for the expanding interest for high data rates and considered as an advancement to 3G UMTS. The standard for LTE is a milestone in the development of 3GPP (3rd Generation Partnership Project) technologies [9] . In December 2008, the LTE standard was finalized and the first publicly available LTE service was launched by TeliaSonera in Oslo and Stockholm on December 14, 2009 as a data connection with a USB modem.

The standard provides downlink peak rates of 300 Mbit/s, uplink peak rates of 75 Mbit/s and QoS (Quality of-Service) provisions permitting a transfer latency of less than 5 ms in the radio access network. LTE has the ability to manage fast-moving mobiles and supports multi-cast and broadcast streams. It can support both frequency division

duplexing (FDD) and time-division duplexing (TDD). Is has supports seamless handovers for both voice and data to cell towers with older network technology such as GSM, UMTS and CDMA2000 with the guarantee of the simpler architecture that results in lower operating costs. The multiple access scheme in LTE downlink uses Orthogonal Frequency Division Multiple Access (OFDMA) and uplink uses Single Carrier Frequency Division Multiple Access (SC-FDMA). These multiple access solutions provide orthogonality between the users, reducing the interference and improving the network capacity. The resource allocation in the frequency domain takes place with a resolution of 180 kHz resource blocks both in uplink and in downlink. The frequency dimension in the packet scheduling is one reason for the high LTE capacity. The uplink user specific allocation is continuous to enable single carrier transmission while the downlink can use resource blocks freely from different parts of the spectrum. The uplink single carrier solution is also designed to allow efficient terminal power amplifier design [10, 11].

I.2.4 WiMAX:

WiMAX (Worldwide Interoperability for Microwave access) has been established by the IEEE 802.16 working group based on Wireless Metropolitan Area Network (WMAN). WiMAX theoretically can have coverage of up to 50 km radius. The name "WiMAX" was created by the WiMAX Forum, which was formed in June 2001 to promote conformity and interoperability of the standard, including the definition of predefined system profiles for commercial vendors. The forum describes WiMAX as a standards-based technology enabling the delivery of last mile wireless broadband access as an alternative to cable DSL. WiMAX has three allocated frequency bands. The low band (2. 5-2.69 GHz), the middle band (3.2-3.8 GHz) and the upper band (5.2-5.8 GHz). it uses orthogonal frequency division multiplexing (OFDM) technology and the maximum data rate in WiMAX is 70 Mbps [9, 8].

IEEE-802.16a was an amendment to 802.16. 802.16a was ratified in January 2003 and was intended to provide last mile fixed broadband access 802.16c. In September 2003, a revision project called 802.16d commenced, which is for fixed subscriber stations. This project concluded in 2004 with the release of 802.16 2004 which replaced all prior Versions including the a/b/c amendments and formed the basis for the first WiMAX solution. In 2005, 802.16e is an amendment to 802.16d and is often referred to

shortened form as 802.16e. The main advantage of IEEE 802.16 WiMAX when compared with 802.11 are: the longer transmission range and more sophisticated support for QoS at the MAC level [12].

I.2.5 Satellite band (C-band):

C-band is the original frequency allocation for communications satellites. It is a designation by the IEEE for a portion of the electromagnetic spectrum in the microwave range of frequencies ranging from 4.0 to 8.0 GHz. It was the first communications frequency band that was allocated for commercial telecommunications via satellites. C-Band uses 3.400–3.625 GHz for downlink and 6.425–6.725 GHz for uplink (Europe and Africa region). The merit of this band is cheaper bandwidth and less disturbance from heavy rain. However, this merit led to make the hardware more expensive. The C-band is used for many satellite communications transmissions, some WIFI devices, some cordless telephones, and some weather radar systems [13, 14].

I.3 PART TWO: microstrip patch antenna

I.3.1 Rectangular Microstrip Patch antennas:

The rectangular microstrip patch antenna is approximately a one-half wavelength long section of rectangular microstrip transmission line. The first proposed concept of the microstrip patch antenna was in 1953. while, practical antenna was developed by Munson and Howell in the 1970s. An microstrip patch antenna in its simplest form consists of a radiating patch on one side of a dielectric substrate and a ground plane on the other side. The microstrip patch antennas shape are shown in Figure I.1. However, other shapes, such as the square, circular, triangular, semicircular, annular and square ring shapes shown in Figure I.2, are also used. Radiation from the microstrip patch antenna can occur from the fringing fields between the periphery of the patch and the ground plane [8].The microstrip patch antenna have been used in many applications in wireless communication system such as in aircraft, spacecraft, satellite, and missile applications. They have four feeding method: coaxial feed, aperture feed, microstrip line feed and proximity feed [1, 15].

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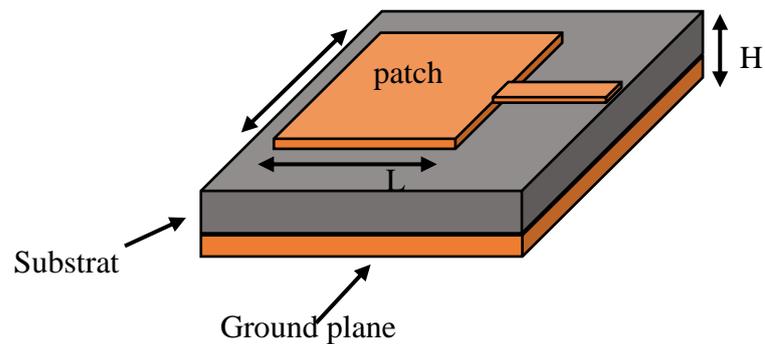
Figure I.1: Rectangular Microstrip Patch antenna

Square   Circular   Triangular

Semicircular   Annular   Square ring
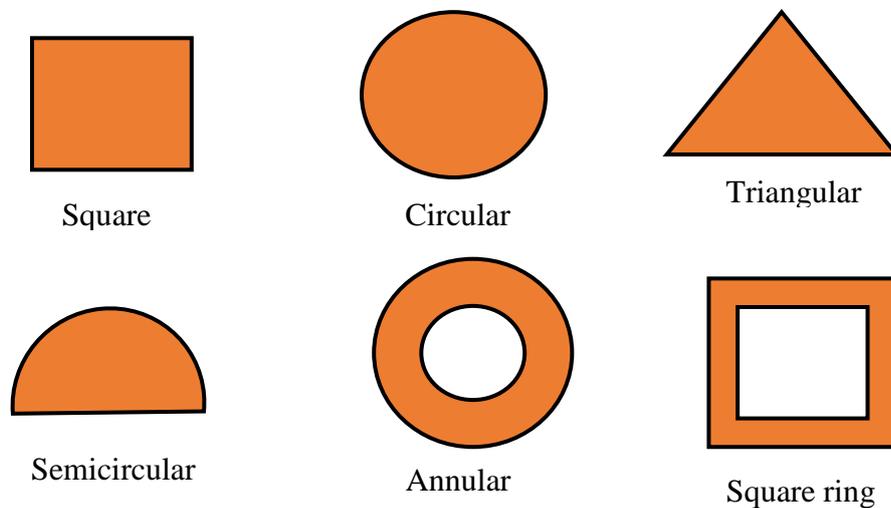
Figure I.2: Different shape of patch antenna

I.3.2 Basic principles of operation:

The basic principles of the patch antenna follow its fundamental mode operation: the electric field is zero at the center of the patch, maximum (positive) on one side, and minimum (negative) on the opposite side. These minima and maxima still change sinusoidally like the phase of the signal. The electric field does not stop abruptly near the patch's edges but the field extends beyond the outer periphery. These field extensions are known as fringing fields as represented in figure I.3 and cause the patch to radiate [16].
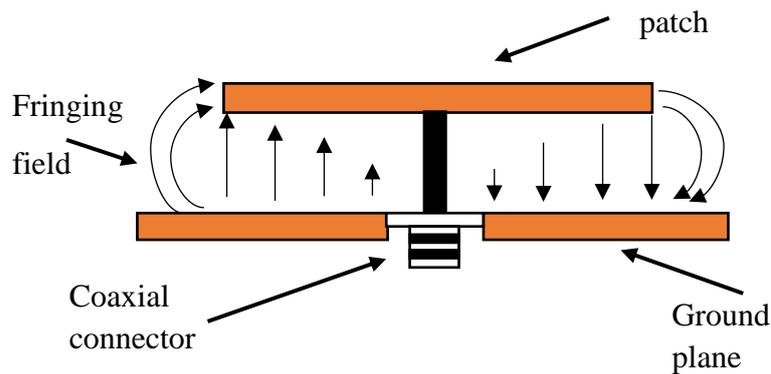
Figure I.3: Electric field distribution in the patch antenna

I.3.3 Advantage and disadvantage:

Microstrip patch antennas are increasing in popularity for use in wireless applications due to the several advantages. The main advantages of microstrip patch antennas are listed as follows [17, 8]:

- Low-cost fabrication.
- They allow for dual- and triple-frequency operations.
- Resistant to shock and vibration.
- Many designs readily produce linear or circular polarization.
- Considerable range of gain and pattern options (2.5 to 10.0 dBi).
- They are easier to integrate with other MICs (microwave circuits) on the same substrate
- Antenna thickness (profile) is small.
- They can be made compact for use in personal mobile communication.

The main disadvantages of microstrip antennas are:

- Narrow bandwidth.
- Dielectric and conductor losses can be large for thin patches, resulting in poor antenna efficiency.
- Sensitivity to environmental factors such as temperature and humidity.

I.3.4 Feed techniques:

There are many different feed techniques and it is used to excite the microstrip patch antenna, in order to radiate by contacting or non-contacting feeding method. In the contacting method, the power fed the radiation element by the direct connection such as microstrip line and coaxial probe. In the non-contacting, the electromagnetic wave transfers the power between the feed and the patch antenna (radiating element). These four-methods considered as the most popular techniques.

a) Microstrip line feed:

In this kind of technique, the feed line is connected directly to the patch edge, figure I.4. It is the most easier technique in fabrication compared to the three other methods. The advantages of this method are that allows one to use a 50 Ω microstrip line without adding a matching circuit [17]. However, the increase of the dielectric substrate can also increase the surface wave and spurious feed radiation, which hamper the bandwidth (typically 2–5%) of the antenna [1]. The impedance of the microstrip line is matched by using of insets at the edge of the patch or by the use of quarter wave line.
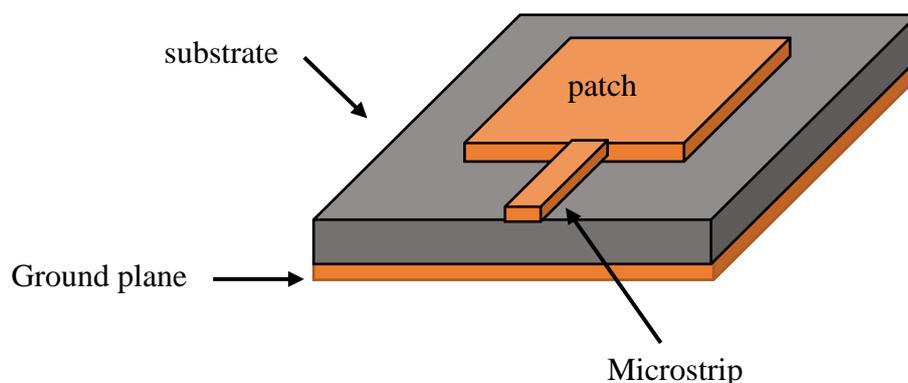
Figure I.4: Microstrip line feed

b) Coaxial feed:

The coaxial feed consists of two rings, where the inner ring is connecting to the radiating patch which passes through the substrate while the outer shield is connecting to the ground plane. The main advantage of this feed is that it can be placed at any desired location inside the patch to match with its input impedance. Its disadvantages are narrow bandwidth, difficult to model specially for thick substrate [1]. The figure I.5 below represent a coaxial feed.
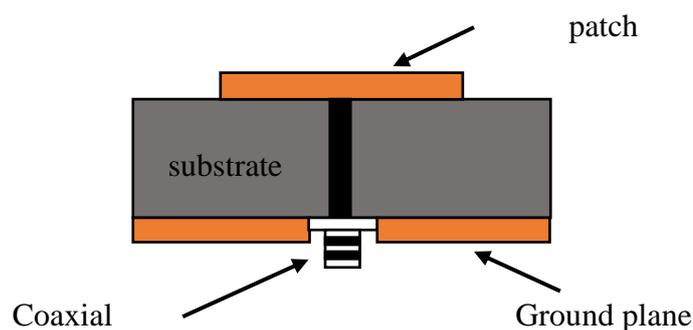
Figure I.5: Coaxial feed

Coaxial probe and microstrip line suffer from numerous disadvantages, so the aperture feed techniques has been introduced to overcome some these problems.

c) Aperture feed:

Aperture feed is from the indirectly or non-connection excitation, it's the most difficult technique of all. It consists of two dielectric substrates separated by the ground plane shown in figure I.6. The top substrate is low permittivity then the bottom substrate. The field is coupled from the microstrip line feed, which centered under the two substrates, to the radiating patch through an electrically small aperture or slot cut in the ground plane. Its Advantages is allowing independent optimization of feed mechanism element [18].
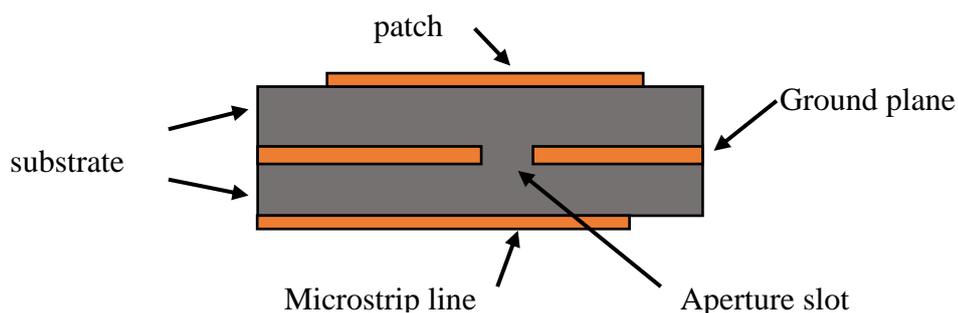
Figure I.6: Aperture feed

d) proximity feed:

proximity feed or electromagnetic coupling is a type of non-connection feed, which consists of two substrates with different permittivity. The feed line is between the two as shown in the figure I.7 and the patch is on the upper substrate. The merits of this technique

provide a very high bandwidth and eliminates spurious feed radiation. for impedance matching, can be achieved by controlling the length and the width of the feed line [18].
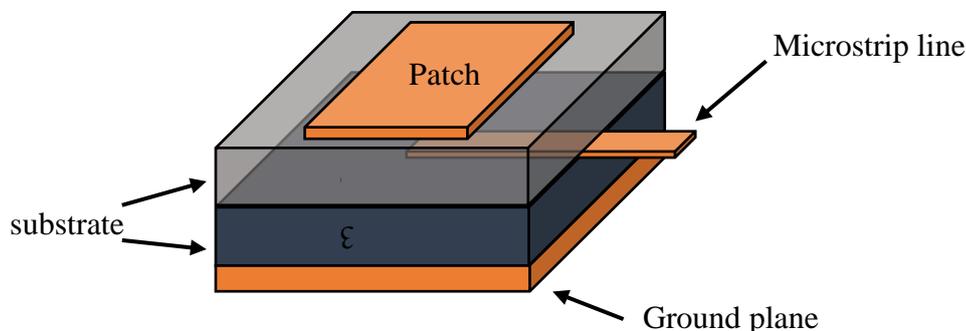
Figure I.7: Proximity feed

I.3.5 Antenna parameters:

Antenna parameters are used to characterize performance and behavior of an antenna when it designed and measured. the section bellow gives some of these parameters such as, radiation pattern, return loss, bandwidth, input impedance, gain and directivity.

a) radiation pattern:

radiation pattern is defined as the quantity of electromagnetic field distribution generated by the antenna and generally determined in the far field region. It can be power flux intensity, directivity, radiation intensity, etc.
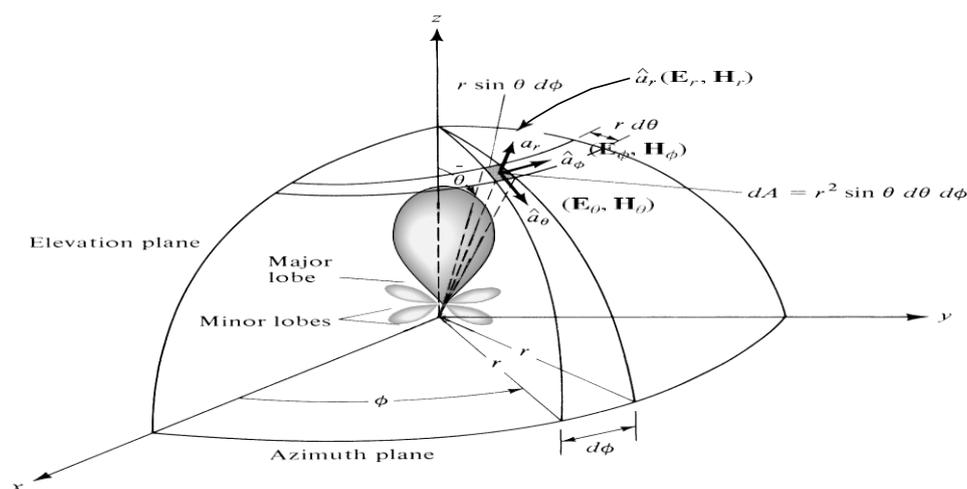
Figure I.8: Radiation pattern [1]

Usually, polar or spherical coordination systems are used to visualize the radiation pattern which normalized with respect to their maximum value [1]. The figure I.8 reprents a spherical plot for a radiation pattern.

b) Return loss:

Return loss is an important parameter when described an antenna. It is a logarithmic ratio measured in dB that compares the power reflected by the antenna to the power incident that is fed into the antenna. It considered as an expression of matching or mismatching of the antenna. the following expression represent the return loss:

$$RL = 10 \log_{10} \frac{P_r}{P_i} \tag{I.1}$$

Where RL is the return loss, P_r is the reflected power and P_i is incident power.

c) Bandwidth:

The bandwidth of an antenna is defined as the range of frequencies within which the performance of the antenna. the parameter equation is according to the antenna specification. For the broadband antenna, the bandwidth is usually expressed as the ratio of the upper-to-lower frequencies of acceptable operation like [1]:

$$BW = \frac{f_H}{f_L} \tag{I.2}$$

For narrowband antennas, the bandwidth is expressed as a percentage of the frequency difference (upper minus lower) over the center frequency of the bandwidth like [1]:

$$BW = f_H - f_L, \ BW = 100 \times \frac{f_H - f_L}{f_C} \ [\%] \tag{I.3}$$

Where BW is the bandwidth, f_H is the highest frequency, f_L is the lowest frequency and f_C is the center frequency of the bandwidth.

d) 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 [19]:

$$Z_A = R_A + j X_A \tag{I.4}$$

Where:

Z_A : antenna impedance

R_A : antenna resistance

X_A : antenna reactance

In addition, the radiation resistance R_A is given as:

$$\mathbf{R_A} = \mathbf{R_r} + \mathbf{R_L} \tag{I.5}$$

where R_r is the radiation resistance and R_L is the loss resistance.

e) Directivity:

The directivity of an antenna is defined as: the ratio of the radiation intensity U in a given direction from the antenna to the radiation intensity averaged over all directions P_{rad}. This expression can define only the direction of the major lobe and it is expressed by [1]:

$$\mathbf{D} = \frac{\mathbf{U}}{\mathbf{U_0}} = \frac{\mathbf{4\pi\ U}}{\mathbf{P_{rad}}} \tag{I.6}$$

Where**:**

D = directivity

U = radiation intensity

U0 = radiation intensity of isotropic source

P_{rad} = total radiated power

f) Gain:

The antenna gain has the same definition as the directivity, except that the total radiation power is replaced by the total power delivered to the antenna port. The gain can be expressed as [19]:

$$\boldsymbol{G} = \boldsymbol{4\pi} \frac{\boldsymbol{U}}{\boldsymbol{P_0}} \tag{I.7}$$

Where P_0 is the power input to the antenna and U is the radiation intensity.

I.4 Conclusion:

Because of the demand on the high data rate and the need for the wireless communication, many wireless technologies and applications are briefly given like GSM, WLAN, LTE, WiMAX. So, it is necessary to have an antenna that can utilize these technologies but with wide band, dual band and small size. These criteria considered as the major challenge to researchers in spite of the fact that microstrip patch antenna has several advantages over conventional microwave antennas, such as their light weight, small volume, and planar configuration. However, its suffer from the narrow band, it's about 5% bandwidth. Fortunately, a lot of methods have been used to enhance the bandwidth of the microstrip patch antenna like using slot, using defected ground structure, change the shape of the radiation element, etc. All of these techniques are introduced in the next chapter.

CHAPTER II

OVERVIEW ABOUT DUAL BAND AND BROADBAND AND FIRST DEIGN FOR MICROSTRIP PATCH ANTENNA

Chapter II

Overview About Dual Band and Broadband and First Deign for Microstrip Patch Antenna

II.1 Introduction:

With recent growth in wireless communication systems and the use of mobile technology applications like voice, data, video [20]. The need for multi-frequency and multi-mode devices such as wireless local area (WLAN), wireless personal area network (WPAN), and cellular phones, is being necessary. In addition, satellite communications also take a place in the telecommunication domain, due to its merits as the big coverage and the uses in many applications for example in GPS, TV, internet, military radars, etc. This is lead to create an antenna with high gain, wide bandwidth, good efficiency, good polarization and fixed radiation coverage.

Recently, the broad bandwidth of an antenna becomes an important auxiliary and the most factor that affect the application of it. For example, the bandwidth for commercial mobile communication varies from 7% to 13% and for ultra-wide band is up to 109 %. In addition, Cellular base-station and wireless access point need an antenna with high gain and a fixed radiation over all the range of the operation frequency that it coverage. The antennas for laptop computers and personal digital assistants (PDAs) and similar, they should have an efficiency in radiation, embedded and omnidirectional. In order to reach the requirement demand on this performance, antenna that used must be able in such way to satisfy this booming demand.

So, we all know that an antenna will affect its performance if its size changes, specifically in terms of dual band, bandwidth and gain. In this chapter reviews about the techniques of improving the bandwidth of a microstrip patch antenna will be introducing. In addition, a dual band design will be given and describe a future simulation. These techniques which we will discuss, is based on modified the radiation element or the ground to save the small size of the antenna. Finally, a simulation of single band microstrip patch antenna for WiMAX application is giving by steps.

II.2 Broadband techniques:

A microstrip patch antenna suffer from many drawbacks like the narrow bandwidth, typical is around 4% to 7%. For this reason, the researchers have developed many several techniques in order to solve the bandwidth problem. These techniques are divided on three approaches categories [17, 21] shown in the table II.1. It is known that the most important factors which can affect the bandwidth are primarily the shape of the radiator, the feeding scheme, the substrate and the arrangements of radiating and parasitic elements. Essentially, a microstrip patch antenna can have a broad bandwidth if it attributed to its low Q value and simultaneously well excited multiple resonances. Alternatively, by inserting a broadband impedance network between the antenna and the feeder, good matching over a broad frequency range can be attained. If two or more adjacent modes are well excited simultaneously, the bandwidth can be twice or more than that for the single resonance. In this section, two broadband techniques will be introduced, first one by modified the radiating element by use U-slot to perturbate the surface current distribution. Second one is by reducing the geometry of the ground size.

Approach	Techniques
Lowering the quality factor Q	Select the radiator shape increase the thickness of the substrate decrease the dielectric constant
Use impedance matching	Insert a matching network Use slotting and notching patches
Introduce multiple resonances	Use parasitic elements (stacked or co-planar) Use slotting patches. Use an aperture, proximity coupling

Table II.1: Broadband techniques for microstrip patch antenna

II.2.1 Enhancing bandwidth by using Slots:

Due to the need for wide band antenna, researchers create some different methods in which they can increase the bandwidth. So, they use of parasitic patches, either in another layer (stacked geometry) [22, 23] or in the same layer (coplanar geometry) [24]. Also, to achieve the wideband they added a chip resistor loading [25] or shorting pins [26]. However, the stacked geometry has the disadvantage of increasing the thickness of

the antenna, while the coplanar increases the lateral size of the antenna, and the chip resistor loading compromises the gain and efficiency.

The promising broadband technique that used by Huynh and Lee [27] showed that a coaxially fed rectangular microstrip patch antenna with a U-shaped slot, figure II.1, can attain over 30% impedance bandwidth, with good pattern characteristics. More, it applied in a single-layer single-patch antenna in which it can guarantee the thin-profile and small size characteristics. The broadband characteristic of a microstrip patch antenna with a U-shaped slot appears, by combined two close resonant frequencies in a single patch to give a wideband operation. On the other hand, if the excited resonant frequencies are far apart, a dual-frequency operation [28] can be achieved with the U slot antenna.
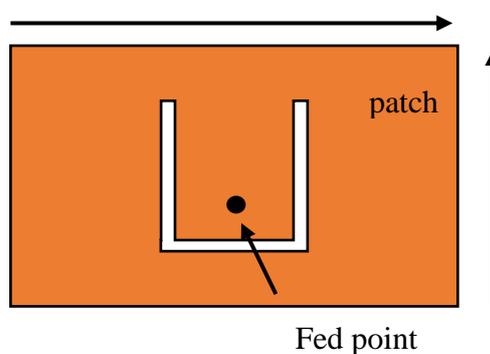
Figure   II.1: Microstrip patch antenna with U-slot

II.2.2 Enhancing bandwidth by DGS (Defected Ground Structure):

Microstrip antennas had some limitations, such as, single operating frequency, low gain and narrow bandwidth problems. This last, many kinds of techniques have been reported for enhancing it by using stacked geometry, using various types of slot, notching the patch, using different feeding techniques, etc. However, all these methods and techniques are modified the radiating element and might affect the antenna by make it bulky.

The Defected Ground Structure shown in the figure II.2 is one of the unique techniques to reduce the antenna size and broad bandwidth [29, 30]. It is realized by introducing a shape defected on a ground plane, thus will disturb the shielded current distribution depending on the shape and dimension of the defect. The disturbance will influence the input impedance and the current flow of the antenna. It can also control the

excitation and electromagnetic waves propagating through the substrate layer. Different shapes of DGS are used such as, rectangular [31], circular [32] and hexagonal [33].
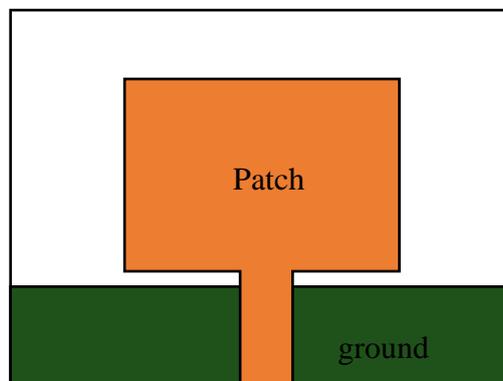
Figure II.2: Microstrip patch antenna with DGS

II.3 Dual band microstrip patch antenna:

Dual band antennas are of great demand, because of their several applications in military, radio, satellite, TV, and especially cellular phone which needs the dual band and multiband sometime. Hence, microstrip patch antennas have attracted much interest, and they are considered as the most candidate to response this needed due to its good advantages. When it exhibits a dual band, this means that microstrip antenna has a dual resonance frequency in single radiating structure, this result more energy saved and avoid the use of two deferent antennas. The simple way of the dual band is by exhibiting the two orthogonal and fundamental magnetic modes TM_{10} and TM_{01}. These two modes can be achieved by moved the fed point to (A, B) like the figure II.4. Recently, many designs have included to achieve the dual band behavior like square patch antenna [34], slot [35], cross slot [36], and notches [37]. In our case, we will make a rectangular notch in the non-radiating edges of the patch to obtain a C-shape patch antenna. This last is one of the methods that modified the shape of the rectangular microstrip patch antenna, figure II.3, such as E-shaped antenna [38, 39], E and H-shaped antennas [40], E-shaped ground penetrating patch antenna [41] in which they achieved the dual band.
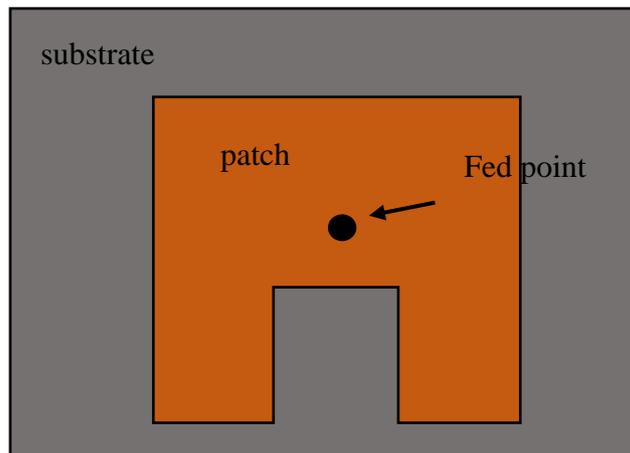
Figure II.3: C-shape microstrip patch antenna

II.4 Steps of designing a single band rectangular microstrip patch antenna:

In order to design a single band microstrip patch antenna for WiMAX 5.5 GHz there is three essential parameters should be defined first [42], which are:

- Resonance frequency f_r: this parameter indicate frequency where the antenna must be operating. To make the antenna operate at the upper WiMAX frequency, the resonant frequency must be selected as $f_r = 5.5\ GHz$.

- Dielectric constant of the substrate ε_r: the dielectric material selected for the design is Rogers RT/ Duroid (tm) 5880 which has a dielectric constant $\varepsilon_r = 2.2$.

- Height of dielectric substrate h: to guarantee the antenna is not bulky, the height of the dielectric substrate is selected as $h = 1.6\ mm$.

The three parameters were selected, the next step is to calculate the geometry of the radiating element (patch), $L \times W$ and the ground dimension $L_g \times W_g$. The parameters are presented in the figure II.4.
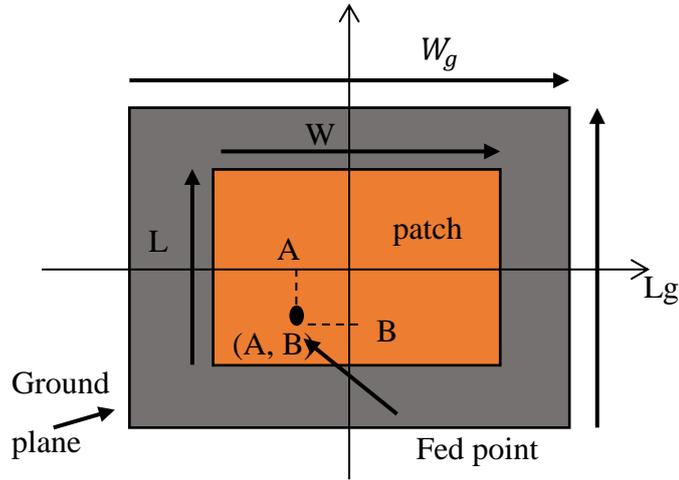
Figure II.4: Top view of microstrip patch antenna

Step 1: Calculation of the width (w): the width of the radiating patch is given by:

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

(II.1)

Where c is the free space velocity.

Step 2: Calculation of the effective dielectric constant (ε_{eff}): the effective dielectric constant is:

$$\varepsilon_{eff} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2}\left[1 + 12\frac{h}{W}\right]^{-\frac{1}{2}}$$

(II.2)

Step 3: Calculation of the effective length (L_{eff}): the effective length is given by:

$$L_{eff} = \frac{c}{2f_r\sqrt{\varepsilon_{eff}}}$$

(II.3)

Step 4: Calculation of the length extension (ΔL): the length extension is due to the fringing field and it given as:

$$\Delta L = 0.412h\frac{(\varepsilon_{eff} + 0.3)\left(\frac{W}{h} + 0.264\right)}{(\varepsilon_{eff} - 0.258)\left(\frac{W}{h} + 0.8\right)}$$

(II.4)

Step 5: calculation of actual length of the patch (L): from equation (10) and (11), the actual length is:

$$L = L_{eff} - 2\Delta L \qquad \text{(II.5)}$$

Step 6: calculation of ground plane dimensions (L_g **and** W_g): The transmission line model is applicable to infinite ground planes only. However, for practical considerations, it is essential to have a finite ground plane. It has been similar results for finite and infinite ground plane can be obtained if the size of the ground plane is greater than the patch dimensions by approximately six times the substrate thickness all around the periphery. Hence, for this design, the ground plane dimensions would be given as:

$$L_g = 6h + L \qquad \text{(II.6)}$$

$$W_g = 6h + W \qquad \text{(II.7)}$$

II.5 Simulation of single band rectangular microstrip patch antenna:

By applied the three essential parameters and follow the six steps above, the design specifications of the microstrip patch antenna are given in the table II.2:

L	W	Lg	Wg	ε_r
17mm	22.1mm	27mm	32mm	2.2

Table II.2: Design specification
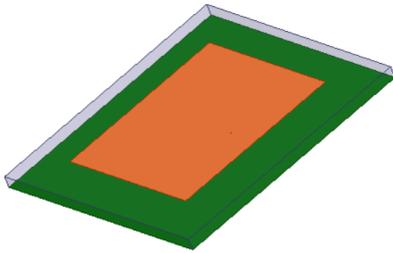
Figure II.5 (b)
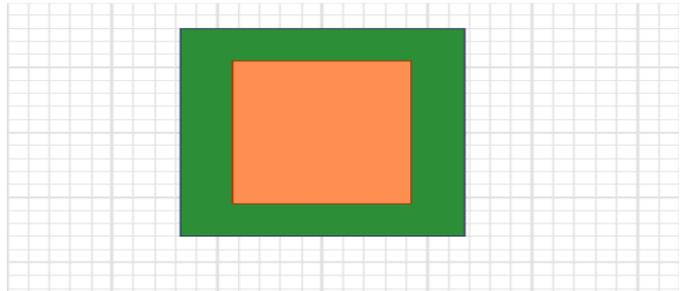
Figure II.5 (a)

Figure II.5 (a): Top view of the design antenna

(b): 3D microstrip patch antenna structure

II.5.1 Simulation results:

The result of the simulation is obtained by using the HFSS software. Figure II.5 (a) and (b) above represent the top view and bottom view structure of the single band microstrip patch antenna. The software can calculate many parameters, in our case four parameters will extract and discuss them.

Input impedance:

The figure II.6 shows the variation of the real and imaginary impedance of the patch antenna with the frequency. At 5.5 GHz, the result indicates where the antenna radiates because the impedance is purely real.
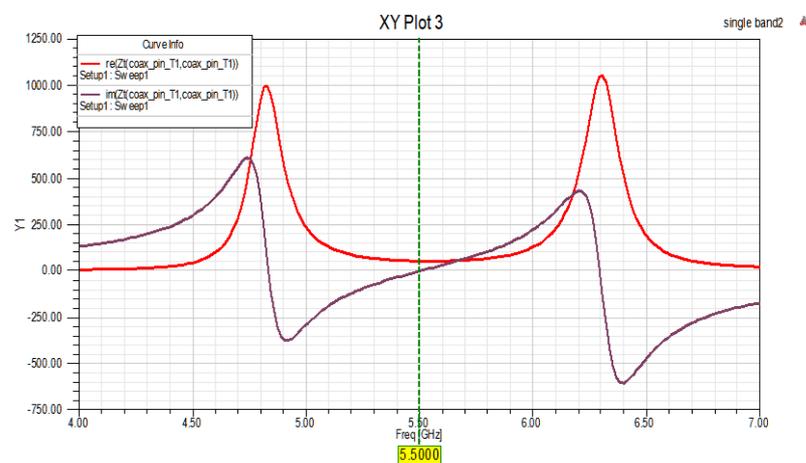
Figure II.6: Z parameter

Smith chart:

Smith chart is an efficacy plot that used in radio frequency. It defines and assists the engineer to solve many problems in the transmission line and electronic circuit in general specially in matching circuit. Figure II.7 shows how is the impedance behavior of the patch antenna with the frequency. The result confirms at 5.5 GHZ there is a good matching.

25
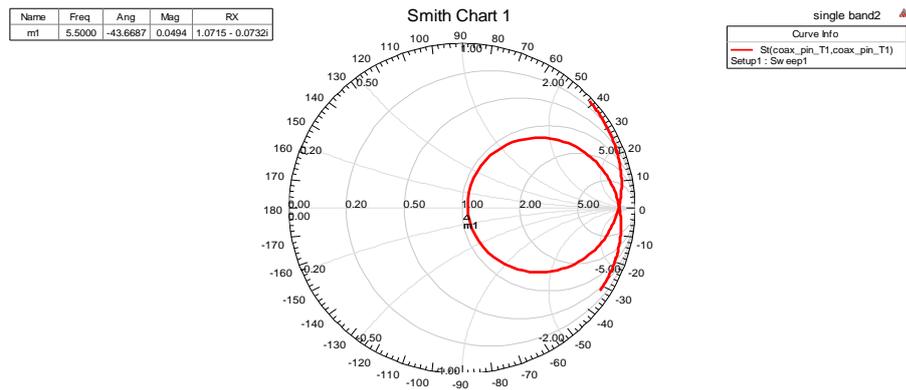
Figure II.7: Smith chart

Return loss:

The figure II.8 below shows a good matching at 5.5 GHz with return loss very near to -30 dB. This antenna is suitable for WiMAX (5.2-5.8) GHz and gives a bandwidth of 215 MHz in -10 dB (VSWR=2).
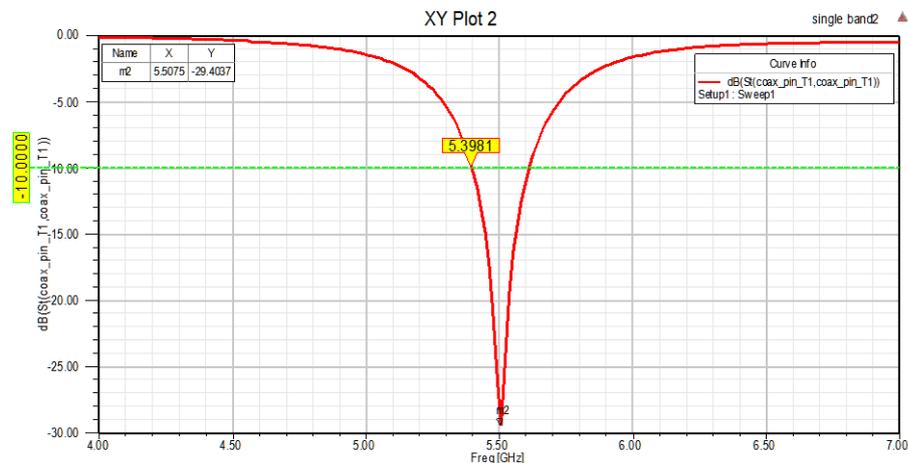
Figure II.8: Return loss (S11)

Gain pattern:

The figure II.9 is a polar graphic of the gain. Two necessary patterns are plotted $\varphi = 0°$ and $\varphi = 90°$ because the microstrip patch antenna radiate normal to the surface. The maximum gain is 7.65 dB both for the two plots. This antenna is a directive antenna.
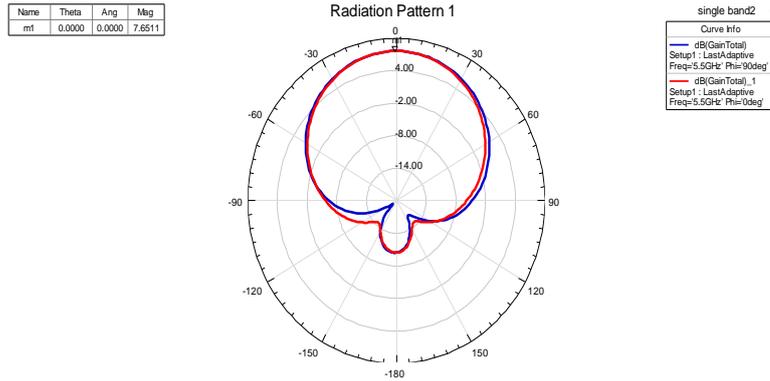
Figure II.9: Gain of $\varphi = 0°$ and $\varphi = 90°$ for 5.5 GHz

Variation of the feed position:

Changing the feed location from (0, B) to (A, B) like figure II.4 can provide another frequency rather then at 5.5 GHz, this phenomenon called dual band. The result in the figure II.10 shows two resonance frequency, one at 5.5 GHz and the author at 4.34 GHz.
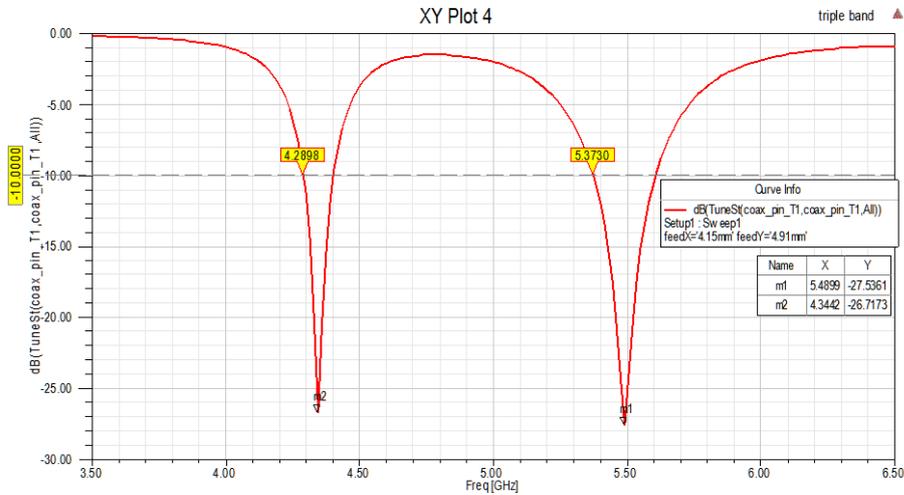
Figure II.10: Dual frequency operation

II.6 Conclusion:

In this chapter, an overview about U-slot and DGS for broadband techniques was given. The merits of these two techniques are to save the antenna size's and also can be reduced it like DGS, because they applied in single layer patch antenna. Their wideband behavior due to disturb the surface current distribution and this advantage overcome adding a structure which can increase the size of the antenna. Dual band techniques were

also given and defined the importance of the phenomenon. After that, we had introduced our first antenna design, it is almost small size with an operating frequency at 5.5 GHz for WiMAX application. This antenna and its geometrical parameters will be used like a start design model to prepare for the enhancement of broadband utilization. Finally, dual band behavior was achieved by made a variation in the feed position.

CHAPTER III

DESIGN AND SIMULATION

Chapter III

Design and Simulation

III.1 Introduction:

The design of the antennas is rapidly developed due to the several tools which have helped the researchers to reduce both the time and the cost. The microstrip patch antenna is one of the antenna that affects with this development, because it takes much interest due to several applications that can covered and its advantages over the wireless communications.

In this chapter, three design models will be given and simulated with extract some interesting antenna parameters like return loss, bandwidth and gain, in order to achieve what we had introduced in the chapters before such as broadband and dual band. Knowing that, all the proposed antennas are based on the reference antenna which designed in the chapter two. This is guarantee the small size for all the design model and might be the size will reduce to get best performance.

Our study is beginning by the first design which is a simple patch antenna model for dual band application with rectangular cut on the non-radiation edge called C-shape patch antenna. The design and simulation of the proposed antenna exhibits two narrow band, one of them is for WiMAX application. Second design, is for the broadband purpose. We take the same optimal dimensions of the C-shape antenna but we change in the ground plan by reducing it with specific value. This modification gives a very good wideband behavior as we will see. At the last design model, a modification of the geometry is realized on the patch plan. This technique also used for the broadband. It gives an interesting bandwidth around 400 MHz. This technique is based on disturb the current distribution on the patch surface.

The study of the three antennas: C-shape antenna, C-shape antenna with DGS and C-shape antenna with U-slot is by varying each geometrical parameter that have a direct impact on the antenna in order to have a good result especially in the return loss and the bandwidth.

III.2 first design: C-shape for dual band antenna:

In the first design, we present a dual band antenna based on modified the radiating shape. The figure III.1 define the geometries of C-shape antenna, and the table III.1 gives its dimension. The antenna is fed with a 50 Ω coaxial.

Wg	Lg	L	W	ε_r
32 mm	**27 mm**	**17 mm**	**22.1 mm**	**2.2**

Table III.1: Dimensions of C-shape antenna
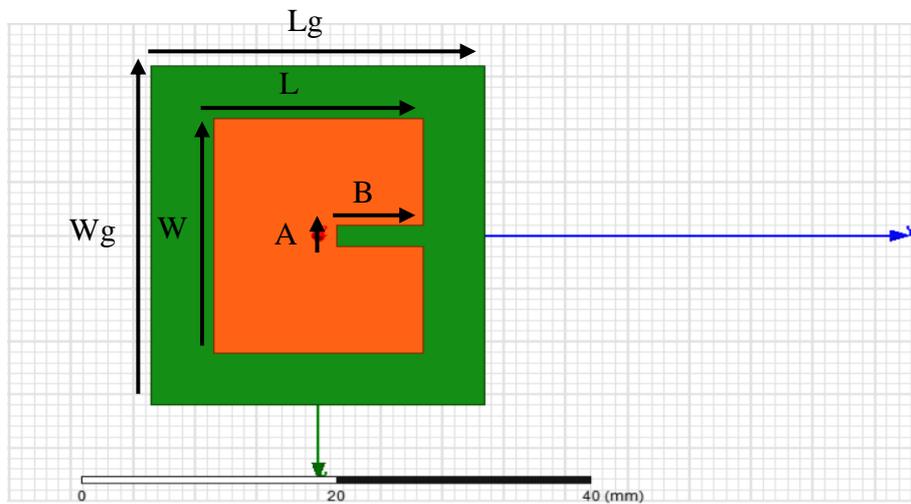
Figure III.1: 3D design of C-shape patch antenna

Geometrical study for the antenna:

The study of the proposed antenna begins by studying the effect of the geometry parameters, in order to show which is given a best performance then the others. Two parameters will be varied (A) and (B), knowing that when we were varied one at a time keeping the other constant.

Effect of the parameter (A):

The figure III.2 shown the return loss at every step when we vary in (A). taking into account, the variable (B) is fixed at 7 mm. The parameter is varied as we can see in table III.2. The result exhibits that when we increase in (A), the low resonance frequency (5.5 GHz) increase to the upper frequency. If we decrease, the low frequency decrease. The variation is affected the matching at the high resonance frequency (6.61 GHZ).

A	$f_r(low)$	$S_{11}(low)$	$f_r(high)$	$S_{11}(high)$
0.5 mm	5.48 GHz	-36.52 dB	6.68 GHz	-29.92 dB
2 mm	5.51 GHz	-38.39 dB	6.61 GHz	-36.71 dB
4 mm	5.57 GHz	-35.88 dB	6.60 GHz	-30.1 dB

Table III.2: Result of the variation in (A)
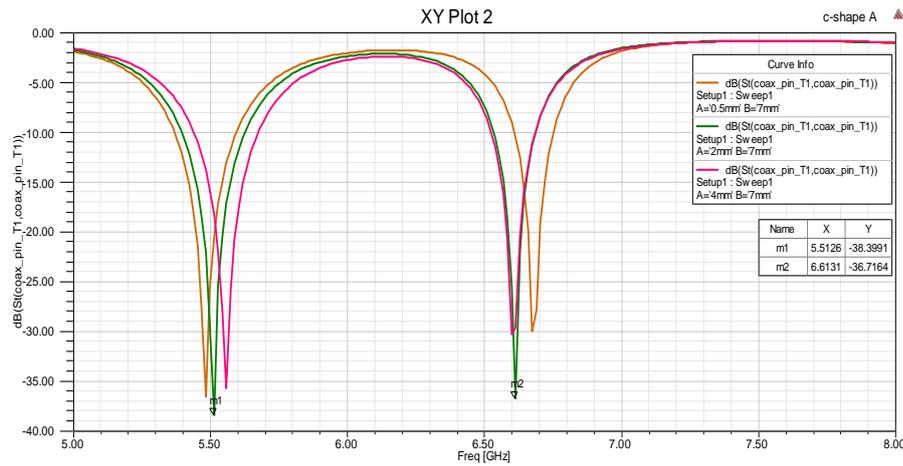
Figure III.2: Effect of variation in (A)

Effect of variation in (B):

In this sub-study, we change in (B) between 6 mm and 8 mm like we see in figure III.3 and we fix the variable (A) at 2 mm. The variable (B) has the same effect as (A), but its effect touched especially the high resonance frequency (6.76 GHz). when we increase in (B) the optimal frequency is decrease. In the other hand, when we decrease the variable the high frequency increase. The low frequency is just affected on the matching. The table III.3 below summarizes the result.

B	$f_r(low)$	$S_{11}(low)$	$f_r(high)$	$S_{11}(high)$
6 mm	5.52 GHz	-37.86 dB	6.69 GHz	-30.11 dB
7 mm	5.51 GHz	-34.62 dB	6.60 GHz	-40.22 dB
8 mm	5.50 GHz	-41.00 dB	6.55 GHz	-27.30 dB

Table III.3: Result of the variation in (B)
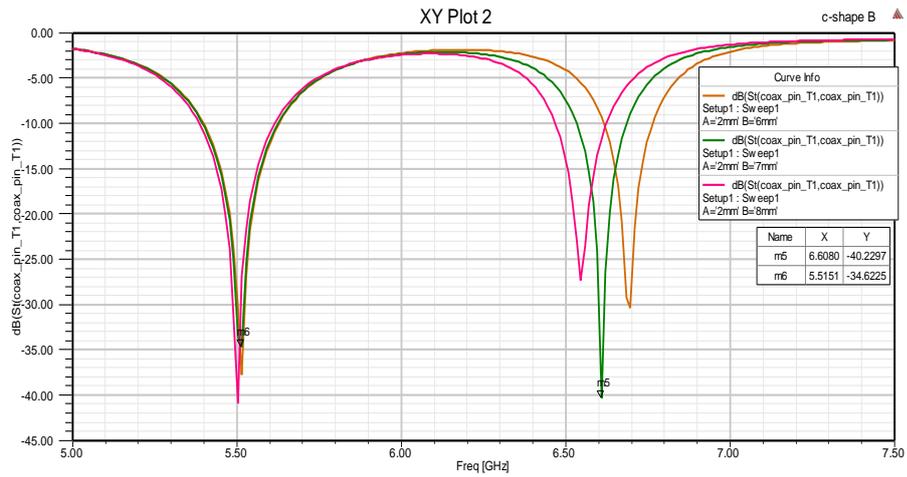
Figure III.3: Effect of variation in B

It clearly appears that the two geometrical parameters are just affect the operation frequency by decreasing or increasing. This is due to the modification in the patch geometry's, which has a mathematical relation with wavelength and the disturbance in the surface current distribution. The figure III.4 shows the return loss of the performance result of the two studies above which is when variables (A) and (B) take 2mm and 7mm respectively. The result indicates a very good matching, -34 dB at 5.5 GHZ is for WiMAX technology and -39 dB at 6.6 GHz is located in the C-band. The bandwidth that is determined from -10 dB is 4.23% for WiMAX and 2.28% for the second band.
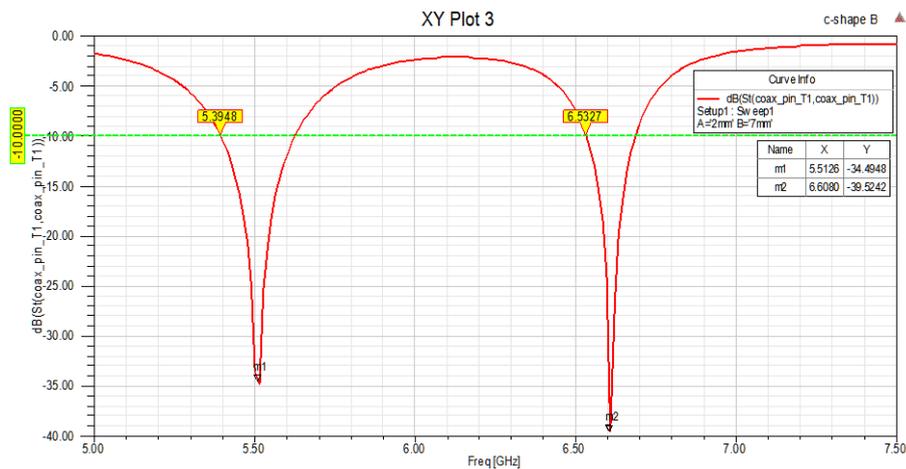
Figure III.4: Return loss for C-shape antenna

Smith chart:

The figure III.5 describes the variation of the impedance with the frequency. It shows that the two resonance frequencies are in a very good matching.
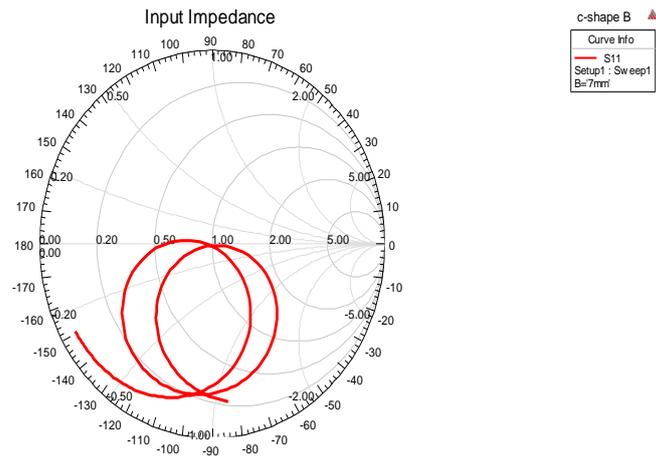
Figure III.5: Smith chart for the proposed antenna

Gain pattern:

The E-plan (φ =0) and H-plan ($\varphi = 90$) gain is depicted in the figure III.6 (a) and (b) for 5.5 GHz and 6.17 GHZ respectively. They show that the antenna has a maximum gain of 7.55 dB at the frequency 5.5 GHz and 6.17 dB at the frequency 6.6 GHz. These two plots indicate that the antenna has single side of radiation either in the E-plan or H-plan, so this kind of antenna is considered as a directive antenna.
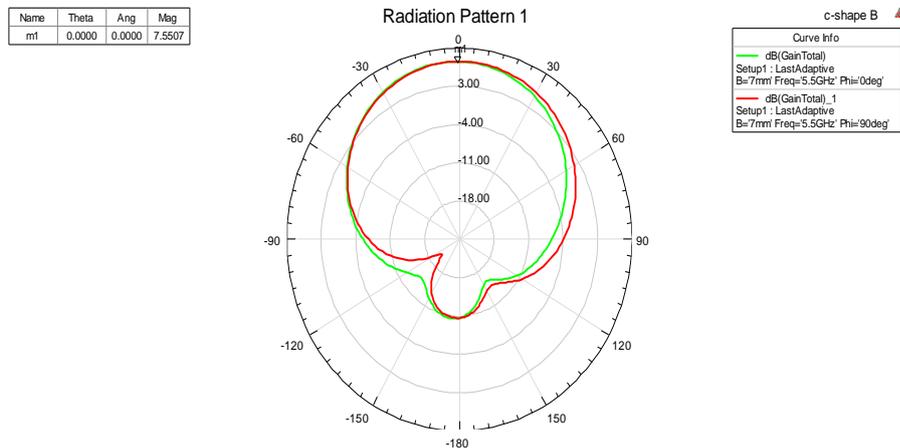
Figure III.6 (a)
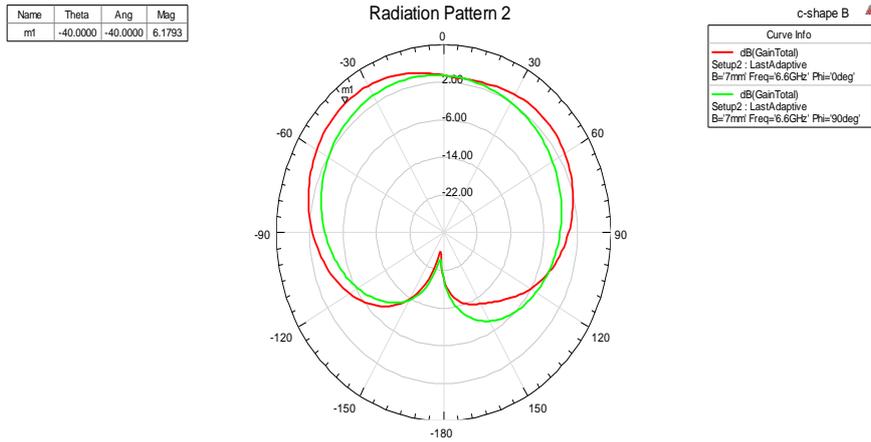
Figure III.6 (b)

Figure III.6 (a): Gain for φ =0 and φ = 90 degrees at 5.5 GHz

(b): Gain for φ =0 and φ = 90 degrees at 6.6 GHz

III.3 second design: C-shape with DGS

In this second design, we take the same geometrical parameters of the C-shape before, but we make a reducing 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.

Wg	Lg	L	W	A	B
32mm	27mm	17mm	22.1mm	2 mm	7 mm

Table III.4: Dimension of C-shape antenna with DGS

Figure III.7 (a)

35
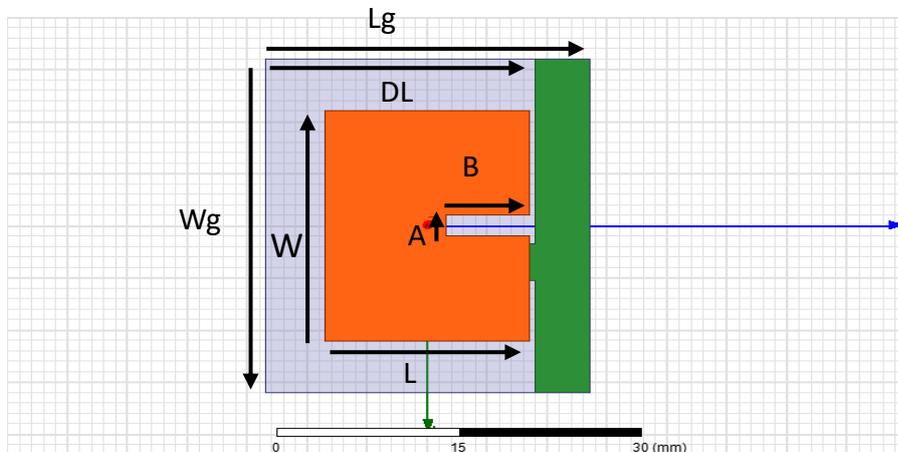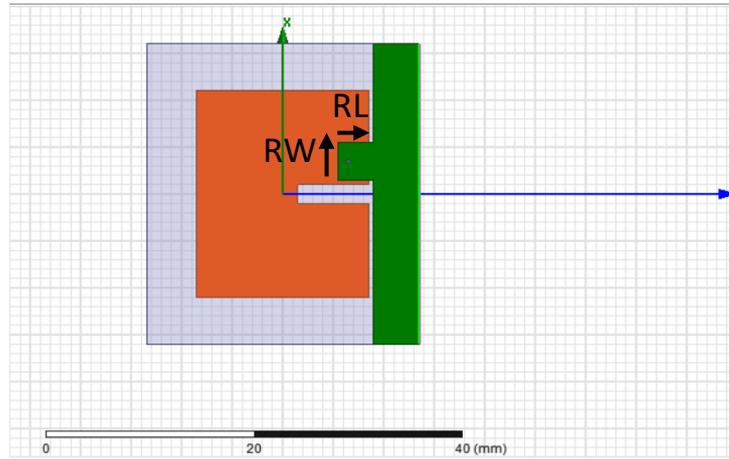
Figure III.7 (b)

Figure III.7 (a): Top view of C-shape antenna with DGS

(b): Bottom view of C-shape antenna with DGS

Geometrical study for the antenna:

To begin the study, three parameters will be varied (RL, RW, DL) in order to get a best result especially in term of bandwidth. Take in consideration, when we vary in parameters, the others stay fixed.

Effect of variation in (RL):

The figure III.8 shown the return loss of the variable (RL), we varied from 3-4 mm with step of 0.5 mm. we observe that the effect of (RL) on the antenna especially in term of bandwidth is inversely to the magnitude of the return loss. The table III.5 gives the statistic of the graph.

RL	$f_r(low)$	BW(low)[%]	$S_{11}(low)$	$f_r(high)$	BW(high)[%]	$S_{11}(high)$
3mm	6.60 GHz	20.75	-32.52dB	10.20GHz	20.09	-20.15 dB
3.5mm	6.49 GHz	26.19	-34.64dB	9.87 GHz	22.28	-27.15 dB
4 mm	6.40 GHz	42.18	-25.82dB	9.62 GHz	23.90	-31.67 dB

Table III.5: Result of the variation in (RL)
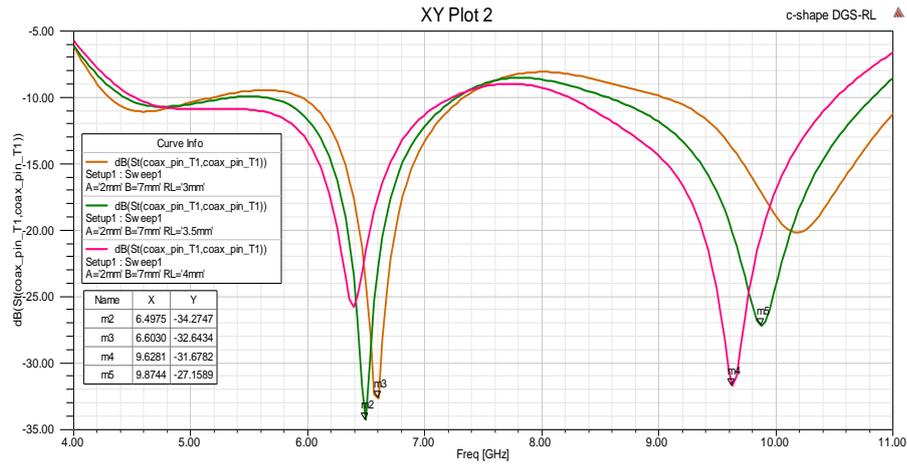
Figure III.8: Effect of variation in (RL)

Effect of variation in (RW):

In this part, the results of the sub-study are given in the figure III.9. The results shown that when we increase in (RW), It's enhanced both parameters bandwidth (at -10 dB) and return loss. However, after 4 mm these results change their behavior to the decreasing. The table III.6 resume the results.

RW	$f_r(low)$	BW(low)[%]	$S_{11}(low)$	$f_r(high)$	BW(high)[%]	$S_{11}(high)$
3.5mm	6.49GHz	23.11	-34.13dB	9.90GHz	21.91	-25.98dB
4 mm	6.42GHz	40.18	-40.90dB	9.83GHz	22.27	-24.89dB
4.5mm	6.32GHz	36.39	-32.13dB	9.62GHz	22.66	-23.10dB

Table III.6: Result of the variation in (RW)
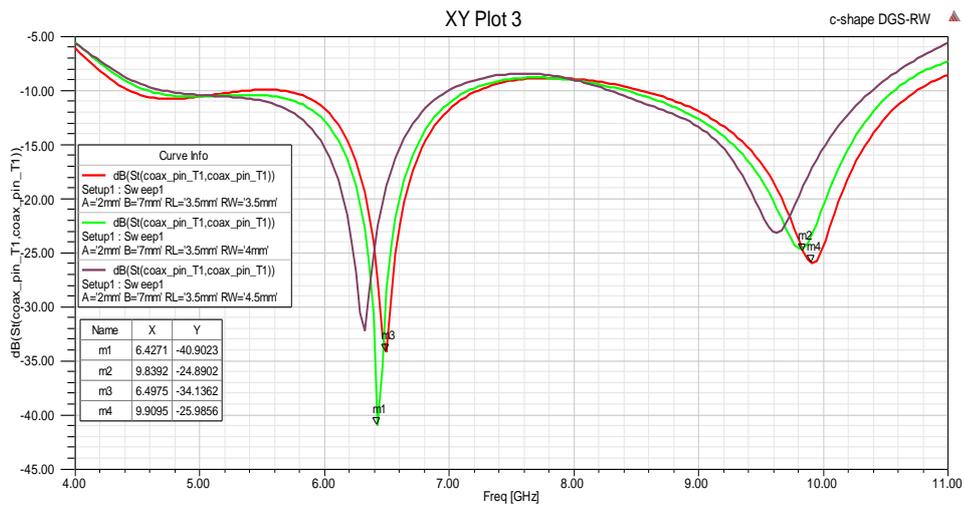
Figure III.9: Effect of variation in (RW)

Effect of DL:

the figure III.10 shows that the variation in (DL) parameter is affect the return loss and the bandwidth also. It appears that the return loss increases with fast rate at 6.42 GHz when we vary (DL) to certain value. After, the return loss reduces. At 9.83 GHz, the effect of the variation touches the resonance frequency by decreasing or increasing. As far as we increase in (DL) the bandwidth is going to be better. The table III.7 gives more observation.

DL	$f_r(low)$	BW(low)[%]	$S_{11}(low)$	$f_r(high)$	BW(high)[%]	$S_{11}(high)$
22mm	6.43GHz	18.66	-19.55dB	10.00GHz	17.10	-24.00dB
22.5mm	6.42GHz	40.18	-40.90dB	9.83GHz	21.97	-24.56dB
23mm	6.39GHz	47.64	-20.12dB	9.60GHz	26.77	-22.88dB

Table III.7: Result of the variation in (DL)
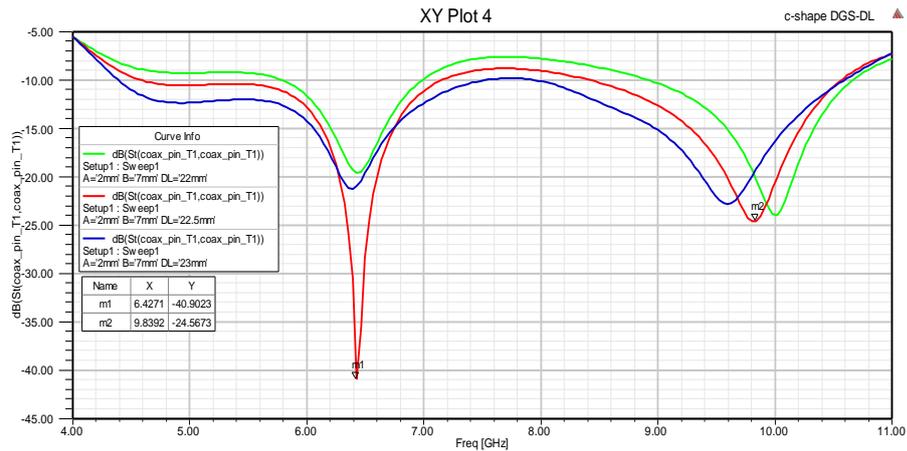
Figure III.10: Effect of variation in (DL)

The technique of improving the bandwidth with defected ground structure (DGS) depicts a very good result. The good result is when DL, RL and RW take 22.5mm, 3.5mm and 4mm respectively. The figure III.11 represents the return loss of the performance result from three studies above. Its shows a dual band antenna, it has a very good matching (-40.90 dB) peak at 6.42 GHz with a bandwidth of 40.18% at -10 dB. This peak is suitable for satellite utilization in the C-band from 4-8 GHz. In the other hand, a peak located in X-band frequency range from 8-12 GHz, this range is for radar application. It has frequency of 9.83 GHz and a bandwidth of 21.97%.
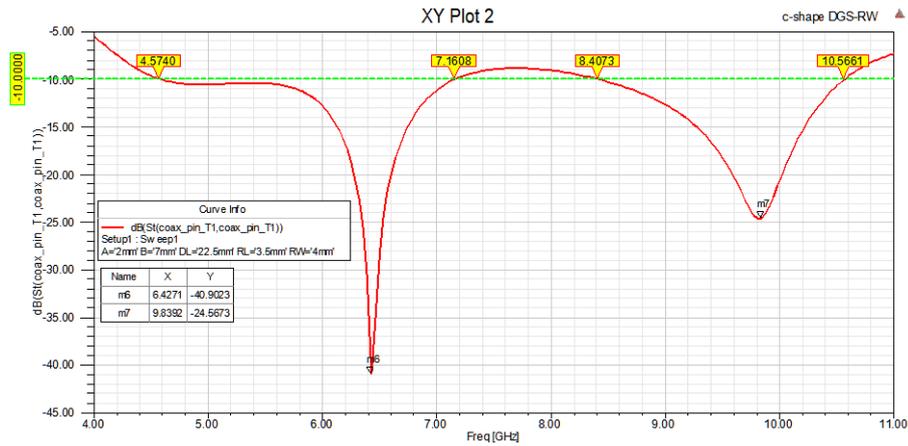
Figure III.11: Return loss for C-shape antenna with DGS

Smith chart

The figure III.12 describes the variation of the impedance with the frequency. It shows that the two resonance frequencies are in a very good matching.
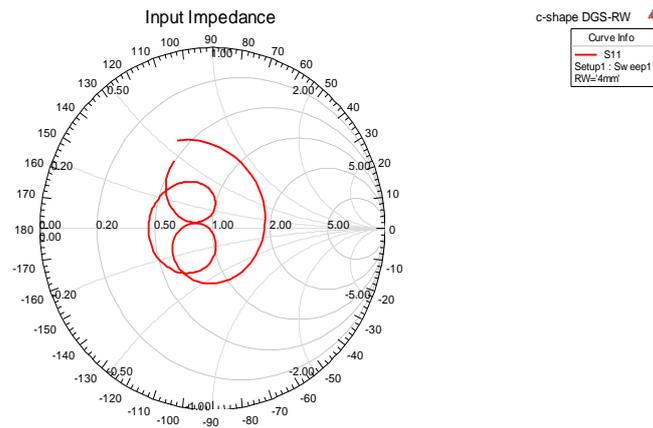
Figure III.12: Smith chart for C-shape antenna with DGS

Gain pattern:

The figures III.13 (a) and (b) below show the gain of the antenna at 6.42 GHZ and 9.83 GHZ. The maximum gain at 6.62 GHz is 3.62 dB, and 2.85 dB for 9.83 GHz. the figure indicates that the antenna has max directivity in the E-plan for $\theta = 25°$ and good coverage between $\theta = -30° \ to -90°$ in the H-plan. The figure shows max coverage when $\theta = -30° \ to -90°$ both plan H and E.
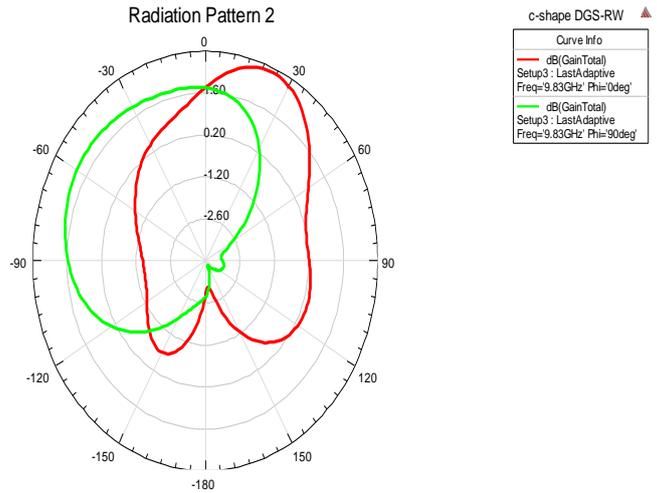
Figure III.13 (a)
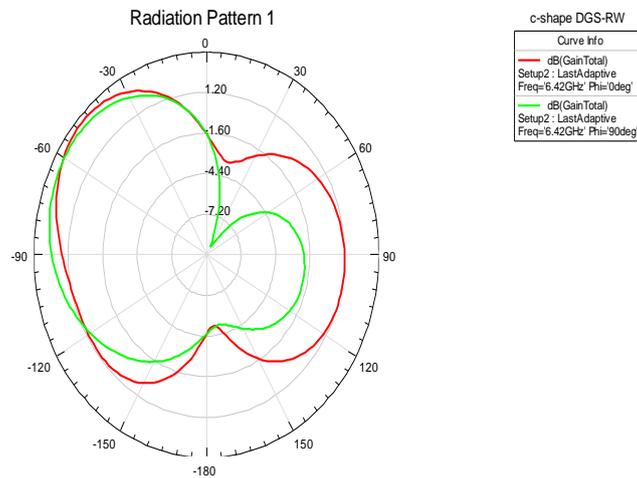
Figure III.13 (b)

Figure III.13 (a): Gain for φ =0 and φ = 90 degrees at 9.83 GHz

(b): Gain for φ =0 and φ = 90 degrees at 6.42 GHz

Note:

The variation in parameter (DL) gives a very interesting result which appears in the figure III.14 (a) and (b). This result is suitable for the Ultra-wideband range from (3.1-10.6) GHz. The Ultra-wideband is a wireless network provided to use in the personal network and it can transmit a lot of data over a short distance with low power. The result shows a bandwidth of 67.71% from (4.31-10.54) GHz.
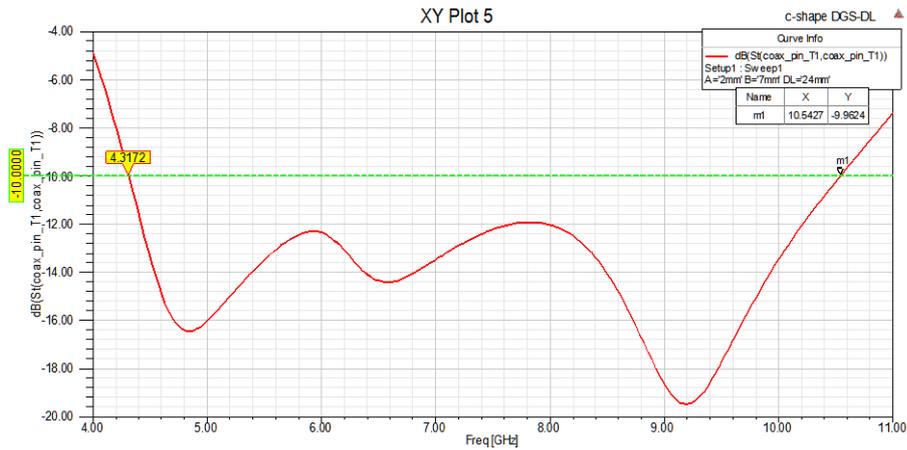
Figure III.14: Return loss for Ultra-wideband

III.4 Last design: C-shape antenna with U-slot

The last design of improving the bandwidth is the C-shape patch antenna with U-slot. The figure III.15 represents the 3D design model, and the table III.8 below gives its geometrical parameters.

Wg	Lg	L	W	A	B
32mm	27mm	17mm	22.1mm	2mm	7mm

Table III.8: Dimension of C-shape antenna with U-slot
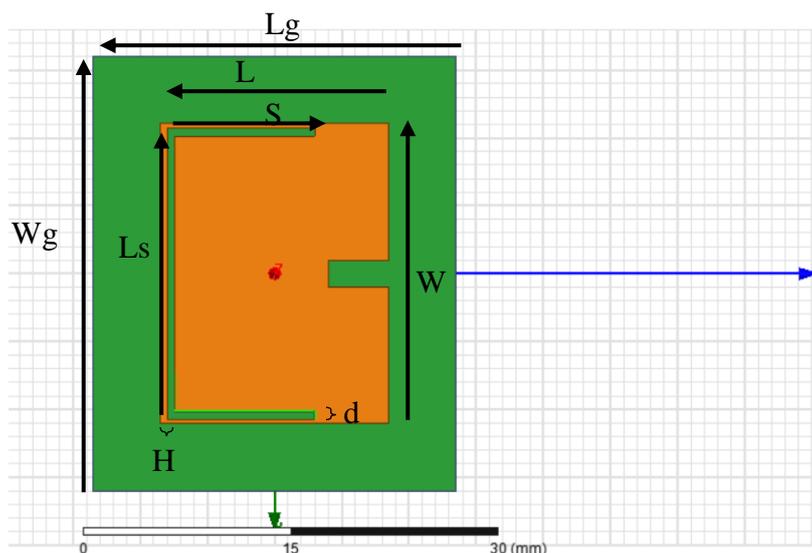
Figure III.15: 3D design of C-shape antenna with U-slot

Geometrical study for the antenna:

The proposed antenna has four variations parameters (S, Ls, H, d), each one will be varied to get the best result.

Effect of Ls:

The figure III.16 describes the variation of the length (Ls). The result indicates that the magnitude of return loss has a great affected with the increasing in the variable. When we increase (Ls) in certain value, the bandwidth is going better and the S_{11} gets a very good peak rate.
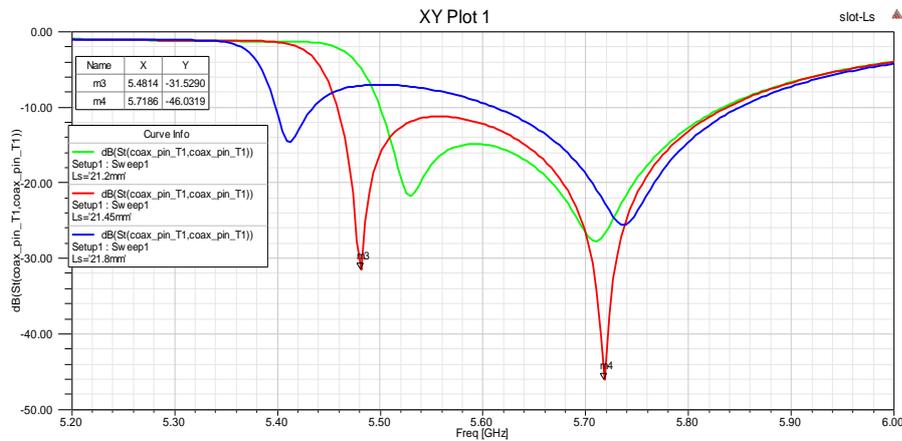
Figure III.16: Effect of variation in (Ls)

Effect of d:

in this case, depth of U-slot (d) is varied. The figure III.17 depicts the effect of the parameter on the frequency behavior. It exhibits that the increasing in (d) makes the resonance frequency increases also. The bandwidth is probably fix with this variation.
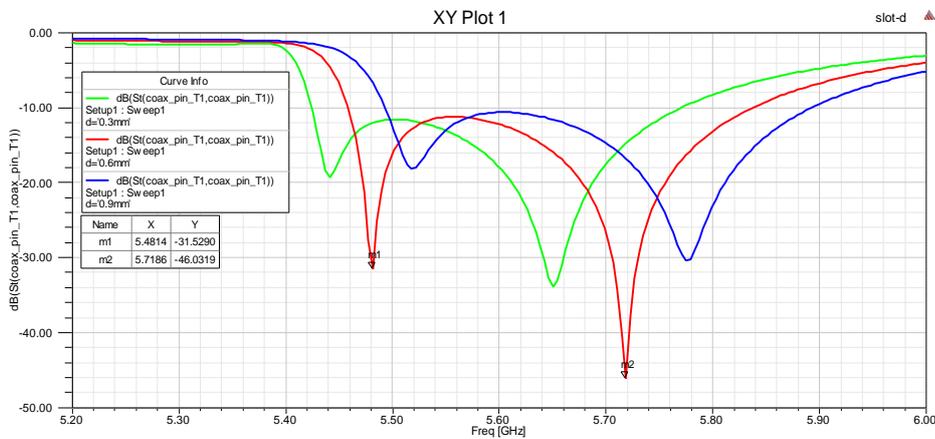
Figure III.17: Effect of variation in (d)

Effect of S:

The result of this sub-study shown in the figure III.18. It's clearly appears that the antenna is completely affected with the parameters (S) either in the term of bandwidth or return loss. The result indicates that when change the value from the optimal case S=11mm, the antenna wastes its matching and the bandwidth is decreasing.
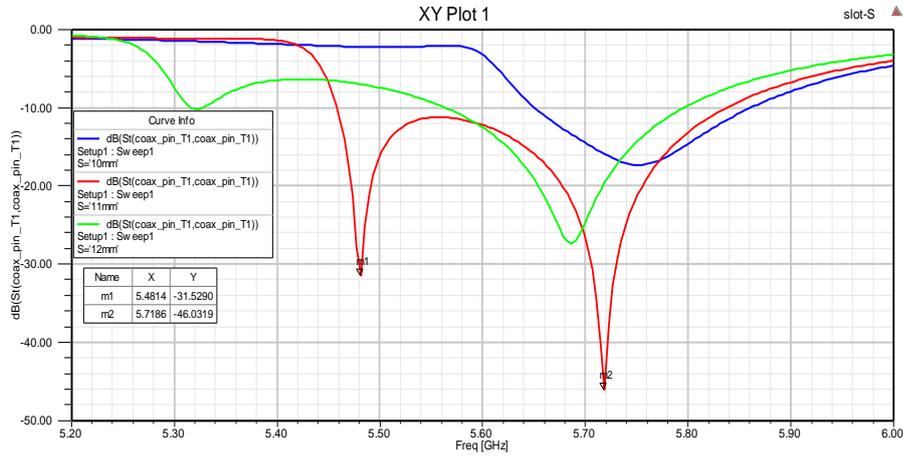
Figure III.18: Effect of variation in (S)

Effect of H

The figure III.19 below shows the effect of variation in (H). it indicates that the effect of parameter (H) is generally on the low resonance frequency. When we increase the variable the resonance frequency decreases.
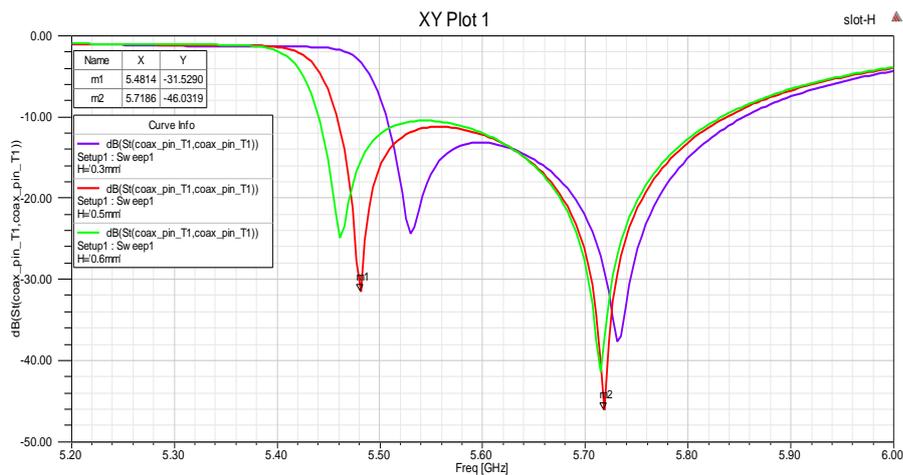
Figure III.19: Effect of variation in (H)

The figure III.20 represents the optimal result from the four studies above. The good result obtains when the parameters S, H, Ls, d, is take 11mm, 0.5mm, 21.45mm, 0.6mm respectively. Its shows also a good bandwidth of 6.47% with dual band, one at 5.48 GHz and it is for the WiMAX application. Second one is at 5.71 GHz; this peak is very near to the IEEE 802.11 (WLAN) at frequency range of (5.725-5.825) GHz.
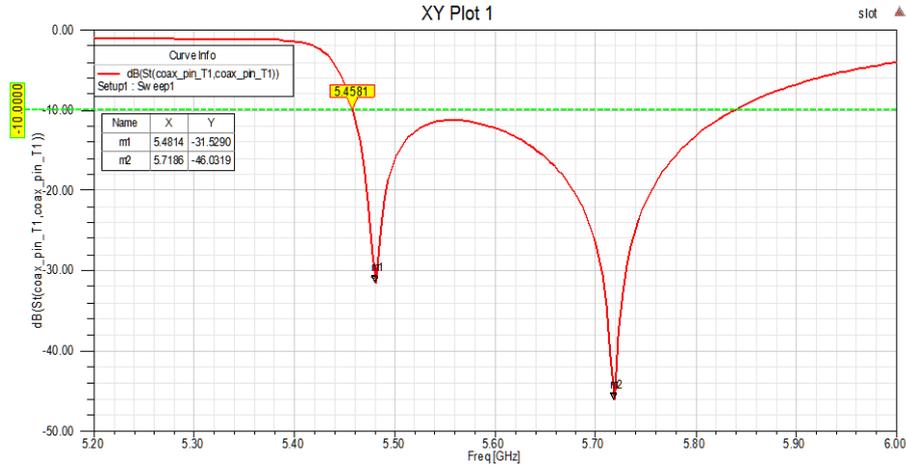
Figure III.20: Return loss for C-shape antenna with U-slot

Smith chart:

The figure III.21 directs the variation of the impedance versus the frequency. It shows that the resonance frequency is in a very good matching.
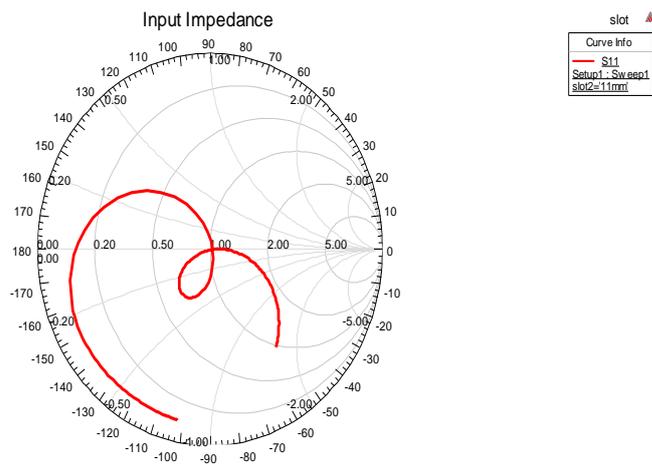
Figure III.21: Smith chart for C-shape antenna with U-slot

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Gain pattern:

The figure III.22 (a) and (b) indicates that the antenna eithe at 5.71 GHz or at 5.48 GHz almost has a maximum gain between $\theta = 30° to -30°$. At the frequency 5.71 GHz antenna has a max gain of 7.56 dB and at 5.48 GHz it has 7.25 dB.
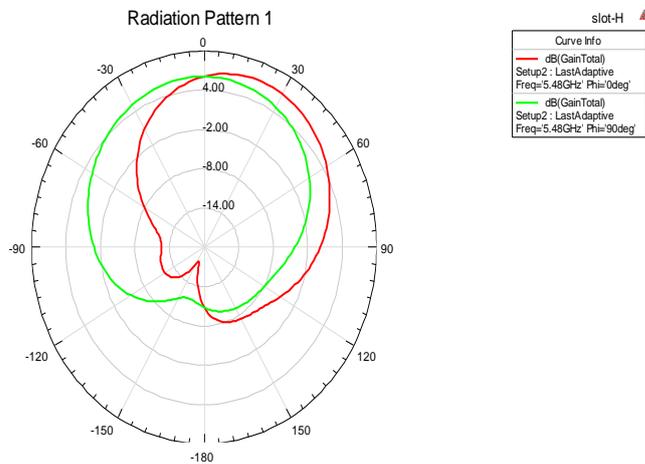
Figure III.22 (a)
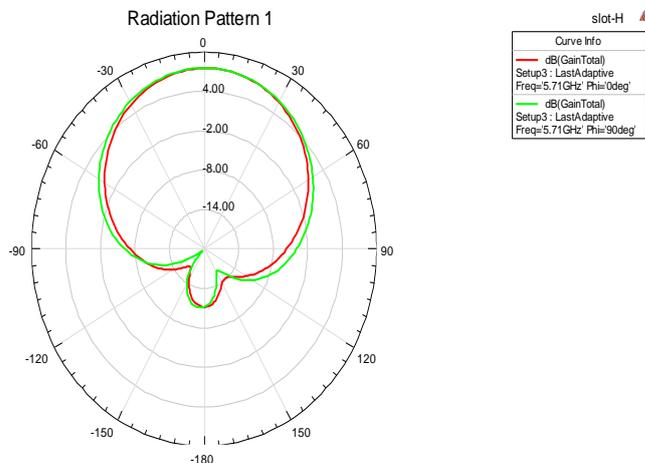
Figure III.22 (b)

Figure III.22 (a): Gain for φ=0 and φ= 90 degrees for 5.48 GHz

(b): Gain for φ=0 and φ= 90 degrees for 5.71 GHz

III.5 The summarizing of the results

The table III.9 summarizes all the results of the designed antennas. We see that the bandwidth of the antenna increases when we introduce a new technique as well as the

return loss. The microstrip patch antenna with DGS shows the high impedance bandwidth of all design wich confirm that the DGS techniques has a great effect on the bandwidth.

Antenna	$f_r\,1(GHz)$	BW[%]	$S_{11}(dB)$	$f_r\,2(GHz)$	BW[%]	$S_{11}(dB)$
Microstrip patch antenna	**5.5**	**3.90**	**-30**	**/**	**/**	**/**
Patch antenna with C-shape	**5.5**	**4.23**	**-34**	**6.6**	**2.28**	**-39**
Patch antenna with DGS	**6.42**	**40.18**	**-40.90**	**9.83**	**21.27**	**-24.56**
Patch antenna with U-slot	**5.71**	**6.47**	**-46.03**	**/**	**/**	**/**

Table III.9: the summarizing results of the antennas

III.6 conclusion

In this chapter, three design models for microstrip patch antenna are given. The first design is C-shape antenna, it is depicted a dual band one at 5.5 GHz for WiMAX and the other is at 6.6 GHZ. The two peaks had a magnitude between -34 dB and -39 dB, this indicates that the antenna radiates the maximum power that arrived, which confirm that there is a matching between the source and the antenna. The second design is C-shape antenna with DGS, this antenna is based on the first design by take the same dimensions. However, a specific modification had introduced by making a reducing in the ground length. This new design had showed a maximum bandwidth of 40.18% for the first peak 6.42 GHz and this band is suitable for satellite using in the C-band. Moreover, an interesting result had seen when we were varied in (DL), this result has a bandwidth of 67.71% from (4.31-10.54) GHz. It's considered as an Ultra-wideband which generally applicated in the personal network. The last design is C-shape antenna with U-slot, it was exhibited a good bandwidth of 6.47% with dual band, one at 5.48 GHz for the WiMAX application. Second one is at 5.71 GHz; this peak is very near to the IEEE 802.11 (WLAN) at frequency range of (5.725-5.825) GHz.

GENERAL CONCLUSION AND PERSPECTIVES

General conclusion and perspectives

In this thesis, four designs have been given and studied. We have been started with fist microstrip patch antenna for single operating frequency as reference model. Second design is a simple patch antenna based on the first design, but we have made a rectangular cut in order to achieve the dual band. the third and the last design have been proposed to improve the performance of the microstrip patch antenna especially the bandwidth in which we obtain a broadband antenna, to response the wireless communications demand.

Our fist design is given in the second chapter. It is designed with approximately mathematical equations to operate at 5.5 GHz for WiMAX. its dimensions are around of 22×17 mm, which probably considered as a very small antenna. The return loss of this first antenna indicates a very good matching, it is -30 dB with narrow impedance bandwidth of 3.9%. For the antenna of dual band which is the second design, two resonance frequencies have been successfully provided. This antenna exhibited two interesting peaks, one is the same as the first design at WiMAX application and second peak at 6.6 GHz. The last operating frequency is in range the frequency of C-band between (4-8) GHz which dedicated for the satellite utilizations. The matching at the two resonance frequencies is under -34 dB, this indicates that approximately all the waves is transmitting. Two other proposed antennas have been designed and simulated in order to overcomes the narrow bandwidth of the microstrip patch antenna where this problem is clearly appeared in the two first design. The effect of technique defected ground structure (DGS) on the microstrip patch antenna gives a bandwidth of 40.18% and 21.97% for 6.42 GHz and 9.83 GHz respectively. The U-slot technique also showed a considered bandwidth around 6.47%.

Perspectives:

Through the work on this thesis four perspectives are observed:

- The DGS technique has a great effect on the bandwidth and also can reduce the size of the antenna.
- The U-slot technique needs knowledge to get a best result especially the bandwidth.
- Dual band and multiband becomes an important field of research and urgent need in the wireless communication.

- Radar, Satellite and WMAN need to the wideband, this is lead to provide an antenna with wide bandwidth.

- The unavailable of antenna fabrication and their tools makes the thesis just based on the simulation.

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