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PATCH ANTENNA DESİGN FOR X BAND APPLİCATİONS

THESIS

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Department of Electrical & Electronic Engineering
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MSc. THESIS

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(Y.1513.300011)

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MAY, 2019

ONAY FORMU

T.C.
İSTANBUL AYDIN ÜNİVERSİTESİ
FEN BİLİMLER ENSTİTÜSÜ MÜDÜRLÜĞÜ

Yüksek Lisans Tez Onay Belgesi

Enstitümüz Elektrik- Elektronik Mühendisliği Ana Bilim Dalı Elektrik- Elektronik Mühendisliği (İngilizce) Tezli Yüksek Lisans Programı **Y1513.300011** numaralı öğrencisi **CEMAL İBRAHİMPAŞA'** nın **"PATCH ANTENNA DESIGN FOR X-BAND APPLICATIONS''** adlı tez çalışması Enstitümüz Yönetim Kurulunun 26/06/2019 tarih ve 2019/13 sayılı kararıyla oluşturulan jüri tarafından ..oybirliği.. ile Tezli Yüksek Lisans tezi olarak ..kabul....edilmiştir.

Öğretim Üyesi Adı Soyadı	**İmzası**
Tez Savunma Tarihi : 11-07-2019	
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DECLARATION

I hereby declare that all information in this thesis document has been obtained and presented in accordance with academic rules and ethical conduct. I also declare that, as required by these rules and conduct, I have fully cited and referenced all material and results, which are not original to this thesis.

Cemal IBRAHIMPAŞA

Family forward

I extend my deepest gratitude to my father, my mother and my sisters who always believed in me and provided me with their endless support, love, and encouragement during my work on this thesis and during all stages of my life.

FOREWORD

I would first like to thank my thesis advisor Assist. Prof. Dr. Saeid Karamzadeh of the Electric and Electronic Engineering at Istanbul Aydin University for his guidance, sharing expertise, and beneficial critiques of this work.
I would like also to thank Istanbul Aydin University and its facilities for providing me with an access to all the books and articles that I needed to finish this work

MAY 2019 **Cemal IBRAHIMPAŞA**

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ABBREVIATIONS

GPS	**:** Global Position System.
GSM	**:** Global System for Mobile.
MPEG	**:** Moving Picture Experts Group Version 2.
MPEG	**:** Moving Picture Experts Group Version 4.
ASI	**:** Asynchronous serial interface.
QPSK	**:** Quadrature Phase-Shift Keying.
8PSK	**:** 8 Phase-Shift Keying.
BUC	**:** Block Up Converter.
HPA	**:** High Power Amplifier.
IEEE	**:** Institute of Electrical and Electronic Engineers.
VSWR	**:** Voltage Standing Wave Ratio.
3D	**:** 3 Dimensional.
2D	**:** 2 Dimensional.
CP	**:** Circular polarization.
LHCP	**:** Left Hand Circular Polarization.
RHCP	**:** Right Hand Circular Polarization.
UWB	**:** Ultra-Wide Band.
WLAN	**:** Wireless Local Area Network.
FCC	**:** Federal Communication Commission.

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ANTENNA DESIGN FOR X BAND APPLICATIONS

ABSTRACT

In the last years, the development in the communications and the broadcasting systems requires to develop a low cost, light weight and easiness of movement and usage antennas. That's a capable of high performance at the same time.

In this thesis X-band Antenna has been discussed and designed which could be used for many applications, for that we discussed one of these desired applications (Satellite Tv Broadcasting) and we explained the fundamental the signal processing within the Tv broadcasting system and we talked briefly about the main equipment that the broadcasting system is consists of. In addition we covered the satellite frequency bands. After that we get more specific in our topic and started discussing with details the antenna types and the antenna parameters that we will use to design our antenna and examine the antenna efficiency, in the following chapter we discussed with extensive details the microstrip antenna shapes, components and specifications, as our purpose is to design a microstrip antenna that will operate on X-band frequency and our desired frequency will be 10.5 GHZ. Microstrip antenna has been chosen because of its easy fabrication and the ability to design it the way that will provide the needed efficiency for its purpose job,

The proposed antenna which we designed, is consist of radiating patch on a Roger RO4003C substrate with a ground patch, and the microstrip feeding line to the patch is set on 50 Ohm. And will give us 8.45 dB peak gain in X-band Frequency range and wide IBW range from 5.8 GHZ till 12 GHZ

The proposed antenna had been designed and simulated using CST studio software.

Keywords: *X-Band, Tv-Broadcasting, Notched antenna, Rectangle slotted.*

X BANT UYGULARAMALRI IÇIN YAMA ANTEN TASARIMI

ÖZET

Son yıllarda iletişim ve yayın sistemlerindeki gelişmeler; maliyeti düşük, hafif, hareket ve kullanım kolaylığına sahip antenleri geliştirmeyi gerektirir. Bu antenler aynı zamanda yüksek performans yeteneğine sahiptirler…

Bu tez çalışmasında pek çok uygulama alanı bulunan X-Band antenleri tasarlanarak incelenmiştir. Bu uygulama alanlarından biri olan “Uydu TV Yayını” ele alınıp; bu yayın sisteminin oluşturduğu ana ekipmanlar ve yayın sisteminin sinyal işlemesinin esasları açıklanarak tartışılmıştır. Özetle; bu yayın sisteminin oluştuğu ana donanımı hakkında, uydu frekans bantlarını da kapsamak suretiyle inceleme yapılmış, tartışılmıştır.

Bu aşamadan sonra konularımızda ayrıntıları daha da belirginleştirerek; tasarlanan antenimizin verimliliğini incelemek için kullanacağımız anten tipleri ve parametreleri detaylı bir şekilde tartışılmıştır. Bir sonraki bölümde küçük şeritli antenlerin(Microstrip Antennas) bileşenleri, özellikleri, biçim ve şekilleri detaylandırılarak etraflıca ele alınmıştır. Buradaki amacımız, 10.5 Ghz X-Band frekansında çalışması istenilen bir küçük şeritli anten (Microstrip) tasarlamaktır. Önerilen tasarıda küçük şeritli antenin seçilme nedeni, kolay üretilmesi ve kullanımda talep edilecek gerekli verimliliği sağlayıcı tasarım kabiliyetidir.

Öneride tasarlanan anten, üst kısmında bir yayılan yama (Radiation Patch) ve en altta zemin yaması (Ground patch) bulunan “Roger RO4003C Substrate”ten oluşuyor. Bu yamaya giden hattı besleyen küçük şeritli anten(MicrostriP) 50 Ohm ayarlı olup, bize vereceği “Gain” 8.45 Db’dir. Ayrıca, önerilen anten, CST stüdyo yazılımı kullanılarak tasarlanmış ve simüle edilmiştir.

Anahtar Kelimeler: *Küçük şeritli anten, X-Band antenleri*

1. INTRODUCTİON

The rapid development in the wireless communication systems and the importance of providing high quality multimedia services for our daily life activities requires to keep developing antennas that's easy to use and easy to fabricate at the same time, and the huge demands on the satellites communication services require us to develop our systems and antennas as it will receive and send the electromagnetic waves to be able to use every possible range of frequency [1]. For example, in Tv broadcasting system the High demands on Ku Band Frequencies to broadcast the huge number of Tv Channel, Events and feeds require us to use another frequency range in addition to KU band such as X-band frequencies. Moreover, in this Systems its common to use the Reflector antenna which require a wide area to set it up. For that developing a small size antenna like the Microstrip antenna to be used in this kind of applications will be considered a big development in the satalite communication systems [2]. In the next part, we will start with discussing the satellite frequency bands.

1.1 Satellite Frequency Bands

As the target of our project is to design a microstrip antenna that will be operated on X-band Frequencies, it is important to have a quick view of the frequency ranges that's been used daily in the satellite communications. Moreover, it is important to know the advantages of each band and the characters of these bands because depending on these characterizes it will be decided on which frequency range the application will be operated. There is so much applications that use Satellite Frequencies. such as radar, tv broadcasting, internet, GPS, weather forecast and much more applications which operates on a specific frequency range. Figure 1.1 shows the frequency bands range and an example of an application on each band [3].

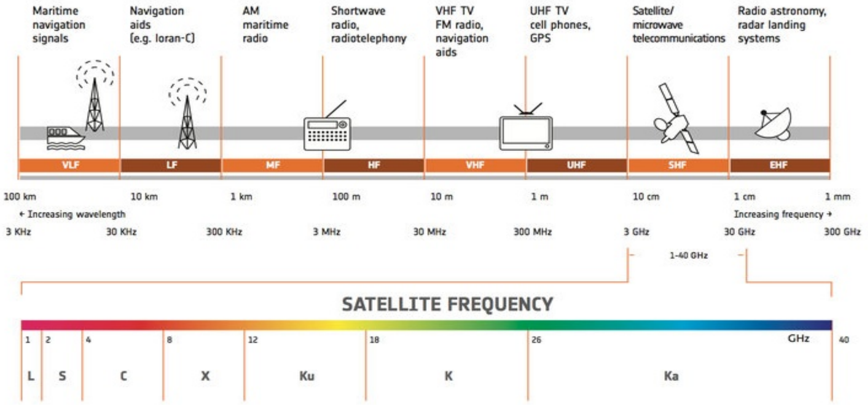

Figure 1.1: Satellites applications with satellite frequencies.

1.1.1 L-band

L-band frequency range is (1-2) GHZ, many applications operate in this range of frequencies Global Positioning System (GPS) is one of these applications also satellite mobile phones GSM. This frequency range is not suitable to be used for streaming applications like videos. And using L band don’t require high quality antenna or accurate directionality [3].

1.1.2 S-band

S-band frequency range is between (2-4) GHZ. In this frequency band we have some satellite application and domestic radar applications such as Weather radar, that use S band frequencies. In addition, that it’s been used for delivering real time data such as roads traffic and navigation systems [4].

1.1.3 C-band

The range of C-Band is between (4-8) GHz and C band is mostly used by satellite communications, especially for TV broadcasting transmissions and feeds. C band usually used in the areas that’s close to the tropical line like far Asia where the heavy tropical rain will interfere higher frequency signal like Ku band signal , because C band signal is less affected by rain fade than Ku band [2].

1.1.4 X-band

The range of X-Band is (8-12) GHz this band is mainly used by the military especially in radar applications but also the X-band is used in civil, military and government applications such as tv broadcasting, weather forecast, and for air traffic control and vehicle speed detection. And it has many advantages like not been affected by weather conditions and its high throughput which make it very suitable to be used to send HD videos, voice and Data [5].

We should know that the design of our antenna will be for X band applications and it will use this frequency range.

1.1.5 Ku-band

The uplink range of KU-band is around 14 GHZ and the downlink range is between 10.9-12.75 GHZ, and This bandwidth has high transmitting signal level as compared to C-band satellites [6]. Ku-band satellites have 30 cm smaller antenna size than C band antennas. This significant reduction in antenna size lowers the cost of the equipment and simplifies the system installation. Ku band is Used for satellite communications and most of Tv Broadcasting channels work on this band, Astra, Hotbird and Turksat is some of the satellites that operate using this band frequencies.

1.1.6 Ka-band

The uplink range is 26.5-40 GHz and the range of the downlink is 18-20 GHZ. This band is usually been used for the military network and for two-way consumer broadband. The antenna of Ka band can be much smaller from the other bands antennas and the range could be between 60 cm to120 cm in diameter. And at the same time if we compare the Transmission power in Ka band with C, X or Ku band beams we will see that its much higher for the Ka Band. lastly because of this band high frequencies, it can be more vulnerable to the rain fade effect. In the figure 1.2 we can see the relation between frequency ranges and its affection to rain fade [7].

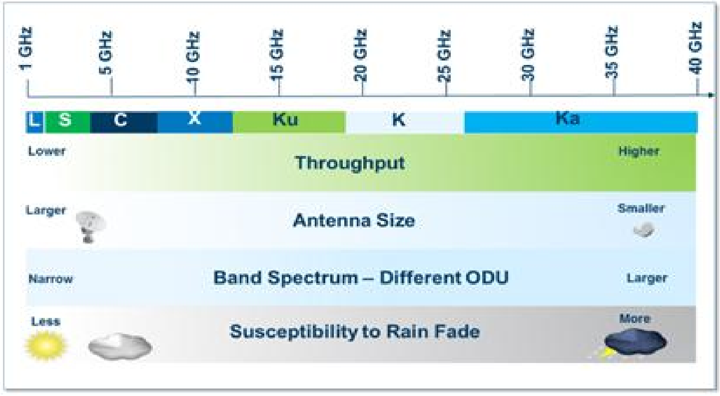

Figure 1.2: Satellite frequency bands and rain fade effects.

1.2 Satellite TV Broadcasting System

As we mentioned before that there is many applications that use satellites and we will focus on one of this applications which is TV Broadcasting system and as any application it consist basically of earth station (the transmission part) where the signal is processed to be ready to be sent to the satellite is consisted of the following equipment which each one of it responsible to do a specific rule and the general diagram of Tv broadcasting system is shown in the figure 1.3 [8].

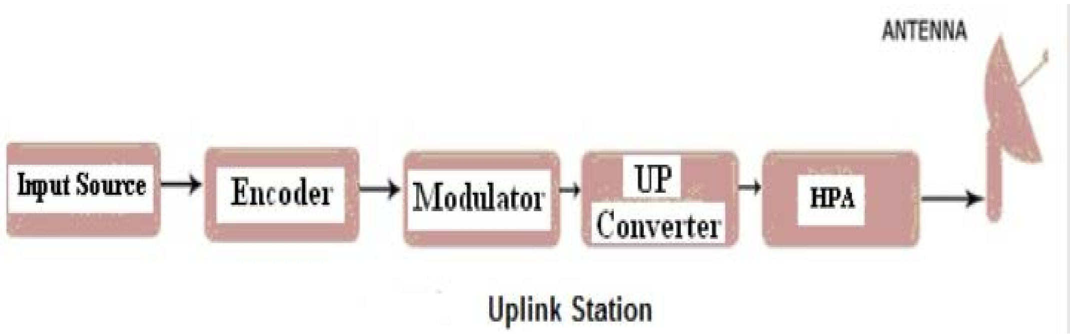

Figure Hata! Belgede belirtilen stilde metne rastlanmadı.**1.3:** satellite broadcasting stages

1.2.1 The input source

It's the source where we want to take the material from and broadcast it through the satellite system. This input source could be a camera or a video player or a streaming device [8].

Figure 1.4: Input source of uplink system

1.2.2 The encoder

Where the first stage of image and audio processing is being done and it will be encoded and transferred to a format that could be send via the satellite and at the first stage the image and the audio will be transferred from the analog format to the digital format separately as the figure 1.5 shows the diagram of the signal processing in the encoding phase and how it’s been processed separately and then multiplex it [9].

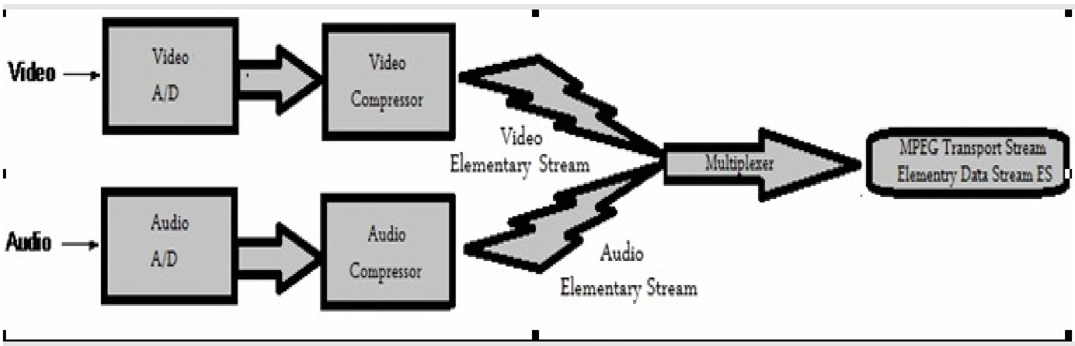

Figure 1.5: Signal encoding stages

Then both audio and video compressed separately to form packetized video and audio stream,the packet contain the desired date to be send then all these packets been collected and added to a timestamp to have the same order which help to reform the information correctly in the receiver and the local oscillator is as it shown in the figure 1.6 [9].

The most important phase of data processing is data encryption to send encrypted signal and the video compression and the most used compression formats are MPEG2 and MPEG4.

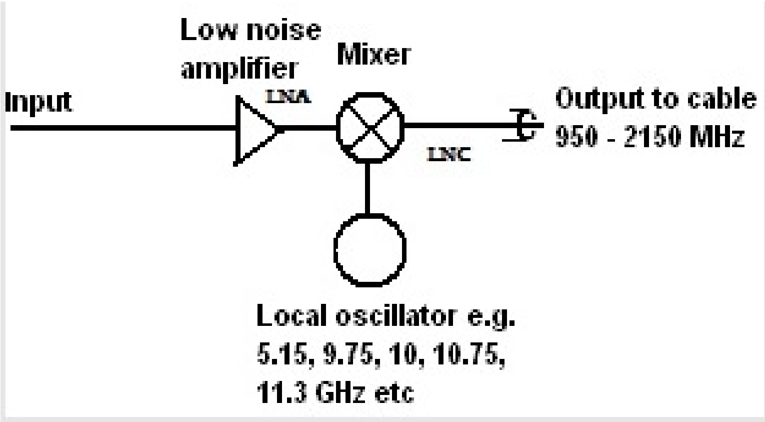

Figure 1.5: Encoding local oscillator system

1.2.3 The modulator

Where the information packets that's coming from the encoder being mounted on the carrier frequency to be sent to the satellite.

The output of the encoder called ASI stream which stands for (Asynchronous serial interface) and each packet has 188 bytes of information and the modulator add to each packet 16 byte, so the total size of each packet will be 204 bytes this process called Reed Solomon.

And we use this RS bytes to discover the error and correcting it during the transmission phase.

The output of the modulator is an L band frequency signal that should range between 950-1750 MHZ [10].

The most techniques that used in mounting the signal on the carrier frequency are QPSK and 8PSK and the difference between then is shown in the below figure 1.7 which demonstrate how the information been mounted on the carrier signal [11].

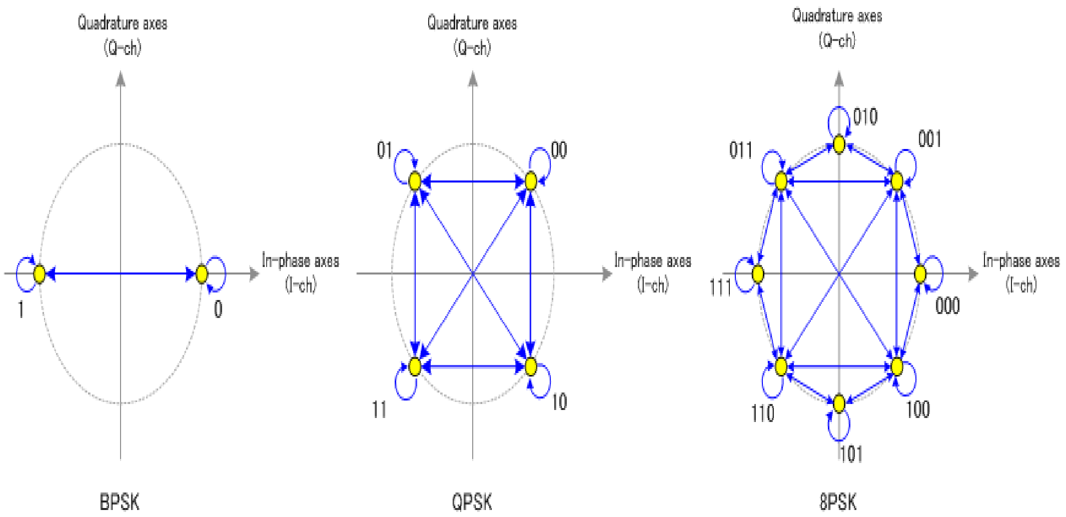

Figure 1.6: QPSK and 8PSK modulation

1.2.4 BUC & HPA

BUC is a block upconverter which convert from lower frequency range which is in our case L band the output of the modulator to a higher frequency range as KU band or C band [12].

Usually block Up-convertor use a phase locked loop (local oscillator) to maintain transmitting the correct frequency and isolate it from the interferences and to do that it requires a frequency reference which is going to be 10 MHZ.

The desired new frequency will be guided to the input of the (HPA) the high-power amplifier and from there to the antenna to be sent to the satellite after the signal have the enough power for a satellite transmission. And an example for the HPA with BUC connected to the antenna is what shown in the figure [12].

Figure 1.7: Satellite HPA, LNB and Antenna

1.2.5 The Antenna

It’s one of the most important equipment within every transmission system, as we can’t send or receive the signal without having well designed antenna. And each application requires a specific type of antennas. So, in the next chapter we will discuss the antenna definition and study its types and the most important parameters of analyzing and designing an antenna in the next chapter.

2. THE ANTENNA AND İTS SPECİFİCATİONS

2.1 Antenna Definition

The antenna is an equipment that defined by Webster's Dictionary as a usually metallic device for example a wire which will forward and receive the radio wave and as it mentioned in the IEEE documentation as a method for the radio wave radiating or receiving [13], and with a simpler definition we can define the antenna as the specialized equipment that make conversions between alternative current and radio wave [14].

We could consider the antenna as the transmission medium between the free-space and the guiding equipment's, and as it shown in Figure below. The guiding device which we can name it as the transmission line. And this transmission line could be designed as a waveguide (hollow pipe) or a coaxial line, that been used to send the electromagnetic signal to the antenna from the transmitting source or on the opposite direction from the antenna itself to the receiver. And here we should be very careful of not having loose in the signal because during the sending the signal through the waveguide is a very sensitive phase. So, we should note that we have an antenna to transmit the signal and on the opposite side we will have a receiving antenna to be able to receive the signal as the figure 2.1 show us the electrical circuit of the antenna function [15].

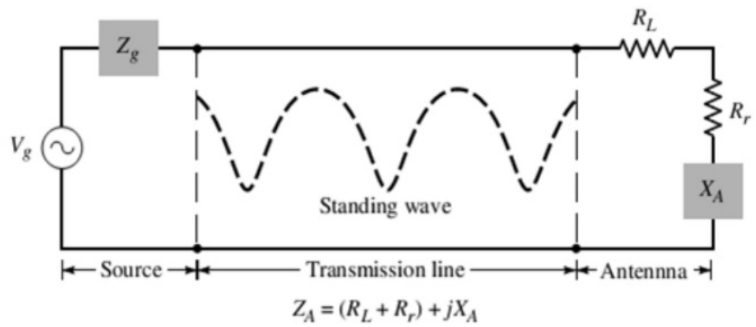

Figure 2.1: The antenna circuit

But we must know that Receiving and transmitting the energy is not the only function that antenna does. That’s because the antenna is an advanced wireless system which means that it will be responsible to *adjust* or to *accurate* the radiation power in certain directions and at the same time will block this radiation on other directions. So, we can see that the antenna is not just working as a signal transmitting unit but also a directional device at the same time to send the radiation in a desired direction. And for the antenna to be able to meet the system requirements it could take different shapes such as a single wire antenna or a single patch antenna or an array of patch antenna, or horn antenna, parabolic antenna also it could be an aperture antenna, yagi antenna or it could be many other shapes [15].

We need to know that in wireless or satellite communication systems, all the component is very important within this system because each unit do a specific rule, but without the antenna we can send any signal to the space. For that a good and practical design of the antenna can simplify the system requirements and also it will result in a better effectuation. As an example, simplifying the TV systems transmission system which could be improved by using smaller and more flexible moving antenna with a high performance at the same time. And that is what we will focus on in this research.

Over the last six decades the major aspect of the communication uprising in our life was the revolution in the antenna technology. And now all communication systems demanding an antenna that have special characters to serve this system in the best way. For that lets have a look of the antenna types that’s used today.

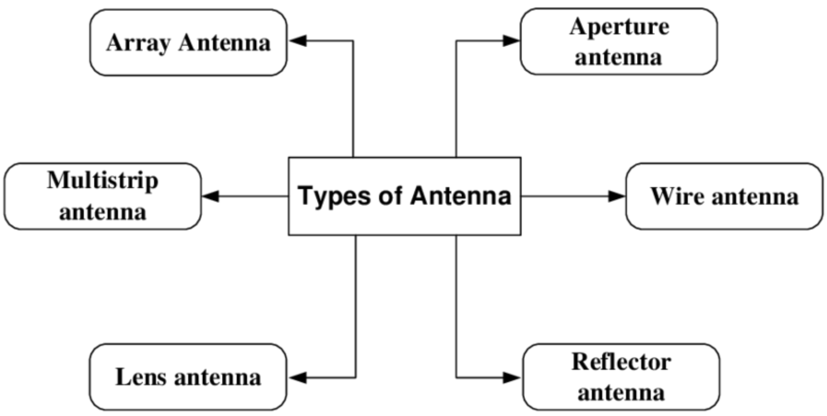

Figure 2.2: The antenna types

2.2 Antenna Types

We will talk and describe briefly the antenna types and the special characters to each type and in which systems are preferred to be used in. as sown in the figure 2.2 [16].

2.2.1 Wire antenna

Usually the wire antenna is made of copper wire or by etching metal wire on rigid substrate. Which indicate that they are not useful or suitable for applications that demanded high flexibility. we could find many shapes of the wired antenna and a few examples of it are the short dipole antenna, monopole antenna and the loop antenna which they could be used in automobile ships crafts and inside the buildings as it shown in the Figure2-3 [17].

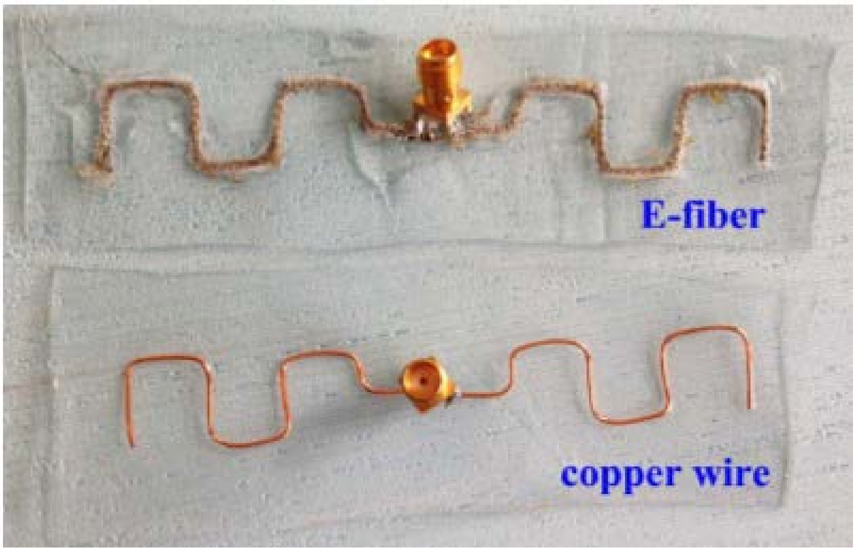

Figure 2.3: Wire Antenna

2.2.2 Aperture antenna

They take the shape of horn which its edges could be circular or square or any other configuration, they are familiar with space application because they have a high gain around 20DB and they could be placed on the outside surface of the aircrafts and their open face (side) could be painted with dialectical material to protect them from the antenna surface environment conditions. the figure 2.3 shows the most used designs of the aperture antennas [15].

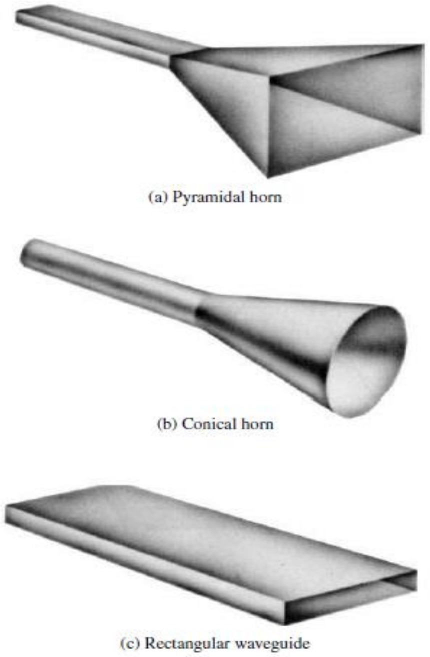

Figure 2.4: The types of aperture antenna

2.2.3 Reflector antenna

The reflector antenna is been used so much in the radar application, tv broadcasting, satellite tracking and space discovery. There are three shapes for reflector antennas (plane, cornered, curved), and example is what we can see in the Figure 2.5.

Figure 2.5: The Reflector (parabolic) antenna shapes

It has the reflector name because the microwave beam will be gathered on the metallic surface and then reflected to the feed horn on the case of the receiving antenna, while on the other hand if it’s a transmission antenna then the wave beam will be directed from the horn feed to the surface to reflect to the outside space [15]. As we can see in the figures 2-6 and 2-7 how the signal reflects from the feed to the reflector in case of signal transmitting and from the reflector to the feed in case of receiving the signal [15].

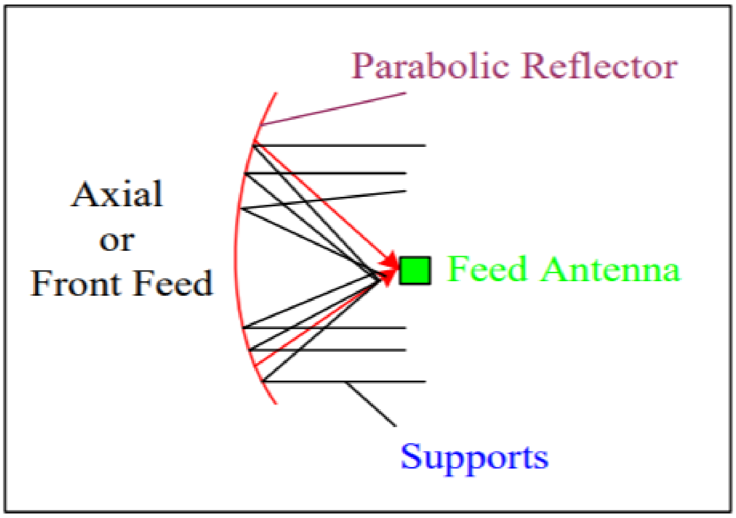

Figure 2.6: The plane reflector and the parabolic reflector antenna

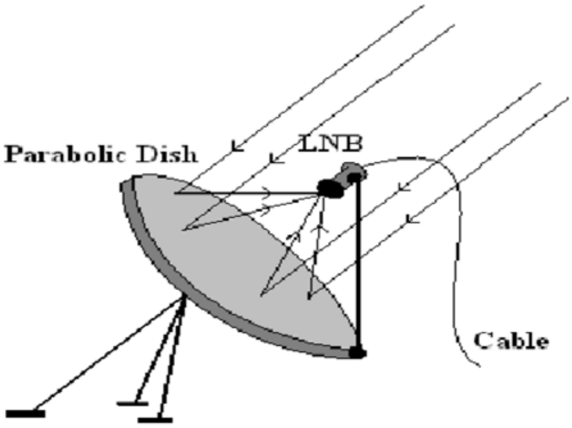

Figure 2.7: The plane reflector and the parabolic reflector antenna

2.2.4 Microstrip antenna

Is one of the most antenna model that's been used these days, and the patch antenna technology is developing rapidly this antenna type has another name which is the printed antenna that's because this antenna is made of a radiated metallic piece (patch) which is printed or attached on a dielectric material also it's called as dielectric substrate and on the bottom side of the dielectric substrate attached a ground patch that will be separated from the upper patch with the dielectric substrate , this radiated patch could be designed into many configurations and shapes, the most used shapes are the circular and the rectangular patch as they are shown on the figure below [16].

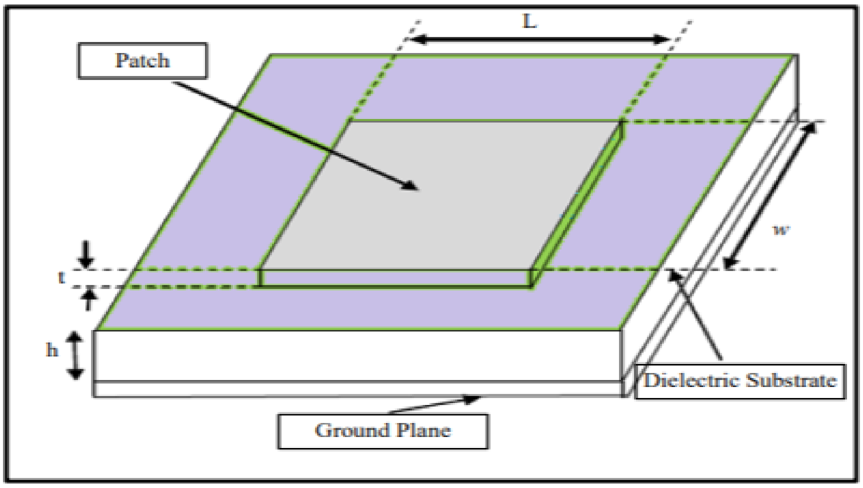

Figure 2.8: The Shape of the microstrip patch

Microstrip antenna (printed antenna) is characterized by its shape, Dimensions as its width, length and substrate thickness, the gain and the directivity and the antenna input impedance are major factors of the antenna character and efficiency [18]. in this thesis we will design a microstrip antenna to use it for X-Band Applications, so we will study more about the microstrip antenna specification and advantages later in the third chapter.

2.3 Antenna Parameters

We will explain and discuss the antenna parameters that characterize the antenna and give the antenna its specifications that sort each type of antennas to a special field of usage and more than that it could allow the same sort of antenna with a little bit of difference to be used in different applications. The antenna parameters that we will talk about are the following:

2.3.1 Radiation pattern

The antenna radiation pattern could be defined as the representation of the antenna characteristics graphically as function of spatial coordination, and this radiation pattern states that how well is the antenna in receipt energy from space or in transmitting the energy to the space.

As the antenna radiate energy in every direction, so that is why antenna pattern in real is a 3D dimensional which usually defined with two planner pattern this is known as the principle plane patterns and the radiation pattern is usually calculating in DB and in the radiation patterns we have many direction of the energy radiation its known as the radiation loop which we will explain them now, meanwhile the figure 2.8 shows the spectrum shape of the antenna with the antenna radiation pattern with the antenna radiation lobes [15].

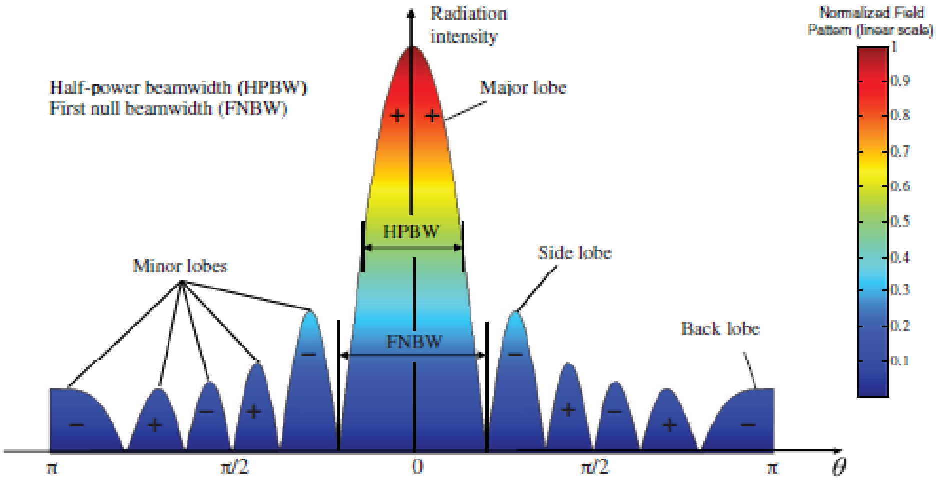

Figure 2.9: Antenna radiation pattern

2.3.1.1 Lobes of the radiation pattern

In antenna radiation there is a main radiation energy direction and there is as we can see in the figure 2-10 some little side radiation directions its known as the lobes of the radiation and it categorizes as:

2.3.1.2 Main (Major) lobe

The main radiation lobe of the antenna is where the major of the antenna radiation is directed and the percentage and the shape of the major lobe define other important parameters such as the antenna directivity and the antenna gain as we will see later [15].

2.3.1.3 Side lobes

Are the loops that appear in undesired directions (different directions than the main lobe).

2.3.1.4 Minor lobes

It's the same case as the side lobes and these lobes should be minimized because it causes noise to the major lobe radiation because of its undesired radiation direction to the main lobe. and the following figure 2-10 shows how does the main lobe looks with the side lobe and the minor lobes.

2.3.1.5 Back Lobe

As we can see it Is the loop that located in a180-degree angle with the main radiation lobe so this lobe should be decreased to the lowest possible value to not effect the main radiation direction of the antenna [15].

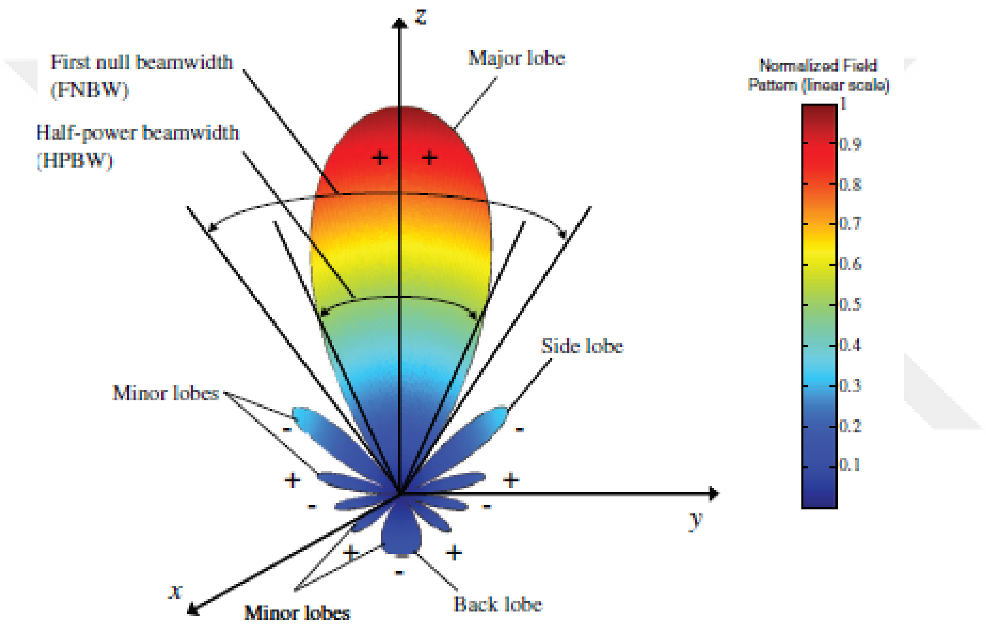

Figure 2.10: Antenna radiation lobes

2.3.2 The return lose (S11)

While we design our antenna the return lose result will be one of the major parameters to check to analyze our antenna efficiency, so the antenna return loss is the measurement or the factor that will that indicate how much power is consumed or lost in the load and did not reflect back, when we first defined electrically the antenna circuit we mentioned the standing waves that will be created when there is unmatching issue between the transmission line and the antenna. So, in this case what will declare how good the match is between the antenna and the transmission line is the antenna return loss. Which will be calculated and measured by using the decibel unit [19]. To understand the return loss calculation let’s assume that we have S11 equals to 0, which indicate that the power is reflected from the transmission line to the antenna. so, to have a good signal transmitted from the transmission line to the antenna that we can see that S11 have to be less than -10 DB to have the estimated antenna efficiency. in the figure 2-10 we can see an example of the return loss for an antenna and as we can see that its around -38 DB.

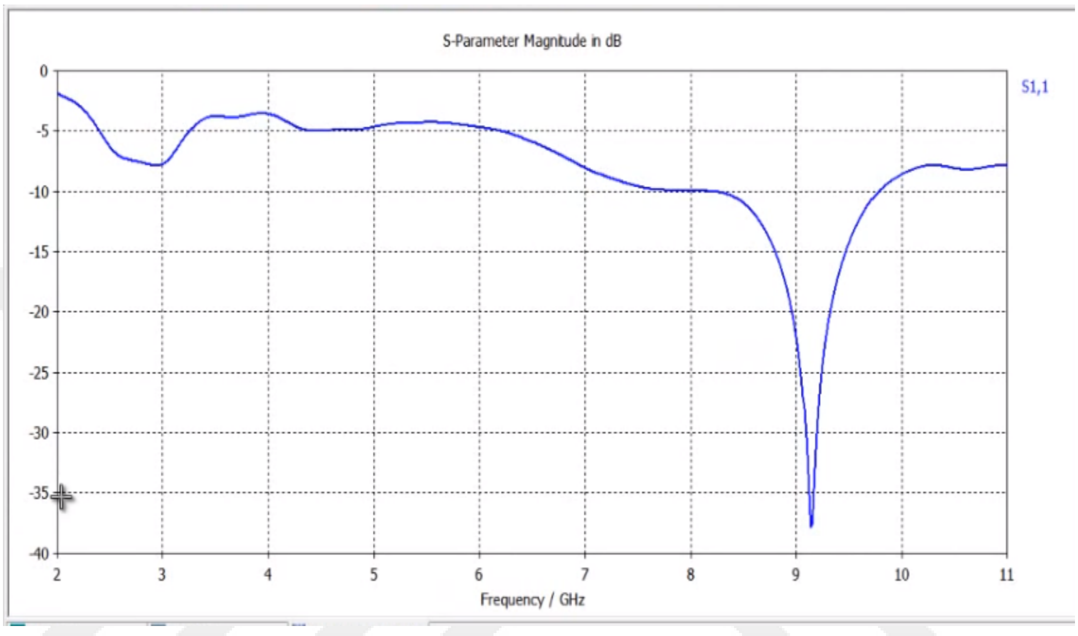

Figure 2.11: The return loss of an antenna.

2.3.3 VSWR

The voltage standing wave ratio or VSWR is ratio of the maximum to the minimum voltage on a loss-less line.

while we are using the antennas for transmission in the practice life there should be a loss on any transmission line, so we must detect the forward and reserve power to be able to calculate the VSWR and the equation to calculate it is [20]:

$$\mathbf{VSWR} = \frac{1+\Gamma}{1-\Gamma} \tag{2.1}$$

when we calculate the VSWR we should always get a positive value so the smallest possible value of the voltage standing wave ratio is 1 which mean that there is no power reflected from the antenna which is the ideal situation in a medium that have 0 losses, while the value of VSWR could be ∞. the most effective antenna is the antenna that has a value equal to less than 2 and getting closer to the value of 1 and that its better because that means the impedance matching between the transmission line and the antenna is very small and that the antenna receives most of the transmitted power [19].

Based on what we discussed we find that there is a strong relation between the S11 values and VSWR values for that lets compare the values of VSWR and the amount of power that the antenna is receiving in the below table [20].

Table 2.1: The Relation Between VSWR and S11 Values

VSWR	S11	Reflected power %	Reflected power DB
1.0	0.000	0.00	∞
1.5	0.200	4.00	-14.0
2	0.333	11.1	-9.55
15	0.875	76.6	-1.16
50	0.961	92.3	-0.35

2.3.4 Directivity and gain

To talk about Antenna directivity let's start with the Isotropic antennas which are theoretical point sources that spread electromagnetic energy in all directions equally. and in isotropic antenna the total radiated power is calculated by integrating the power flux density over the surface of a sphere of radius r that surrounds the antenna

$$\text{Surface Area}=4\pi r^2 \quad (2.2)$$

The disadvantage in the isotropic antenna is when the radiation will spread further when the distance from the transmitting antenna will increase, therefor the surface area of the antenna radiation will increase commensurately with the square of the radius of radiation area. So, in this case the antenna will spread the radiation in all the surrounding directions evenly to cover the increasing larger area, which will cause the density of the electromagnetic power to decreases commensurately with the square of the distance from the antenna [15]. For that if we see the below figure we will see the difference between the antenna that have good main radiation lobe that’s directed to specific direction and the isotropic antenna that will radiate equally to all its surrounding sphere.

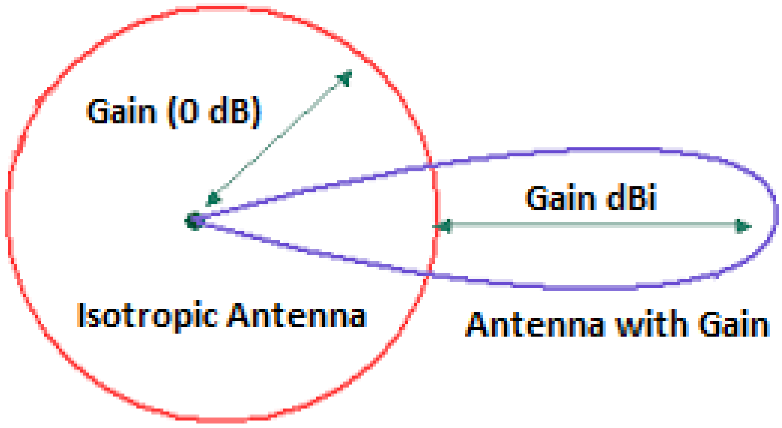

Figure 2.12: The gain of isotropic and directive antenna

Because the power density of an isotropic emitter decreases rapidly with distance we need to control the directivity of the energy that's radiated from real antennas which will increase the power density in desired directions and reduce it in other directions.

Directivity: is the ratio of the power density or how directed is the antenna radiation pattern in its most concentrated direction to that of a theoretical isotropic emitter of the same total energy of transmission level.

$$D=10\times Log10(\text{actual antenna isotropic antenna}) \quad (2.3)$$

We should know that upon to the antenna directivity characteristics the antenna could be in different applications:

- Low-directivity antennas transmit to all surrounded directions and receive the data from all directions more or less equally. this characteristic is very practical for the mobility applications in which the direction between the sender and the receiver is changeable. And the signal receiving could be from any direction like the mobile applications.
- High-directivity antennas are able to transmit and receive signals over a greater distance, but to be able to do so the antenna should be directed towards another antenna which called line of sight connection. Like the antennas that used in the satellite television. Where the antenna radiation is directed to a specific point in the space and with the smallest movement of the antenna the connectivity between the antenna and the satellite will drop directly.

2.3.5 Bandwidth

The antenna bandwidth is a crucial parameter in the antenna, and it show the range of frequencies that the antenna will transmit with the estimated properties, and there is a direct relation between VSWR and the antenna bandwidth, more precisely the antenna bandwidth is the frequency range where VSWR value is less than 2. Also, it is very important to know that the antenna bandwidth term is different than the signal bandwidth where the signal bandwidth indicate the size of the frequency range that used for the signal transmission.

2.3.6 Polarization

In the electromagnetic wave the electrical field of this wave determine the signal polarization by selecting the plane that the electrical field will spread in [21].

More over the signal polarization is very important factor for antennas and radio communications in general. And specially if we are talking in the tv broadcasting systems. Because usually antennas are very sensitive to the signal polarity and usually only transmit and receive the signal with a specific polarization. And it is important to match the antenna Rf polarity with incoming or outgoing radio signal polarity because if they were cross polarized with the antenna then the signal will not be received by the antenna . We have two kind of wave polarizations and it’s as it shown in the figure 2.10 they called linear and circular polarization [16].

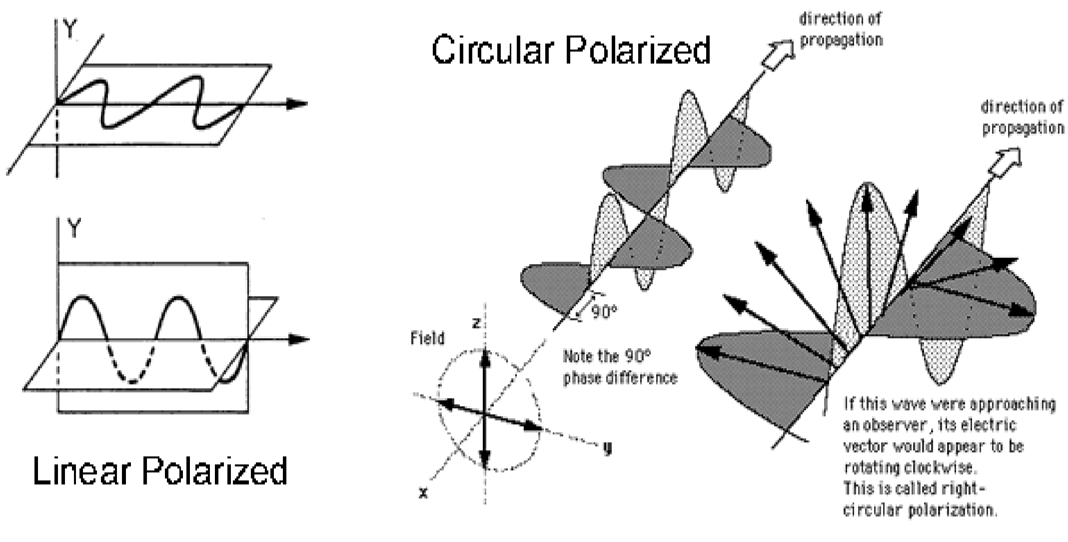

Figure 2.13: Polarization types

2.3.6.1 Linear Polarization

it is defined when electromagnetic wave polarization in which the electric vector at a fixed position in the space remains pointing at a fixed direction although varying in the magnitude. There is two defined types of the linear politization [15]:

<u>Vertical polarization:</u> in which the electrical field is in vertical (orthogonal) direction to the earth surface.

<u>Horizontal polarization</u>: where the electrical field of the electromagnetic wave is analogous with the earth surface.

Both polarities could be used at the same moment with the same frequency, but they will be in opposite transponders in the satellite and they could be found in C-band and Ku-band. We can see the vertical and horizontal polarity drawn in the figure 2-14 [22].

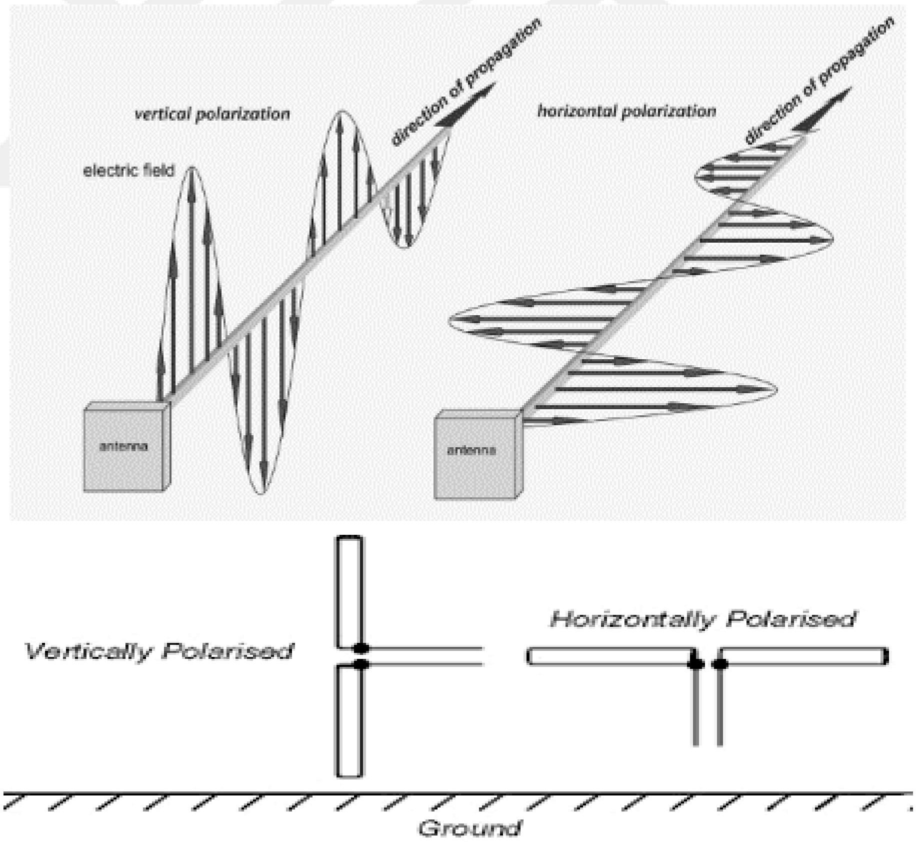

Figure 2.14: Linear polarization vertical and horizontal

2.3.6.2 Circular polarization (CP)

Is the second main type of signal polarization and to get a circular polarization there should be two orthogonal components of electric field (linear component) in addition that those two components should have the same magnitude, but they are 90-degree time phase shifted from each other [23].

And to understand the concept of having two linear component that have ninety degree shifting let's have a look at the figure 2-15 which also show relation with the direction of the propagation [24].

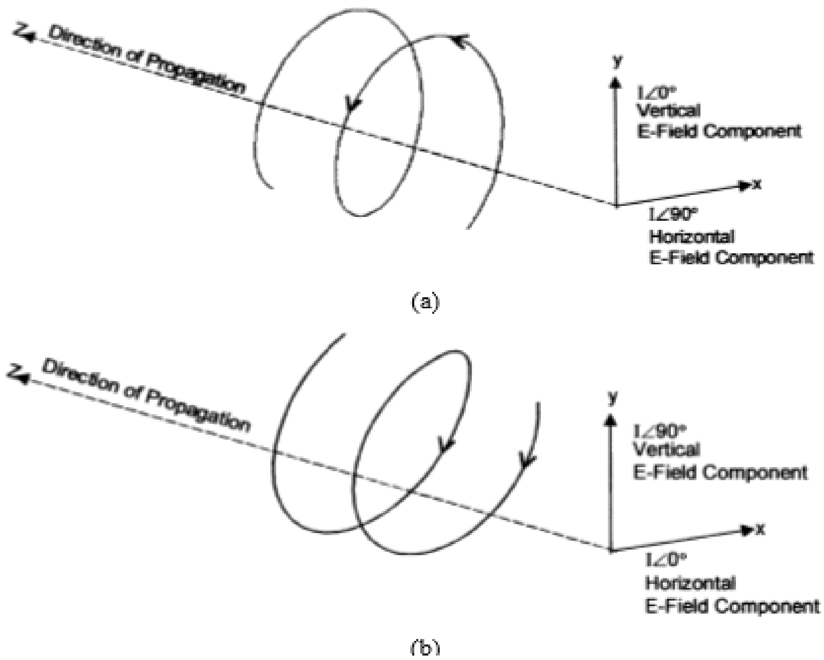

Figure 2.15: Draws of circular polarization.

In Circular polarization antennas we could have many important advantages if we compared it to linear polarized antennas which made the circular polarized antennas a vital technology in the recent wireless communications applications for example the mobile telecommunications and the satellite communications.

The CP antenna hs proved to be a good method in resisting the multi-path interferences or fading and use it as an advantage and that's happening when the signal reflects a polarization shifting will be caused for this signal and these reflections could be from any surface type, and then two types of reflection would happen which are LHCP reflection and RHCP reflection. The LHCP antenna will reject the reflected RHCP signal, so that's will reduce the multi-path interferences from the reflected signals [25]. And by RHCP we mean right hand circular polarization and with LHCP we mean left hand circular polarization which are the two circular polarization types.

Figure 2-16 will show us a summary for all polarity types in the linear and the circular polarization signal.

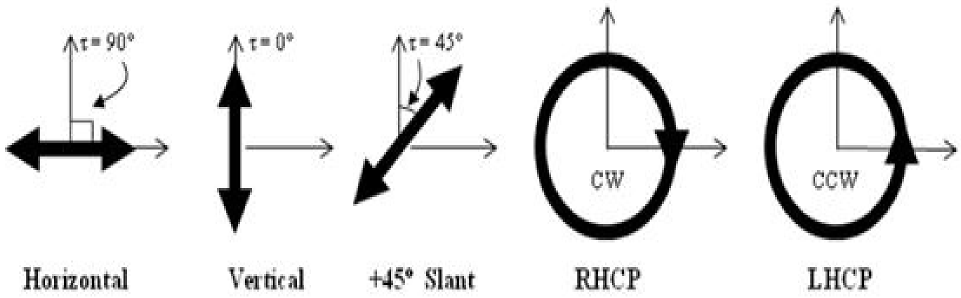

Figure 2.16: All types of the antenna polarization

3. MİCROSTRİP ANTENNA

3.1 Introduction

The microstrip antenna was first introduced by Deschamps in 1953. but it took till 1970 to be developed and that’s when the electrical circuit evolution took a place and helped to achieve designing light and effective patch antenna. Starting from 1970 the patch antennas had been used in the military sector and been integrated with the rockets and aircrafts, and that showed that microstrip antennas suitable to been used in many movable application [26].

The microstrip antenna has many advantages, for example its low fabrication cost, plus its light weight, small size in addition to that the fabrication of the microstrip antenna with the desired design is not complicated and that’s by using the printed circuits. All these advantages were the reason that this type of antenna is being used these days in several types of applications such as mobile phones, GPS devices, remote sensing and direct broadcast satellite [27].

In this section we will discuss the structure of the microstrip antenna in the feed methods of this antenna in addition to its advantages and disadvantages.

3.2 Microstrip Antenna Structure

As we discussed in the previous chapter that the microstrip antenna is made of a radiated metallic piece (patch) which is printed or attached on a dielectric material also it’s called as dielectric substrate and on the bottom side of the dielectric substrate attached a ground patch that will be separated from the upper patch with the dielectric substrate.

The microstrip antenna and specially the radiated patch and the ground slot could be designed in many different shapes and placed in different configurations its all up to the target of this antenna and upon to that it will be designed in the way that will give the best possible results for that we can see different geometric shapes for the patch from the simple square or rectangular patch to more complicated shaped that will include slots and many adjacent small patch configurations.

And as we said the purpose of the antenna is the major factor of the microstrip antenna design and dimensions.

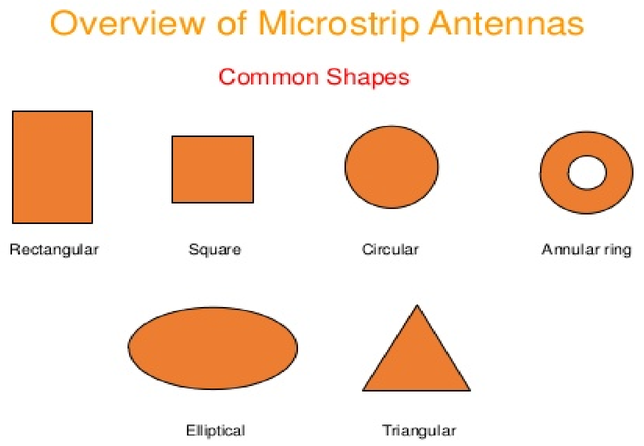

Figure 3.1: Common Shapes of The Patch Antenna

Now lets talk about the material the usually this antenna is made of and let's start with the radiated patch mostly it made of a very thin layer of corrosion resistance material for that copper is one of the most used materials as a radiating patch while the substrate that as we can see the below figure will separate between the two patches and will be the source of the mechanical support for this antenna by retain the required space between the two faces and an example of the substrate material are FR4 and Roger4003C and the common aspects pf this materials that they come with high dielectric constant to give a stability in antenna performance. When we need to do a more complicated shapes Nickel is one of the material that could use to do the slots in the copper patch [28].

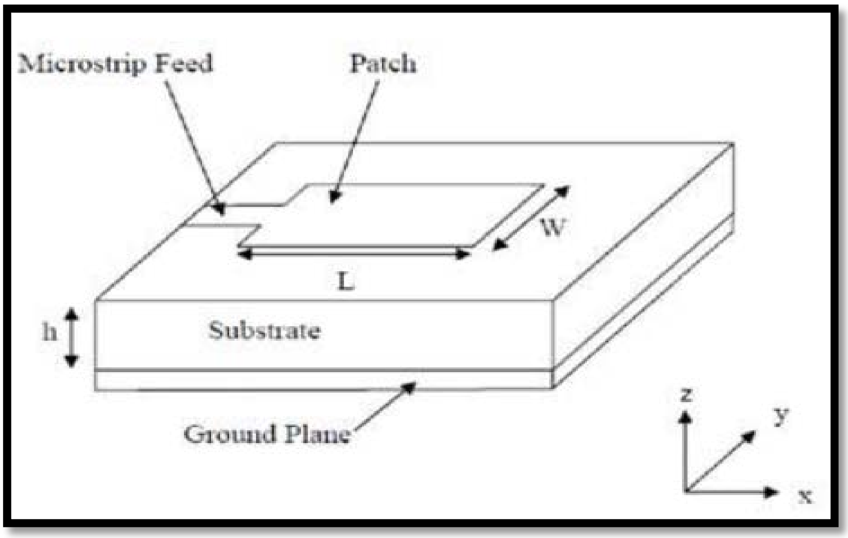

Figure 3.12: The microstrip patch

There are many factors that could affect the microstrip efficiency, and these factors are: the radiation efficiency, the desired frequency, return loss and the directivity [29]

and we can calculate the width of the patch [30]:

$$W=\frac{v0}{2fr}\sqrt{\frac{2}{\varepsilon r+1}} \quad (3.1)$$

and the length of the antenna will be [29]:

$$L=\frac{1}{2f_r\sqrt{\varepsilon_{reff}}\sqrt{\mu_0\varepsilon_0}}-2\Delta L \quad (3.2)$$

and ΔL is equal to [31]:

$$\Delta L=0.412H\,\frac{(\varepsilon eff+0.3)\left(\frac{w}{h}+0.246\right)}{(\varepsilon eff-0.258)\left(\frac{w}{h}+0.8\right)} \quad (3.3)$$

and finally, ε_{eff} calculated by [32]:

$$\varepsilon_{eff}=\frac{\varepsilon r+1}{2}+\frac{\varepsilon r-1}{2}\left(\frac{1}{\sqrt{1+12\frac{H}{W}}}+0.04\left(1-\frac{w}{H}\right)^2\right) \quad (3.4)$$

3.3 Microstrip Antenna Advantages and Disadvantages

As we mentioned earlier the low fabrication cost, and light weight with the small size; and most importantly the ability to control the design and the shape is the general advantages of the microstrip antenna that put it to be the first choice of antenna types in many applications but as every antenna there is some disadvantages of the microstrip antenna but the principle key is that these disadvantages could be minimized thanks to using new techniques in the patch configuration and in the feeding method [26].

3.3.1 Microstrip advantages

- Microstrip is light in weight and could take a small place.
- They could be attached to the host surface.
- Low fabrication cost and design flexibility.
- Microstrip support liner and circular polarization.
- They could be used in personal communication devices
- Microstrip antenna allow multiple frequency operation

3.3.2 Microstrip disadvantages

- Lower power gain
- Narrow bandwidth
- Polarization impurity
- Extra radiation caused from the antenna feeds and junctions

3.4 Microstrip Feeding Techniques

One of the most important aspect in antenna designing is how to plan or draw the feed of the patch antenna and its importance come from its effect on the antenna polarity and the antenna input impendence in addition to the overall antenna effectivity.

We can feed the microstrip with two technique directly and indirectly, and the difference between these two options is that when we feed the microstrip directly its done by using a connecting element like using coaxial probe [33] or by using a microstrip line [34], while on the other hand when the feeding is indirectly there will be no metallic medium to connect the feed line and the patch and there two ways to apply this feeding either by using the proximity coupling [35] or by using the aperture coupling [36].

3.4.1 Coaxial probe feeding

As it illustrated in the below draw the conductor of the coaxial feed will have two layers one from the inside and the other is from the outside, while the inside layer will penetrate and extends within the substrate to reach the radiating patch at the same time the outside side layer will be connected to the ground patch.

The positive point of this method is that the feed line will be located inside the patch and with this location it will match its input impedance. But the disadvantage of this method is that it can’t be done without penetrating the substrate layer by making the connecting hole in addition to the narrow bandwidth in the probe feeding [28].

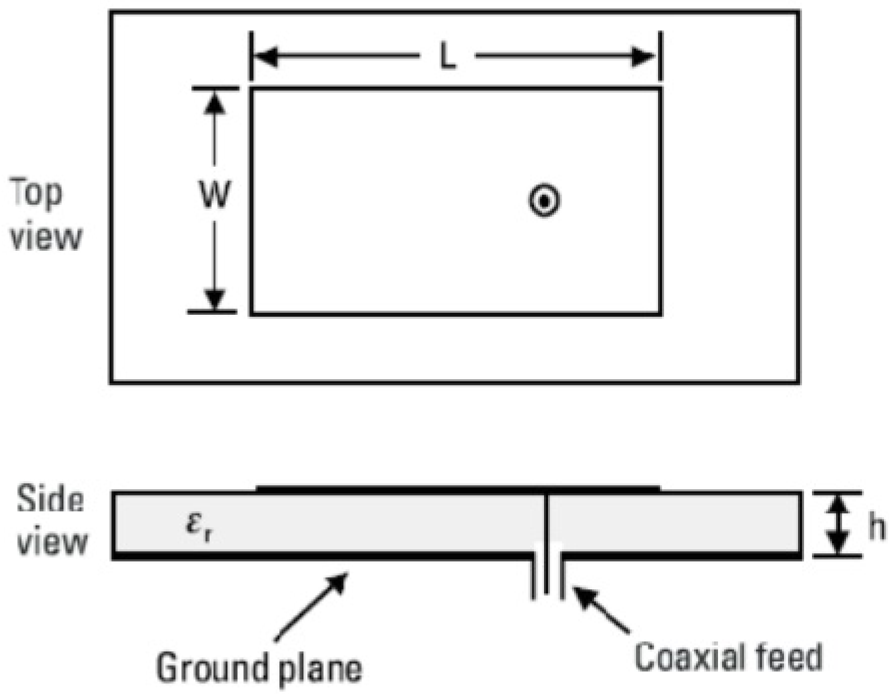

Figure 3.3:: Microstrip coaxial feeding

3.4.2 Microstrip line feed

Using this method, the antenna feed will be attached directly to the microstrip patch border, which mean that the impedance of the feed line should be matched with the edge impedance for maximum line transfer.

The advantage of this method is that the antenna feed will be attached with the antenna patch on the same side (the upper side) of the substrate, so it will provide a planer structure.so the fabrication will be easier [28]. In our designed antenna we will use the line feed method as we will see later.

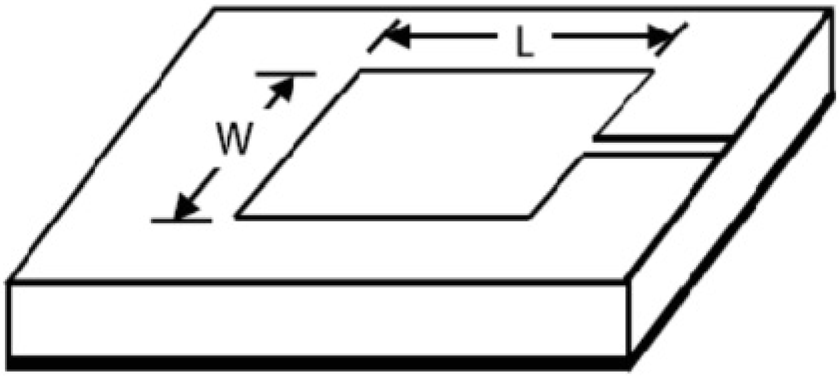

Figure 3.4: Microstrip line feed

3.4.3 Aperture coupled feed

In the previous two methods we were explaining the directly feeding methods now we will start with the indirect methods of feeding the patch which is the aperture feeding. With this method and because we said its indirect method so the feed line and the patch layer will be totally separated than each other and this separation will be done by the ground slot which also will be laid between two separated layer of substrate, and as it illustrated in the figure 3-5 by making a hole or an open space in the ground slot we can arrange the indirect coupling between the feed line from under the ground slot and the radiated patch from the upper side of the ground slot and the substrate.

A lower cross in the polarity is one of the major advantages of this technique for that the coupling between the feed and the patch should be in a centered area within the patch and because the ground slot will be laid between two separated substrate we can in this case has the advantage of using two different types of the substrate materials. Each material for a substrate which will help to get an optimal efficiency and performance from the antenna [37].

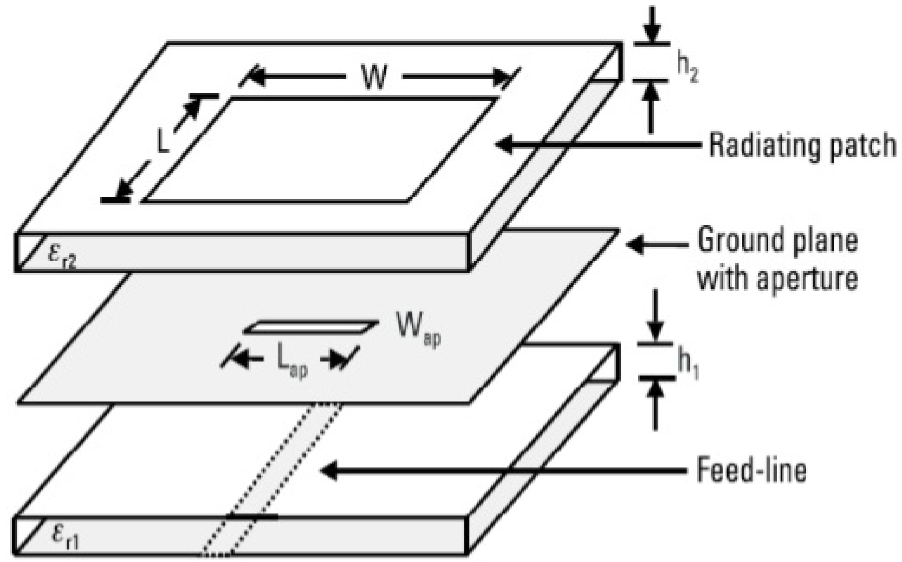

Figure 3.5: Aperture coupled feed

3.5 Microstrip Patch Array Antenna

After explaining the specification of the patch antenna and as we mentioned before that single patch antenna has few disadvantages and one of the useful methods in overcome these disadvantages is by designating an array antenna which is consists of more than one single radiated patch or several patches that's connected between each other to form a single patch antenna mounted on a the same pieces of substrate, and the purpose of that is to obtain a better designed and more efficient radiation pattern and directivity and at the same time suppress undesired radiation direction, and these characters helped to design antenna to be applied in more advance application like the satellite communication and higher frequencies applications [37].

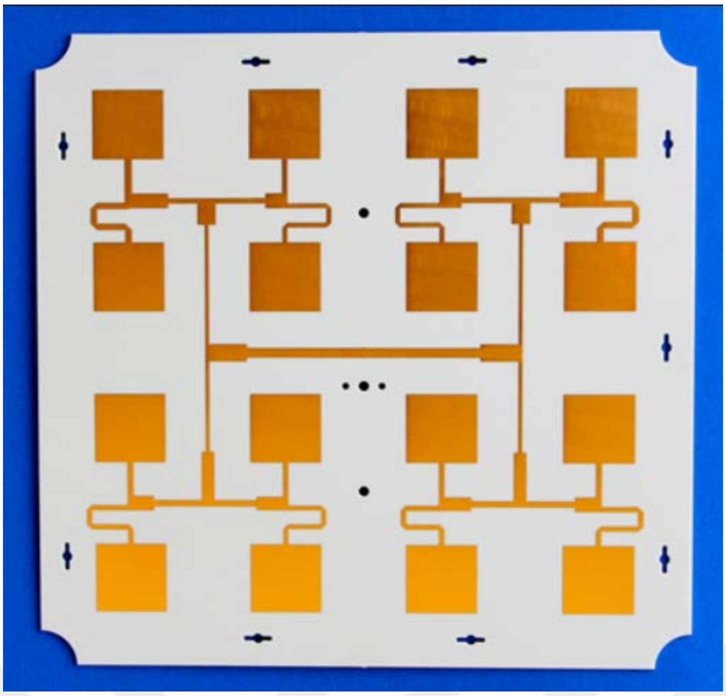

Figure 3.6: Example of microstrip array antenna

3.5.1 The advantage of the array antenna

As we mentioned before the array antenna is used in more advanced applications because of the ability to design a desired application requirements and specifications, so let’s count some of these advantages:

1. increase the antenna gain and provide enhanced radiation beam.

2. eliminate or decrease the interference from undesired directions.

3. provide diversity reception.

4. maximize the signal to the inference noise ratio SINR.

3.5.2 Microstrip antenna feed design

We have two critical aspects in the array antenna which are the single element design and the feed connectivity between this elements, and the feed connectivity could be done by using two ways either continues feed connectivity or parallel feed connectivity and this connectivity method usually its been chosen upon to the application purpose of this array antenna.

3.5.2.1 Series (continuous) feed

The patch elements will be placed parallelly and a single continues feed line will connect these elements identically from the same point and there will be one path of the power to the elements as it shown in the figure 3-8 and a small amount of power will enter to each single patch and each single patch could be coupled to the next element by probe or aperture or proximity coupling.

The series feed has two classification which are transposed and un transposed. The advantage of the series feed is having better antenna efficiency than the parallel feed, but the negative side is having a narrow antenna bandwidth [37].

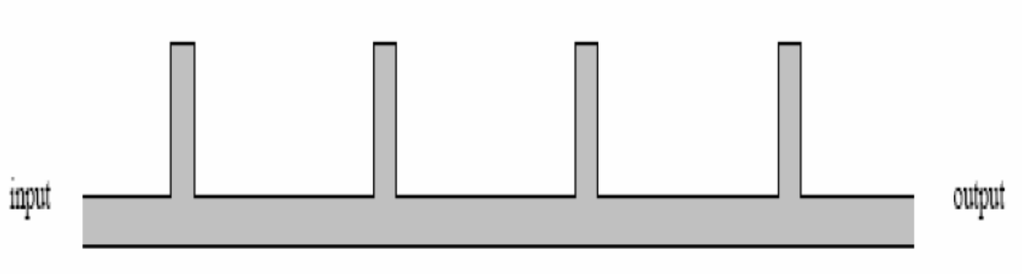

Figure 3.7: Series feed method example

3.5.2.2 Parallel feed

In this method we will have a single power input and then the power will be distributed into parallel feed lines, and each one of these feed lines will either being divided into parallel feeds or each one of it will end in a single patch element. The common shape of parallel feed lines usually has a one directional network as it shown in the figure 3-9 and its important to know that if the distance from each patch element to the input source is identical then the power will be divided equally between these elements.

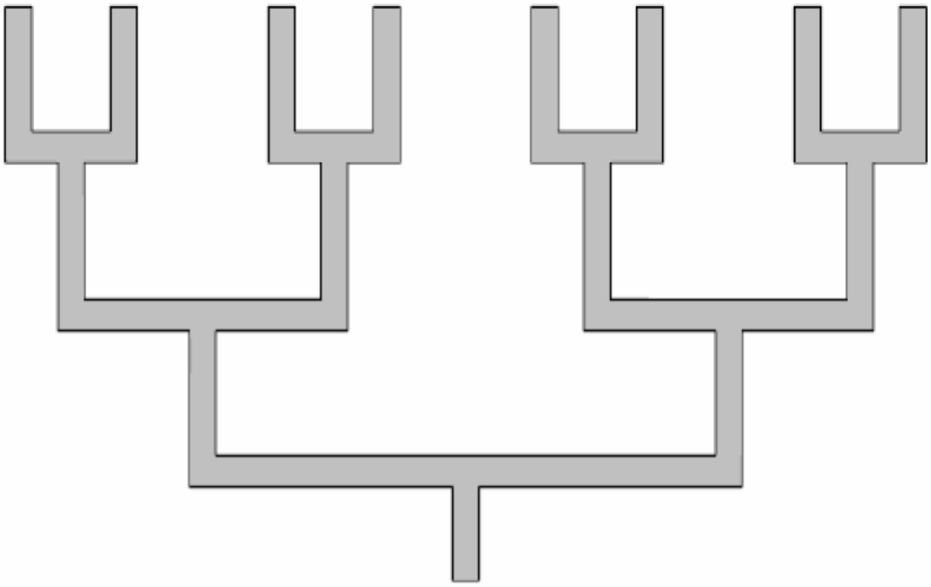

Figure 3.8: Parallel antenna design

In the following chapter, we will design a single element of microstrip antenna to be used in X-band applications and we will explain the steps that we did, and the material that we used in the antenna and we will see which microstrip feeding technique from what we discussed in this chapter we will use. and finally we will analyze the antenna parameters that we studied in the second chapter and compare our antenna results with some other designed antennas.

4. THE PROPOSED WORK

4.1 Introduction to the Proposed Antenna

We have many applications to be applied on X-band frequencies, and Tv Broadcasting Systems is one of the most used application in the satellite communications and antenna science, and in far Asian side and the tropical areas the C-band is mostly used as we discussed in previous chapter due to the tropical weather conditions and in the other areas the Ku-band has been used for tv broadcasting, what we will do is using the high range of X-Band frequencies.to be suitable for Patch antenna and because we need a new solution for when the Ku-band is on high demand of transmissions and there is no available capacity. Usually reflector antenna is the only type on antennas that been use in the tv channels specially that the gain of the reflector antenna is around 30-40 DB, but the printed monopole antenna could be a good alternative or backup solution because of the advantages we discussed before and for our work its very suitable because of its small size and its mobility.

In this thesis we discussed the basics and the advanced techniques of the tv broadcasting systems and we discussed the frequencies bands then we explained and spoke about the different antenna types to be able to continue in depth study about the omnidirectional microstrip antenna and its advantages to be used for our desired frequency range, and it’s important to know that we choose this frequency instead of C band to not get affected with other WLAN frequencies in addition to the negativity in using C-Band that we discussed in first chapter. It’s important to know that to get excellent antenna gain using microstrip antenna we have to use array antenna, so for that our work is to design a simple element of this antenna which a have good values to be used later in the array antenna. Finally, we used CST studio software to design and analyze our antenna [38] [39].

4.2 The antenna Shapes and Geometric Measurements

In the below figure 4.1 we have two sections view of our antenna a top section and a bottom section which shows the substrate and the designed patch. and in our design, we used a double face patch to be able to uplink using a frequency from our estimated range.

The substrate is build using Rogers RO4003C material which is a glass reinforced hydrocarbon/ ceramic laminates designed for high volume commercial application [40] and this material is designed to offer a superior high frequency range performance and comparing to the FR4 material RO4003C fabrication cost is by far cheaper than the FR4 which considered also as an important specification. Also, it has a low dielectric tolerance and loss which gave it the excellent performance in the high frequencies. It should be known that this material is used in satellite broadcasting LNB which we spoke about in previous chapter also in Microstrip and cellular base stations. relative permittivity $\boldsymbol{\varepsilon}r$ = 3.55, and the dielectric loss tangent is $\boldsymbol{\delta}$ = 0.0027 [41] the size of our designed antenna is 40*38*1.524 mm^3 which means that the width of the antenna is 40 mm and the length is 38 mm and the antenna thickness of the substrate is 1.524 mm. the patch will consists of main rectangle part adjoint by smaller rectangular parts to form two notches from both sides on upper face of the substrate to operate effectively on the higher estimated frequency and to give us mush enhanced impedance bandwidth [42] while on the ground face of the substrate we have a rectangle patch and a rectangular slots had been cut from it we will explain why we did it while we are explaining the steps and the results. The radiating patch will be feed with 50Ω and our designed antenna is shown in the figure 4.1

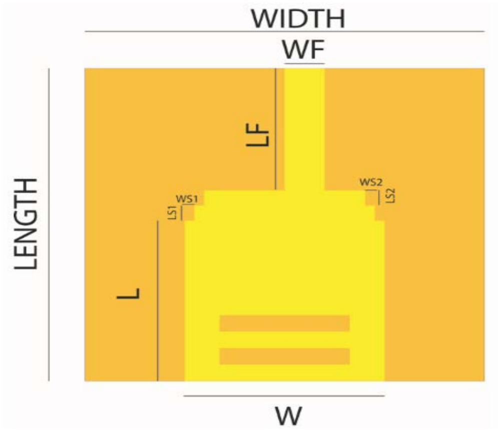

Figure 4.1: The designed antenna geometric sections

Al the parameters that shown in the figure 4.1 are listed in the table 4.1.

Table 4.1: The Designed Antenna Dimensions

Parameters	Values (mm)	Parameters	Value (mm)
Sub Width	40	WF	4
Sub Length	38	LF	16
Sub high	1.524	WS1	1.5
W	20	LS1	1.5
L	19.5	WS2	1
WC	3.8	LS2	1
LC	2.7	Mt	0.1
LS3	2	WS3	13
LS4	2	WS4	13
WG	38	LG	16
WG1	4.5	LG1	10
WG2	4.5	LG2	10
WG3	4	LG3	0.5

And in the table 4.2 we will find the measurement units that we used in our simulation

Table 4.2: The Measurement Units

Dimensions	Mm	Voltage	V
Temperature	kelvin	Current	A
Frequency	GHZ	Resistance	Ohm
Time	NS	Capacities	F

and we will have in our design one input port, so we will focus our study on S11 parameter from the S parameters and to explain more the port is any place where we can deliver current and voltage to the antenna. The width of our port will equal to 6WF and as we defined WF is width of the feed line, and the high of the port is (5h+mt) again h is substrate high and mt is high of the ground plane.

4.3 Antenna Designing Steps

In the first step we attached the patch to the upper face of the Roger substrate as it shown in Figure 4.3 which shows the upper face of our antenna, and we designed the upper face with 2 notches from the left side and from the right side to have enhanced impedance matching and that the side notches affect the electromagnetic coupling between the rectangular patch and the ground plane [43]. we can see the first stage step in the figure 4.2.

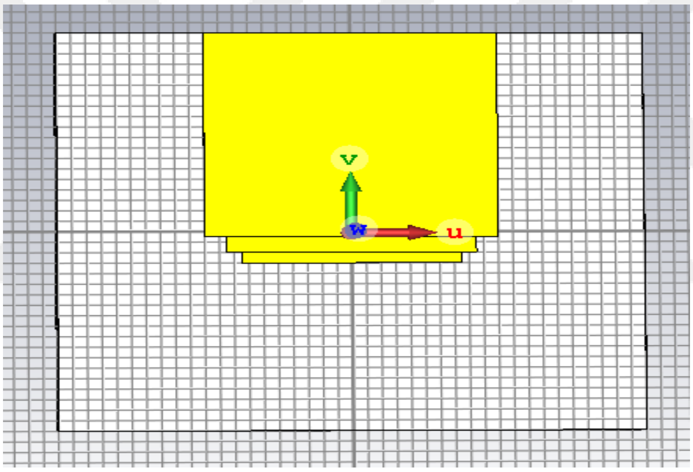

Figure 4.2: Shows the upper sketch of the designed antenna

After that and when we start testing the antenna we added rectangular cuts in the upper patch to reduce the patch size which will improve the current distribution [44] and we will see it in the figure 4-5. Attached to upper patch is the feed that will be fed with 50 ohms, in the figure 4.3 we can see the patch shape with the S11 result of the current design and as we mentioned before the feed of the antenna is printed on the top side of the substrate to attain the ohm characteristic impedance [44]. And the ground patch is attached to the opposite side of the substrate in the side of the feed and it shown in the figure 4.3

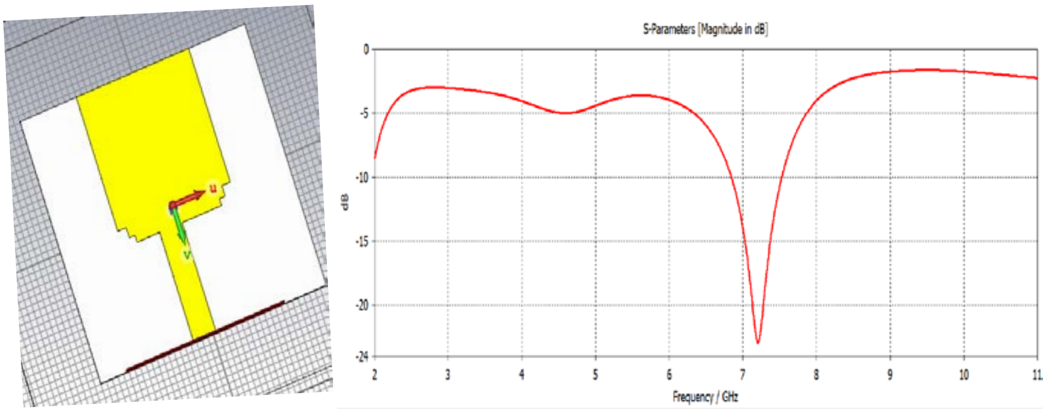

Figure 4.3: The bottom sketch of the antenna

In the next step we added a rectangular patch to the ground slot from the feed side to have a better efficiency on the X-band range frequencies [42] as it shown in the figure 4.4 we can see the current design and a better result for our desired frequency.

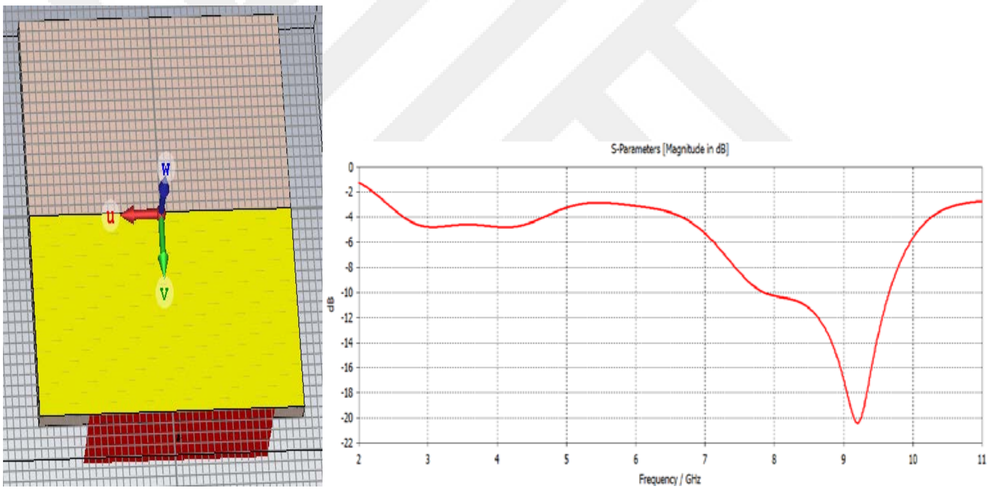

Figure 4.4: The ground patch of the designed antenna

Till here we start having a good result but it wasn't the best result that we were looking at so we start refining the design and did the following steps to Ensure much better result so we did a rectangular cut in the ground patch and this cut is under the feed patch and the purpose of this cut is to remove the inductive nature of the antenna patch and will help increasing the bandwidth range by producing resistive input impedance [45], then we analyzed the current distribution in our patch and accordingly we did two rectangular slots in upper surface as we mentioned before and the same in the ground patch which helped us to inhance the antenna gain from around 6 DB to be 8.5 DB at the last step that we did is that we made the ground slot patch width less than the upper patch width shape of the antenna ground face and we see the improved result of S11 parameters and how it show a very good result at our specific frequency.

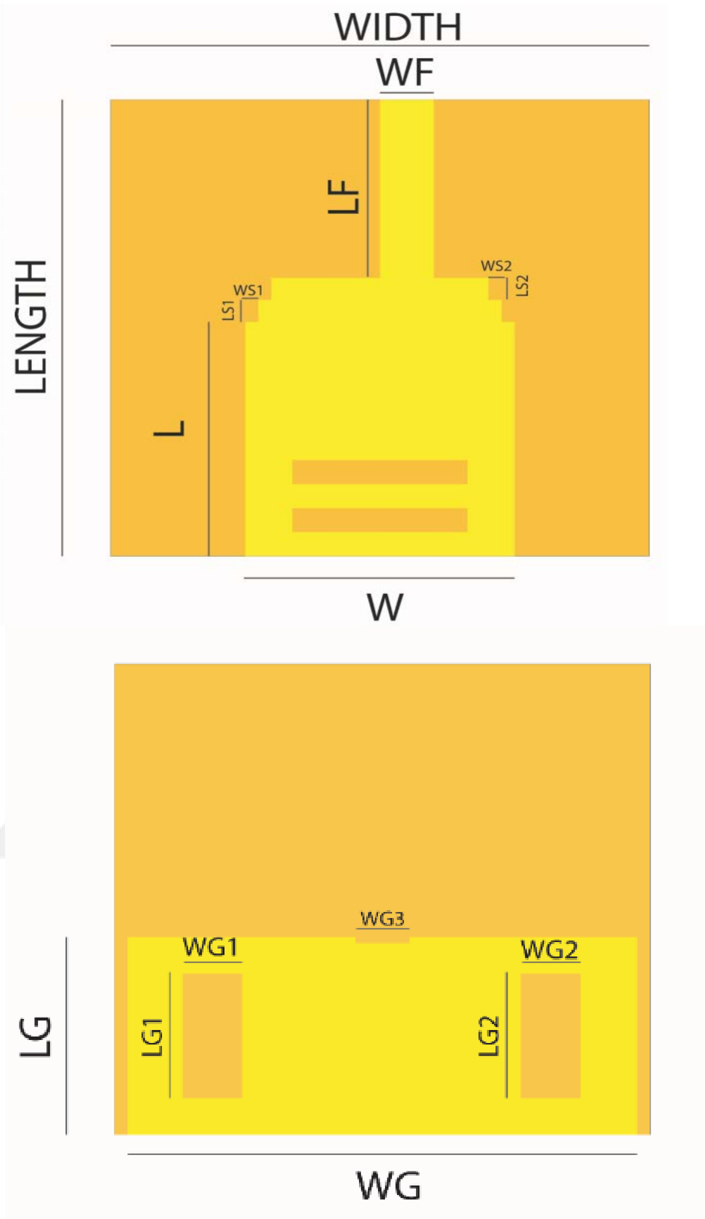

Figure 4.5: The Final design of the antenna

4.4 Antenna Simulation Results and Discussions

In this part we will show and explain some of the important characteristic of our designed antenna such as: Return loss (S11), VSWR, antenna gain, and the radiation pattern and we will compare the results of our antenna with the antenna result on other frequencies and see the difference in the efficiency.

4.4.1 Antenna return loss (S11)

As we discussed before the Antenna return loss is one of the major parameters to check our antenna efficiency, so the antenna return loss is the parameter that show how much power is consumed or lost in the load and did not reflect, so the return loss (S11) shows how good is the match between the transmission line and the antenna. But it is important to know that because we just have 1 port in our design we are interested in analyzing S11, if we had more than 1 port for example 2 port in this case we must analyze S12, S21, S22 in addition to S11, so back to the S11 its value must be less than -10 DB to have the estimated antenna efficiency. In the below figure 4.6 we can see the return loss for our designed antenna on the desired X-band frequency range that we designed our antenna and that in this range the S11value will be less than -10 DB which will prove the efficiency of our design for X band applications.

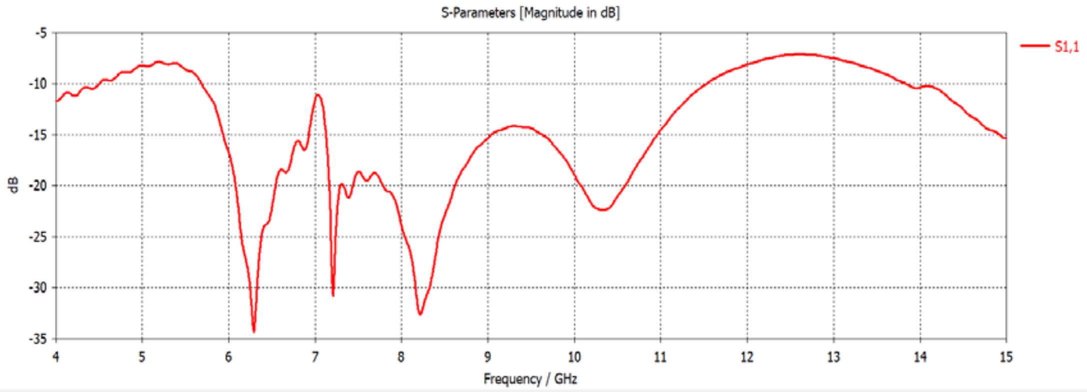

Figure 4.6: S11 of the designed antenna

Moreover, earlier when we were designing the antenna we were calculating the return loss and if we compare the current result to the results that we got in the figures 4.7 we will see the huge improvement that we reached.

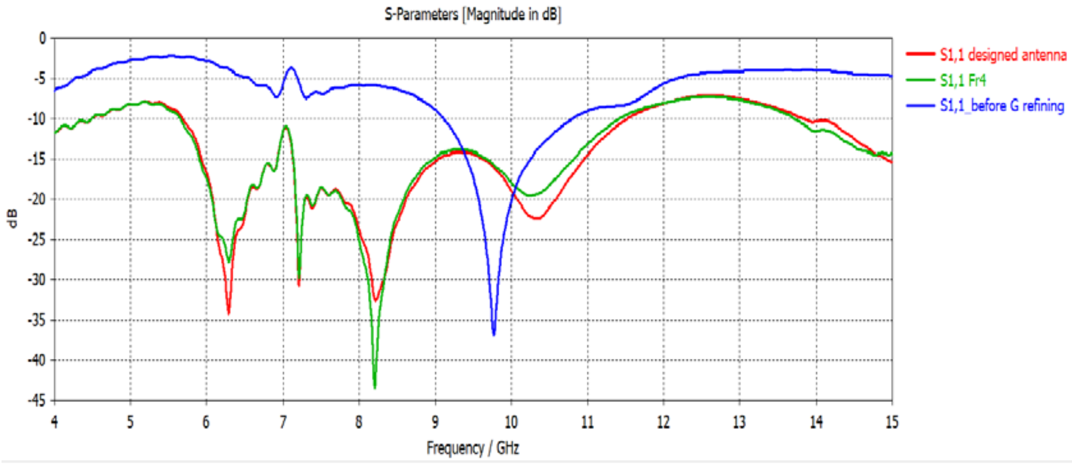

Figure 4.7: S11 results comparison

So, if we check S11 value that we reach before refining and editing the Ground slot with cutting the side edges and give resize the length of it we can see that we got a very narrow S11 response. And that the new changes helped with improving the electromagnetic coupling between the upper patch and the ground slot [46] and we can see that our S11 result is better when we use Rogers RO4003C for the substrate instead of using FR4 as Rogers RO4003C specification are more suitable for X band frequencies than the FR4.

let's Also see the figure 4.8 where we can see the antenna reference impedance and how its value is constant on 50 Ohm.

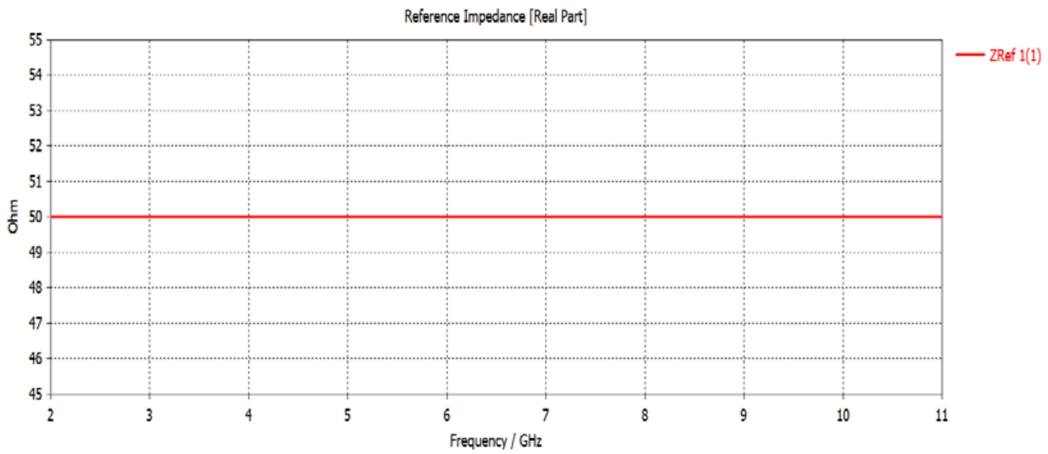

Figure 4.8: The Antenna Reference impedance

4.4.2 Voltage standing wave ratio

While designing any antenna we have to be careful that the antenna impedance is very important factor to minimize the impedance mismatch loss (where the feeding power will be reflected back to the power source instead feeding the antenna and the antenna will not radiate) so to determine how well the antenna is matched with the transmission line we analyze The voltage standing wave ratio or VSWR because its calculate the ratio of the maximum to the minimum voltage on a loss-less line. As we discussed in a previous chapter that we must detect the forward and reserve power to be able to calculate the VSWR and the equation to calculate it is:

$$\text{VSWR} = \frac{1+\Gamma}{1-\Gamma} \qquad (4.1)$$

So, when we calculate the VSWR we should always get a positive value, so the smallest value of VSWR is 1 which means no power is reflected from the antenna which is the ideal situation in a medium that have no losses in the transmission line and for example if VSWR equal to 3 that means 75 % of the power is delivered to the antenna, while the value of VSWR could be ∞. the better antenna is the antenna that has the smaller value of VSWR because that means that the impedance matching between the antenna and the transmission line is very small and that the antenna receive most of the transmitted power and as we see on the figure 4.9 that the VSWR value in our antenna is less than 2 from 5.7 GHZ till almost 11.8 GHZ while outside this range the VSWR value is more than 2 which mean that this antenna will not be operational outside of this range, and if we check the value curve in the same figure we will see the VSWR value in our desired frequency will get closer to the value of 1 which mean that there is almost no power reflected from our antenna which also show the efficiency of this antenna design and also that mean this design require the minimum power to send the signal as the reflected amount of the signal power is very low.

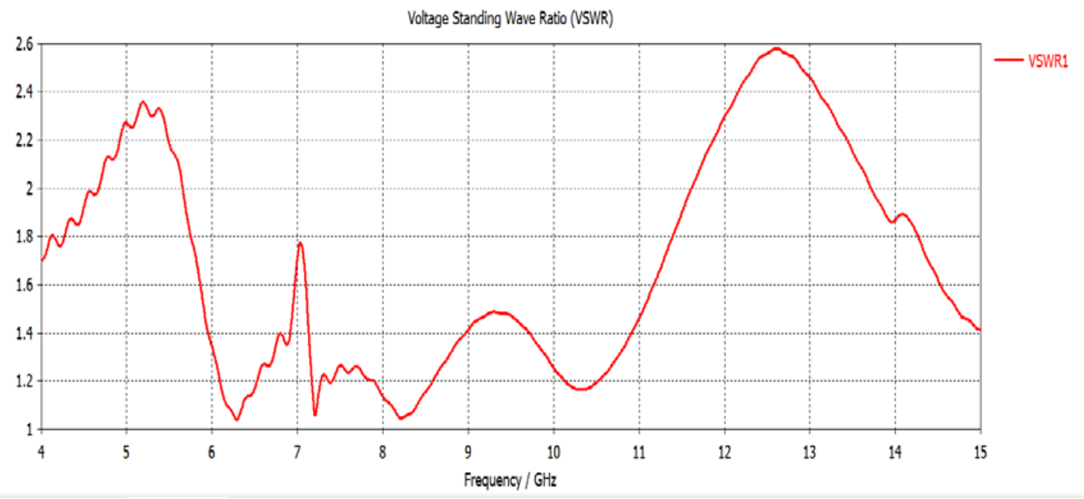

Figure 4.9: VSWR of our designed antenna

And as we did while we were analyzing S11 let's compare the VSWR results in the main steps of our antenna design till we reach the last statues.

As we can see in the figure 4-10 that in the beginning before refining the design of the ground slot we had a barrow bandwidth impedance which was between 9-11 GHZ and this small range will not allow us to use our antenna in many X Band application but after the cut of the Ground slot the bandwidth impedance has been improved and we gained a wider bandwidth. Also, when can see that changing the material from Fr4 to roger RO4003C gave us wider and more stable bandwidth impedance.

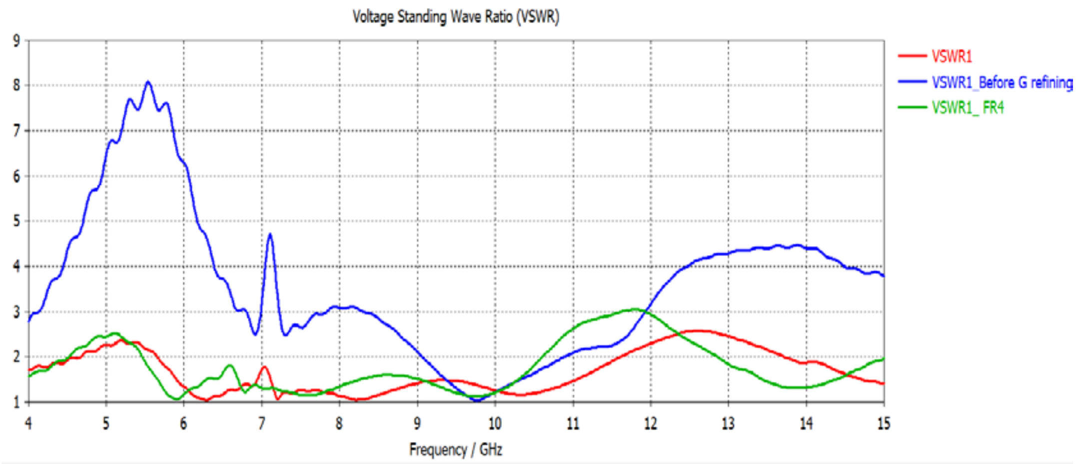

Figure 4.10: VSWR Results Comparison

4.4.3 The antenna radiation pattern and directivity

We measured and compared the radiation patterns for more than one case, first one is for the antenna while its operating on X-band frequency that will be used for Tv Broadcasting between 10.5-12 GHZ , and we will explain and show the other cases step by step to see the improvement in our work and it's important to note that we took Phi=0 and Phi=90. So, in the figures 4-11 and 4-12 we can see the radiation pattern for our final design of the antenna and we can read the statistics to see the ideal main lobe value the side lobe

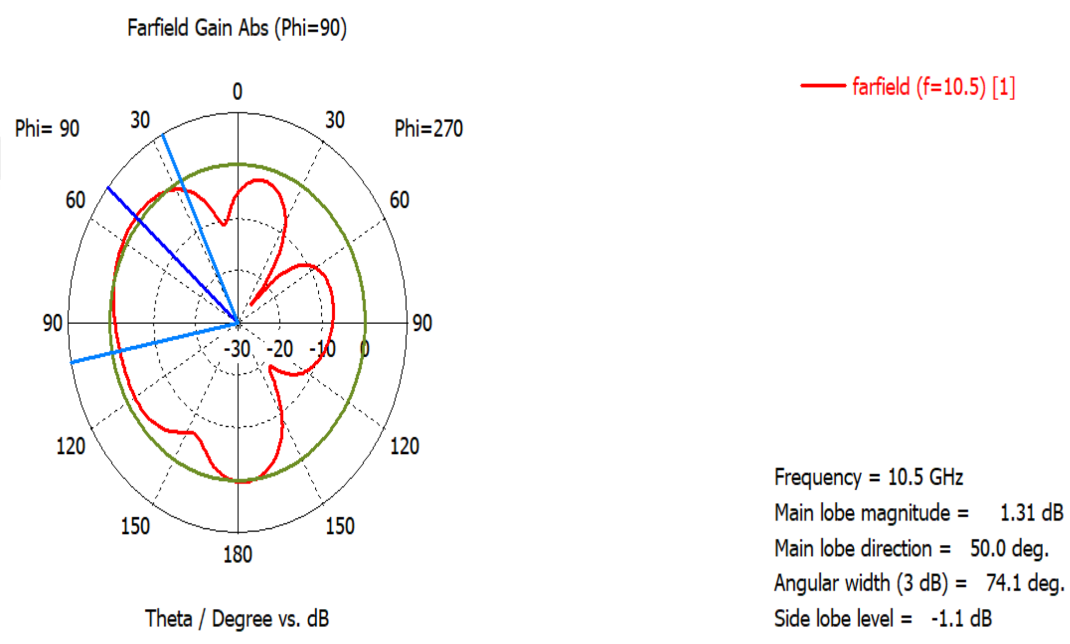

Figure 4.11: 1D radiation pattern on 10.5 GHZ

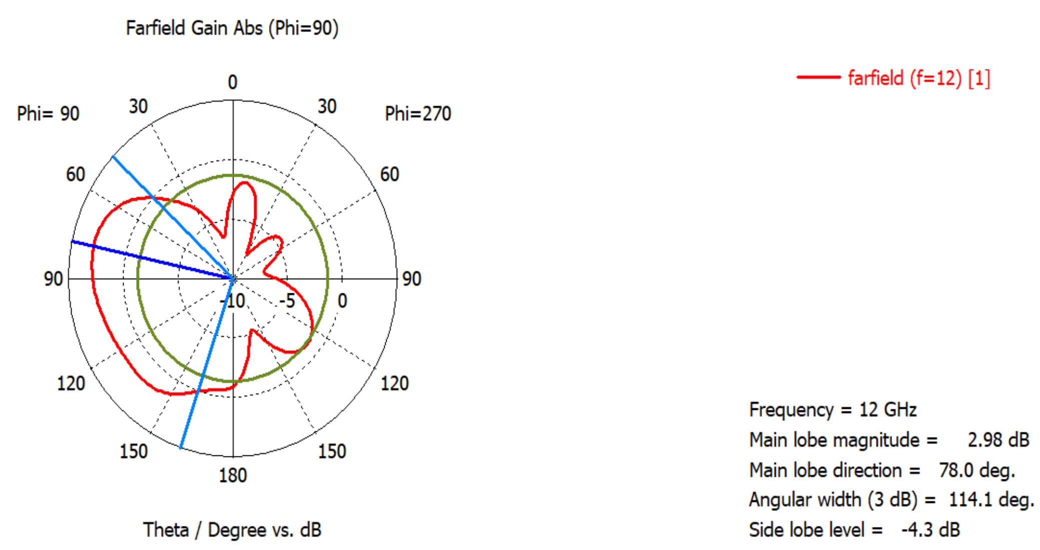

Figure 4.12: Radiation pattern on 12 GHZ

And we can analyze our antenna directivity and Gain to see that we achieved very good values and as we can see in the figure 4.13 that our antenna gain is 8.49 DB while we can see that the Directivity is equal to 8.72 DB as it shown in the figure 4.14.

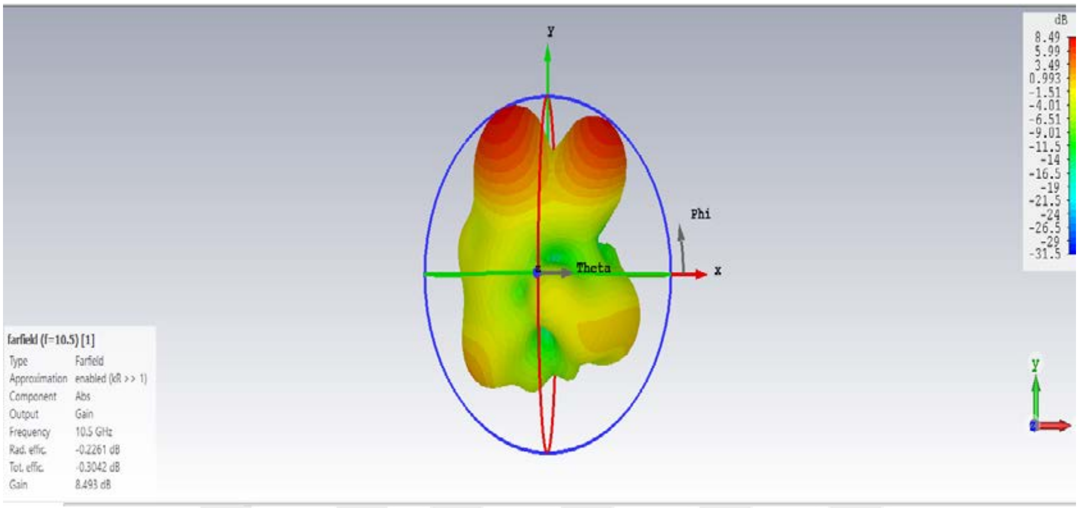

Figure 4.13: The Designed Antenna Gain and 3D Radiation Pattern Analyzing.

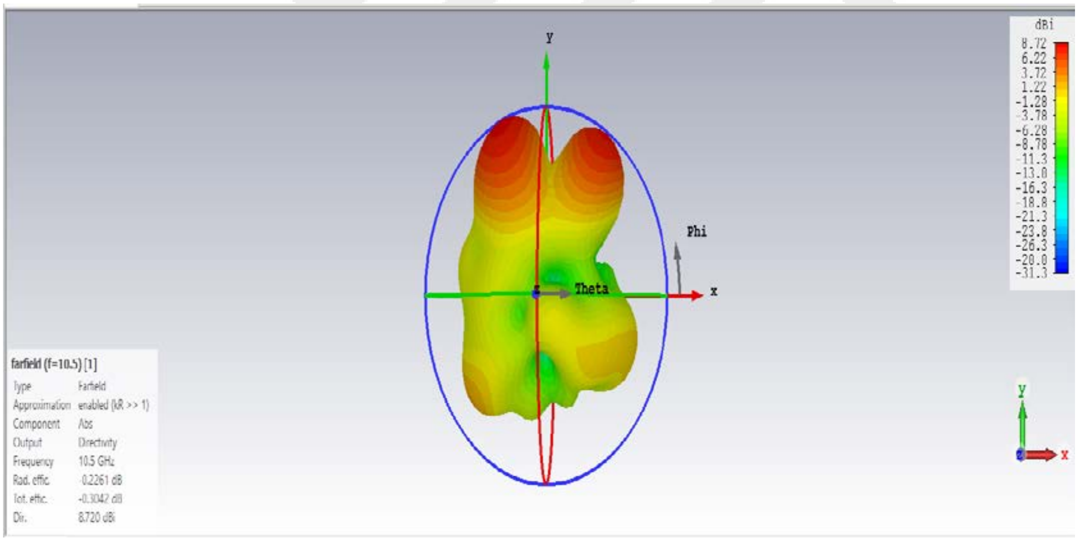

Figure 4.14: The designed Antenna Directivity Analyzing.

And now let's compare the above results with the result that we will have when we used Fr4 as a substrate for the antenna and let's compare it to the result that we achieved before adding side slots on the Ground patch and make a suitable distance between the ground patch and the upper patch of the antenna but using the same material which is Roger RO4003C.

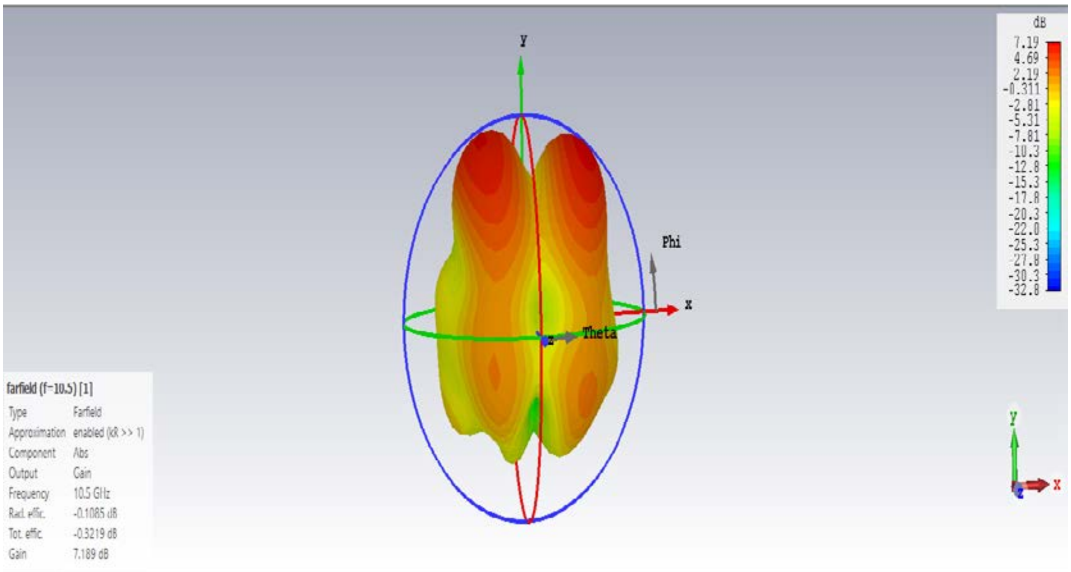

Figure 4.15: 3D radiation pattern of the antenna without Refining the Ground slot

So, we can compare the results of this phase to our final design we can see the improvement that we got when we refined the antenna not only In S11 and VSWR as we saw before but also in the radiation pattern and antenna Gain and the same we will see in the Figure 4-16 where we did the simulation on the last antenna Design but using Fr4 as a substrate material.

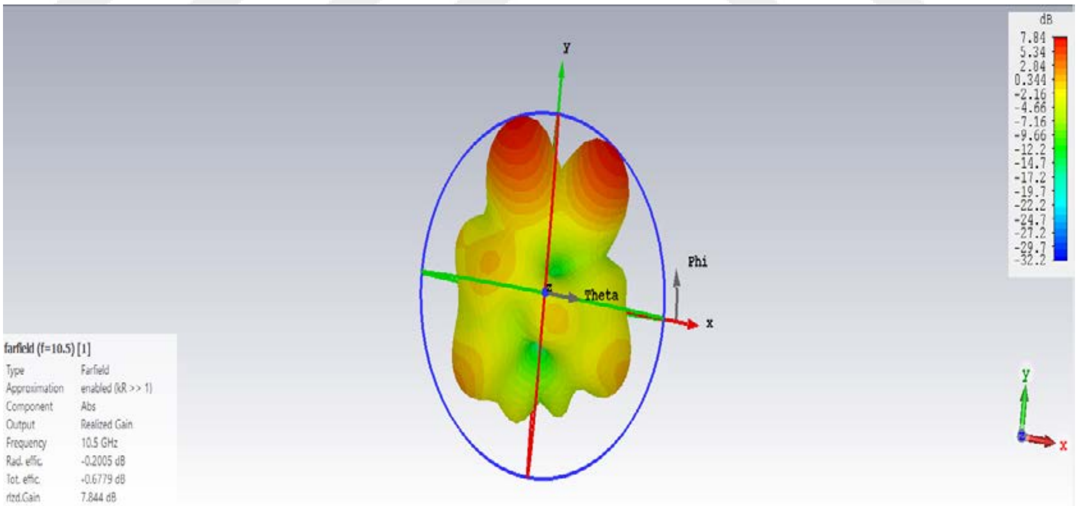

Figure 4.16: 3D radiation pattern of the antenna using FR4 as substrate material

4.4.4 The antenna Gain and efficiency

Antenna Gain describe how much power is transmitted in the direction of the peak radiation to the isotropic radiation of the antenna and its values is measured in DB, and we can always get this result after we have the radiation pattern of the antenna, and as we can see in the above figures our designed antenna had 8.72 DB as a peak gain on the desired frequency, and for a single element of microstrip it's a good value, and to increase this value we will recommend to use this single element design in an array antenna which will achieve higher Gain to be comparable with the gain of the reflector antennas.

On the other hand, the antenna efficiency is the ratio of the power that delivered to the antenna to the power that been radiated from the antenna, and when we say that the antenna has a high efficiency that means that most of the power that delivered to the antenna input is been radiated away. The antenna efficiency is a number between 0-1 or could be described as a % percentage. And we see in the figure that we reached a so the percentage of the radiation efficiency = 100*10^ (-1.658/10) = 94% which is a very high efficiency for a micro strip antenna

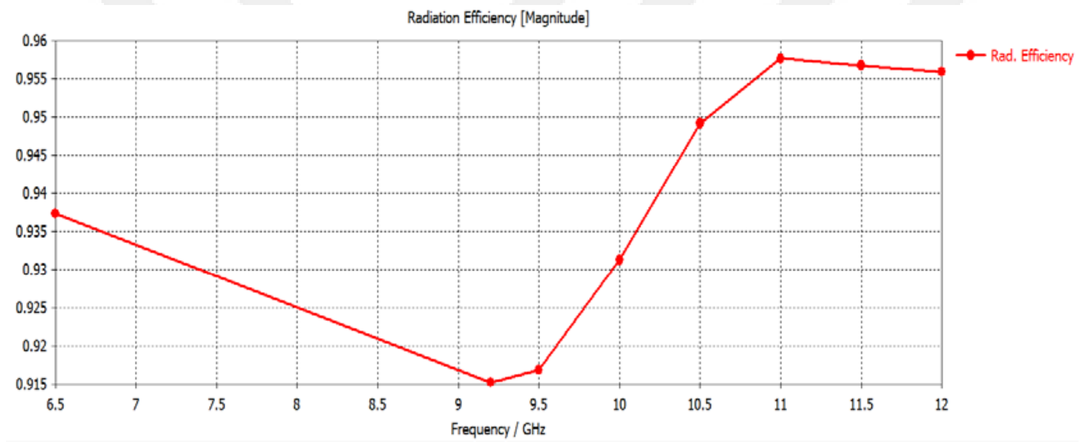

Figure 4.17: The Radiation Efficiency of The Antenna

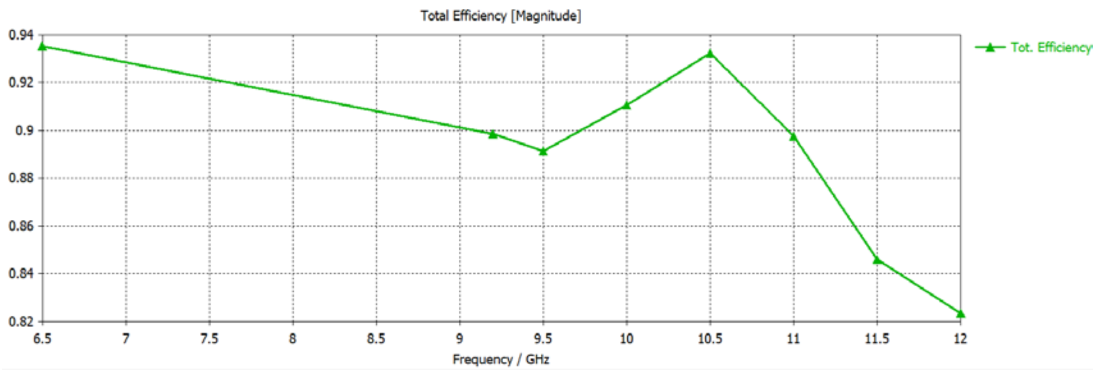

Figure 4.18: The Total Efficiency of The Antenna

4.4.5 Surface current distribution

The last study that we did on the antenna is Surface current distribution, to see the antenna behavior after the last design that we reached. If we check the

Figure 4-18 we can see the importance of the distance that we made between the upper patch and the ground patch where there current intensity and also in the feedline the current is intensely located and we can see the rectangle cuts in the upper face and in the lower face that they helped with improving the current flow on the patch surface in general.

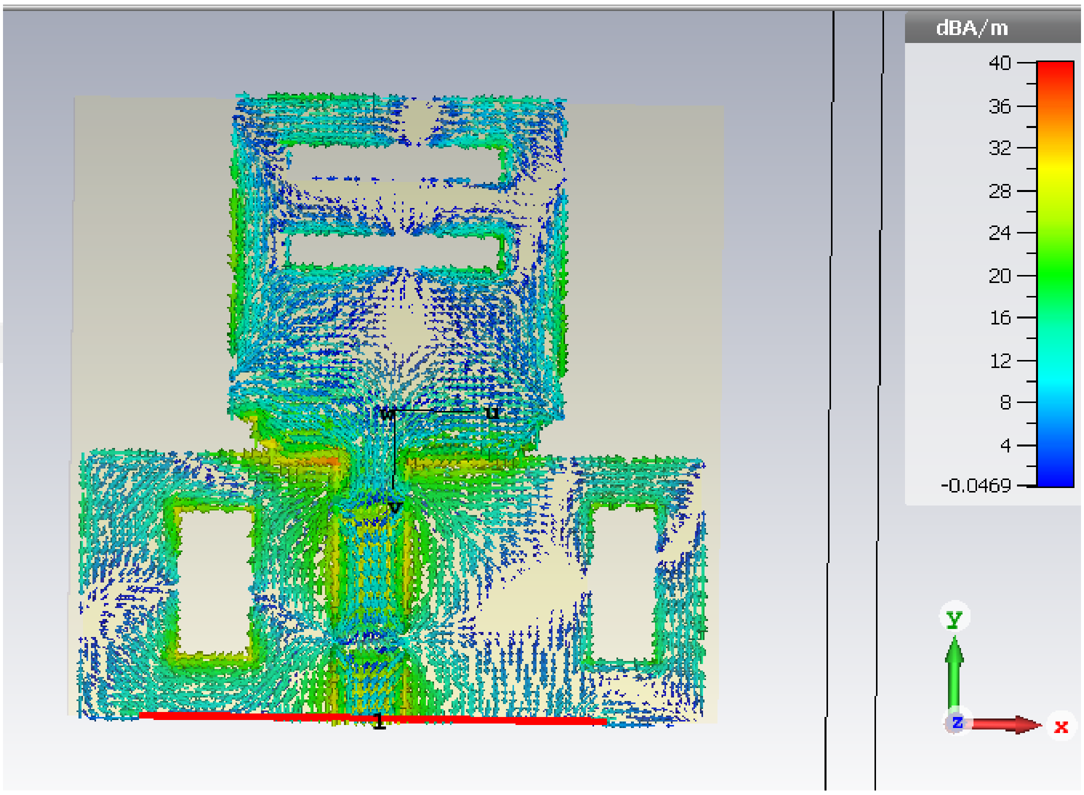

Figure 4.19: The Surface Current Distribution of The Antenna

At last we compared our proposed antenna in terms of dimensions gain frequency range and S11 values with some of other antenna designs, and this references numbers and values are mentioned in the table 4.3.

Table 4.3: Reference Antenna Comparesion

REF NO	Dimensions (mm)	Center Frequency (GHZ)	Substrate material	Peak GAIN (DB)	S11 (DB)	VSWR<2 Range (GHZ)
[47]	12*18*1.6	10.5	FR4	6.25	-18	5.5-12.7
[48]	33.10*16.84*1.57	8.2	FR4	8.6	-58.2	7.9-8.3
[49]	9.12*7.44*1.6	9.49	FR4	4.31	-23.87	8.5-11
[50]	21.129*21.129*1.535	9.36	RT5880	7.622	-18.81	8.8-9.7
[51]	17.79*21.96*1.588	8.9	RT Duriod	8.15	-16	8.5-9.5

Table Hata! Belgede belirtilen stilde metne rastlanmadı..**1:** (continue) Reference Antenna Compassion

[52]	14*16*1.544	9.1	FR4	4.6	-28	8.7-10
[53]	30*30*3	9.5	FR4	4.6	-18	9.05-10.72
The proposed antenna	40*38*1.524	10.5	RO4003C	8.49	-23	5.8-11.5

5. CONCLUSİON

In this thesis we initially Explained the satellite frequency bands and spoke precisely about one of the important applications that could be used in X-band which is the Tv Broadcasting and how the signal been processed from the video input source to the encoder and the modulator and we spoke briefly about the signal encoding then how the signal pass through the Block up converter to reach to the antenna, in the next chapter our focus was on the antenna and the most common types of the antennas such as wire antennas, reflector antennas, microstrip antennas and aperture antennas to start later with explaining the antenna parameters and its characters as we used this parameters later to analyze our designed antenna like the antenna return lose. VSWR, polarization and antenna gain and directivity. later as our antenna will be a microstrip antenna we defined the microstrip antenna and that it consists of a radiated patch, a dielectric substrate and a ground slot. To talk later about the direct and indirect feeding techniques and the advantages of each feeding method to sum this chapter with the array of microstrip antenna. Later on we start designing our microstrip antenna that will be used for X-band frequency application and we used RT 4003C as a substrate material for its efficiency results on our desired range of frequencies and later on we compared the result that we had with the result that we will got if we used the FR4 common material, and found out that the RT 4003C will give better results and stability. Also, we explained step by step how we start did start from our basic design and then how we did the refining of the design to achieve better results. Finally, our antenna was able to give around 8.49 DB peak gain on 10.5 GHZ which is a X-band Frequency also our antenna has a wide IBW range from 5.8 GHZ till 12 GHZ as the value of VSWR is less than 2 within this range so we can use our antenna effectively with the whole frequency rand of the X-band, also we studied the current surface distribution and found out the importance of the rectangular slots that we did on the radiated patch and on the ground slot of the antenna. After that we compared these results to a similar designed antenna that have been used for X-band frequencies. In a conclusion our antenna has a very good results in X-band frequency range and it could be used in many applications that operate at the band range, Tv broadcasting is one of these applications and it could be used in radar applications and many more applications.

The antenna design and analysis had been done using CST studio simulation software. In the end and as we illustrated in this thesis that the array antenna will give enhanced results, for future work we recommend to use our designed antenna as a single element within an array antenna to give a higher gain and to be able to replace other antenna types that give a high gain but have a much bigger physical size compared to an array microstrip antenna such as the reflector antenna.

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