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PATCH ANTENNA DESIGN FOR KU-BAND APPLICATION

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Master's Thesis

Supervisor

Prof. Dr. Osman Nurı UÇAN

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The thesis titled PATCH ANTENNA DESIGN FOR KU-BAND APPLICATION prepared by MARWAH FARIS MUNEAM AL-SHAIKHLI and submitted on 23/12/2022 has been **accepted unanimously** for the degree of Master of Science in Electrical and Computer Engineering.

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Marwah Faris Muneam AL-SHAIKHLI

Signature

DEDICATION

I would like to dedicate my thesis to my supervisor Prof. Dr. Osman Nurı UÇAN my beloved parents, my dear husband and all my family.

ABSTRACT

PATCH ANTENNA DESIGN FOR KU-BAND APPLICATION

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CST studio simulations created and tested many Kuband patch antenna designs. Between 10.7 and 12.75 gigahertz is the "Kurtz-under-band" (Kuband). When creating an MPA array for satellite communication, the patch component design, number of frequencies, wide-band or multiple-frequency operation, and polarization must be considered. This list of other concerns is not exhaustive. This infrastructure requires the patch to run in the Ku band. Using a vertical feed instead of a horizontal feed makes antenna array assembly easier. You must choose your antenna's feeding mechanism in advance if you want it to perform successfully across several frequencies. The antenna must support two-way Ku-band communications (downlink and uplink). This case covers 10.7 GHz to 12.75 GHz (14 to 14.5 GHz). Consider the antenna's polarization and ability to flip polarizations. Complexity in production can affect electromagnetic properties. Patch antenna design evaluation involves a mathematical model of the patch element and feed. Antenna electromagnetic description should now be possible. Wide-band or dual-band patch antenna feed and tuning must account for potential frequency band migrations. Building and developing the Ku-band multi-purpose antenna might lead to new antenna designs that operate better over a wide variety of frequencies. This thesis models a microstrip rectangular patch antenna. Gain, efficiency, and return loss are remarkable.

Keywords: Antenna, Efficiency, Ku-Band, Multi-Purpose Antenna, Return Loss.

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ABBREVIATIONS

MPA	:	Multi-purpose antenna
SSFIP	:	Strip-Slot-Foam-Inverted Patch
UiT	:	Arctic University of Norway
HTS	:	High Throughput Satellites
Ku-band	:	Kurtz-under-band

1. INTRODUCTION

The satellite business is beginning to place a greater emphasis on the usage of satellites for mobile communication as it continues to grow. Antennas, in addition to having a high gain and a wide frequency range, need to meet a number of other requirements, including being extremely transportable, sturdy, lightweight, and having a low power consumption. For mobile applications, array antennas provide a number of improvements over standard parabolic antennas, the most significant of which is the antenna's ability to be steered electrically. Array antennas also cost less than ordinary parabolic antennas.

Uplink and downlink communications in Europe are carried out using the Ku-band, with the downlink operating at frequencies ranging from 10.7 to 12.75 GHz and the uplink running at frequencies ranging from 14.0 to 14.5 GHz.

The Arctic University of Norway, often known as UiT, is hard at work designing a novel array antenna design that will be compatible with satellite ground stations. Transmission of data by satellite is possible at any time and from any location, provided that the necessary equipment can be loaded on a vehicle and used to send data while the vehicle is moving. This makes satellite data transmission possible around the clock and anywhere. Receiving data from a satellite while a vehicle is in motion is referred to as "on-the-move satellite communication," which is a descriptive term for the operation. Satellite communications can be carried out via public, private, or military networks; they can even be employed at accident sites. Satellites are used to relay information from one location to another. Over the course of the past several years, a large number of prominent organizations have indicated an interest in making use of satellite networks to give internet access on a worldwide scale. This has led to the construction of a sizable fleet of High Throughput Satellites (HTS). According to Isotropic Systems Ltd., a company that develops low-profile, multi-band, electronically steered antennas for satellite operators, "To fully enable HTS, the industry requires very innovative antennas with varied price and performance," capable of tracking from mobile platforms or tracking moving satellites whether fixed or on the move, efficiently and at costs that generate accretive returns for operators through an attractive end-user business case.

When satellite applications are employed in distant locations that are not covered by cellular networks or in terrain that has challenging topography, antennas that are designed for on-the-go satellite applications will enable satellite communications.

Array antennas have the ability to alter the direction of radiation without requiring the individual pieces of the array to undergo any kind of physical movement. This approach is described as having digital pointing control. As a result, the connection between the car and the satellite will continue to function normally even while the car is traveling at high speeds. In order to do this, we will need to make use of an antenna that is compact, lightweight, and potent. Microstrip patch antenna arrays are an excellent choice when it comes to satisfying these requirements. Antennas of the kind known as microstrip patch array antennas are characterized by the utilization of singular microstrip patch antennas as the radiating elements of an array. The antenna has a ground plane at its base, and a metal patch that is printed on top of a dielectric substrate. Both of these components sit above a dielectric substrate. A multi-purpose antenna, often known as an MPA, is a form of planar antenna that may be utilized for a variety of purposes. Patch antennas are ideally suited for use in mobile environments because to their diminutive size, low weight, and long-lasting nature.

Multiple-path-error correction, often known as MPAs, is a technique that may boost the functionality of a wide variety of various sorts of systems, such as radar, communication, and navigation.

1.1 BACKGROUND

One of the most important aspects of today's advanced society is the simplicity with which people from different parts of the world are able to communicate their thoughts, ideas, and information to one another. When we have to get in touch with people rapidly over long distances, using technology is helpful since it allows us to do so more efficiently. Chakravarthi details in great detail [1] the historical deluge of inventive solutions that people have developed in response to this conundrum over the course of human history. Pigeons, runners, and horsemen are some examples of long-distance communication techniques that may be utilized. Other options include using telegraph or telephone. In addition to the use of the human voice, the utilization of percussion instruments such as drums, whistles, and other acoustic instruments such as horns and cymbals proved to be even more productive and successful.

In the past, fire beacons and lighthouses were also utilized for the purpose of rapidly transmitting messages across enormous distances. When many lines of communication are networked together, a message may be sent out to a significantly larger number of people. Despite this, early systems required an excessive amount of time to provide big volumes of data and were unable to reach a sufficient number of people to be of any service. As widespread access to electricity became accessible, this began to change.

Consonni and Silva [2] talk on how electrical signals may be used in the process of communication. When telegraphs were initially invented in 1837, electrical signals were utilized as a means of communication. However, by the early 1840s, Morse code had established itself as the way of transmission that was generally recognized. In his patent from 1876, the man who is credited with inventing the telephone, Alexander Graham Bell, initially contemplated utilizing analog signals to transport voice [3]. It was decided to lay cables all over the big cities with the hope that people would be able to communicate more easily and quickly if the number of wires were cut down and a wireless system was built. After the publication of Maxwell's theory in 1865, he demonstrated that electromagnetic waves move at the speed of light and that accelerating electric charges form electromagnetic waves as they move through space. These findings were significant contributions to the field of physics at the time. Heinrich Hertz first proved this concept in 1888, while he was working on the development of a dipole transmitter [4]. He did this by firing sparks at opposite ends of a copper ring. In 1897, Marconi developed and patented his own telegraph transmitter. Heinrich Hertz had previously utilized sparks to transmit Morse code, and Marconi's device was conceptually identical to those sparks. Later on, Fessenden came to the conclusion that he could have accomplished the same thing with only a single electric spark, and there would have been no need for a high-frequency continuous wave in his radio waves. This particular transmitter was capable of transmitting not only Morse code but also other audio signals such as music, and it had far less frequency dispersion than spark-based transmitters did. Due to the fact that it can amplitude modulate signals, the triode vacuum tube has been the most popular type of vacuum tube ever since it was first developed in 1906. This innovation took place in the United States. In 1933, Armstrong was the first person to demonstrate the benefits of frequency modulation. All of these developments contributed to laying the groundwork for the contemporary communication and society that we have today.

1.2 PROBLEM STATEMENT

This thesis will synthesis and analyze a broad variety of patch antenna designs for the Kuband (Kurtz-under-band) frequency range using simulations run in Microwave Office. The Kuband frequency range is referred to as the "Kurtz-under-band."

When planning an MPA array for satellite communication, it is important to consider a number of aspects, such as the kind of polarization to use, the number of frequencies to use, whether to use a wide-band or multiple-frequency operation, and the design of the array's patch elements. These are just a few of the many factors to take into consideration.

In order to be compatible with this system, the patch's frequency range must be set to the Ku band. It's possible that using a horizontal feed may make the design of an antenna array more complicated; for this reason, a vertical feed is recommended instead. The feeding mechanism needs to be decided upon before the antenna can be made to function well throughout a wide frequency range. Downlink and uplink Ku-band capabilities are required of the antenna. These frequencies range from 10.7 to 12.75 GHz (14 to 14.5 GHz). It is also possible to consider the polarization of the antenna as well as its capability of switching between polarizations. In addition to considering the electromagnetic properties, it is essential to take into consideration the complexity of the production process.

1.3 CONTRIBUTION

The design and modelling of a wide-band microstrip patch antenna element that is fed vertically is presented in this thesis. It operates in the Ku-band in both directions and features a resonant aperture; its design is based on the SSFIP structure. Even while Parikh et al. [5] do provide a single-element antenna that operates at uplink and downlink frequencies in the Ku-band, the antenna that they present does not achieve the same amount of bandwidth or gain as the one that is shown in this thesis. The antenna that was offered by Pavuluri et al. [7] is effective on both the uplink and the downlink, in contrast to the antenna that was shown by Aliakbarian et al. [6], which can only be employed on the downlink frequency. On the other side, the offered antenna is better suited and has higher gains than any other option.

Patch reactor-based antennas were not found very frequently, which suggests that this particular design option has not received a lot of attention from researchers. This patch reflector is one of a kind since it can be configured to work at Ku-band frequencies. This makes it a very useful tool.

In this dissertation, we describe an innovative way for qualitatively designing and tuning a wide/dual-band patch antenna. This method was developed as part of our research for a doctoral program. The technique covers the design of all the components of an SSFIP structure with a resonant aperture, and it includes guidelines for a variety of tuning procedures.

The planning and modelling of the feed network are not included in the scope of this thesis. This location will not have the arranged simulation of antenna elements take place.

1.4 GENERAL OVERVIEW OF THE PROJECT

For the purpose of evaluating the patch antenna design, a mathematical model of the patch element and the feed that is associated with it is necessary. It is now possible to obtain a comprehensive electromagnetic description of the antenna. When building wide-band or dual-band patch antenna components, it is important to take into consideration the possibility of future frequency band migrations and design the antenna feed and tuning operations accordingly. With the information obtained throughout the process of constructing and tuning the Ku-band multi-purpose antenna, it is possible to design other antennas that operate at other frequencies.

1.5 THESIS OUTLINE

There are five main sections that will make up this thesis. The first chapter is the introduction, and it provides a high-level summary of the research's motivations, challenges, and intended outcomes.

The article's second half is a literature survey of the related background material. The potential uses of laser radar designs were discussed to provide context for the study's aims.

Electromagnetism, antennas, and microstrip circuits, as well as the coordinate system and definitions used in the thesis, are all covered in detail.

A more in-depth examination of the strategy is provided in the next section. In Chapter 3, we look at whether or not this model can be used to accomplish the aims. The design and simulation software, as well as some of its capabilities, are described. In Chapter 3, we provide you with the tuned antenna's parameters, along with design parameters and simulation results.

Findings and analysis are presented in Chapter 4. Here, we'll share the findings and discuss their significance. The simulation results of the antenna element with the patch re ector are shown. Chapter 4 details the design and tuning process after a discussion of the impacts of the various antenna components.

The story's conclusion and summation are presented in the fifth and last chapter. In this post, we discussed the difficulties of project management and the part that many parties play in it. We intend to document our opinions and reach an agreement in writing.

2. LITERETURE REVIEW

2.1 INITIAL STAGES OF GROWTH

According to reference [8,] Deschamps came up with the idea of using microstrips as antennas for the first time in 1953, not long after the first microstrip transmission line was developed. In 1955, Gutton and Baissinot received a patent for the first microstrip antenna they had developed. Denlinger established in 1969 that both circular and rectangular microstrip resonators (patches) are capable of functioning as effective radiators; however, it wasn't until a considerable amount of time later that this was indeed the case. In the early 1970s, in response to the rising demand for thin, conformal antennas that could be fitted onto the surfaces of missiles and spacecraft, the first microstrip antennas, also known as MPAs, were developed. These early, more fundamental MPAs had bandwidth restrictions and were inefficient overall because of them. Researchers have developed a variety of unconventional strategies throughout the course of the years in an effort to overcome these constraints and enhance the capabilities of the MPA.

2.2 BASIC CHARACTERISTICS

In order to create an MPA, a patch of conducting material is applied on top of a substrate that is grounded. The patch can take on a variety of shapes, such as a square, circle, ellipse, annulus, or triangle, among other possible configurations. The process of selecting a shape is affected by a variety of factors, including bandwidth, polarization, side lobes, and gain. As the intricacy of the form rises, the task of analyzing its aspects gets ever more difficult. According to [9], the amplitude of the surface currents of the patch will grow when the signal frequency is close to resonance. This will happen when the conductor size is approximately half the wavelength, which is when the resonance will take place. This implies that if, for example, the squared length of an MPA is near to half a wavelength, then it will resonate and radiate at the frequency of this wavelength. This is also true if the squared length of an MPA is close to a quarter of a wavelength. Because of the surrounding electric fields at the open ends of the patch, the electric field does not terminate at the end of the patch; as a result, the patch behaves as though it were considerably larger than it actually is.

There are a number of advantages associated with the utilization of MPAs, some of which include their low pro liability, low weight, low cost, conformability and flexibility, as well as simple fabrication and integration with circuits [10]. Because the MPA possesses these qualities, it is compatible with a diverse range of cutting-edge wireless network configurations. The most significant problems associated with typical MPAs are their limited bandwidth, poor polarization purity, and poor radiation efficiency.

2.3 ENHANCED BANDWIDTH AND MULTI-FREQUENCY OPERATION

In this section, we will be concentrating on the impedance bandwidth, which is the frequency range over which a signal can be efficiently transmitted either from the antenna to the feed or from the antenna to the receiver load. This bandwidth determines how well a signal can be received or transmitted by an antenna. The range of frequencies across which an antenna transmits information with adequate performance is referred to as its bandwidth. The frequency range that might be deemed to be the bandwidth of the antenna is the one that has an input efficient (S parameter S11) that is less than -10 dB or a voltage standing wave ratio (VSWR) that is less than 2. If the bandwidth is too narrow, it's likely that the antenna won't be able to detect even minute changes in the broadcast frequency. This is especially the case if the bandwidth is extremely narrow. Because of the components that make up the antenna, the frequency at its centre might shift somewhat if there is a change in temperature. This can be troublesome if the antenna has a narrow bandwidth.

Because the bandwidth of typical MPAs is restricted, solutions for increasing it have been developed and investigated in recent years. These strategies may be broken down into three primary categories: lowering the Q (Quality factor), developing an impedance matching network, and making advantage of a variety of resonances.

2.3.1 Impedance matching network

Implementation of an impedance matching network is one method that may be used to boost bandwidth. Either the tuning stub or the quarter wave transformer may be a component that stands on its own; alternatively, the slots and notches on the patch might serve the same role. In Mishra et al. [11], multi-frequency functioning is explored for two different patches: one patch with a notch, and one patch with a slot.

2.3.2 Lowering the Q

Due to the fact that Q is proportional to the square root of the bandwidth, basic MPAs have a high Q while having a very low bandwidth. By lowering the Q in this way, it's possible that the bandwidth can be increased. The Q value is a representation of the losses that are caused by the antenna. According to [10], the shape of the patch can have some influence on the Q, although this influence is not considerable. Despite the fact that the shape is essential for the radiation performance, changing the shape of the patch is not always a realistic method for reducing the Q.

You may also decrease Q by utilizing a substrate that is more substantial and has a relative permittivity that is lower. The performance of an antenna may be improved by combining a thick substrate with a low permittivity, as seen in Table 1.1, which compares the characteristics of a variety of different combinations of substrate thickness and relative permittivity. However, a thicker substrate has the reverse impact, increasing surface waves and lowering efficiency. A reduction in relative permittivity enhances radiation efficiency, while a thicker substrate has the opposite effect. According to the basic rule that Q has a negative correlation with antenna volume, increasing the width of the MPA will result in an increase in the bandwidth. Because a coaxial probe requires a longer feeding probe, the inductance of the probe will grow as the substrate thickness does so as well. Because of the extra inductance, there will be a limit placed on the amount of bandwidth that may be achieved. In the section on the coaxial probe feed, some of the strategies that may be implemented to reduce the amount of supplemental inductance were covered. For instance, it has been demonstrated that an L-shaped probe may give a broad bandwidth [8]. When aperture coupling is utilized, for example, a higher number of substrates are utilized, which results in the achievement of a wider bandwidth. The change in inductive impedance that is caused by thick substrates may be compensated for by fine-tuning the tuning stubs of aperture-coupled systems, which allows for the shift to be cancelled out.

Table 2.1: Substrate characteristics

Relative permittivity		Small	Large
Substrate thickness	Thin	-	Lines and circuits
	Thick	Antenna	Surface waves

2.3.3 Multiple resonances

The bandwidth of a signal can be increased by using several resonances. After that, we add additional resonators, each of which has a resonance frequency that is relatively near to the frequency of the others. It is possible to achieve this goal by the utilization of multilayer patches, parasitic patches, or slots in the patch itself. It is feasible to achieve wider bandwidths when many resonances are located in close proximity to one another, but antennas that can function at a variety of frequencies benefit from having their resonances located further apart.

It's possible that changing the design of a patch in some way, like adding slots to it, would cause it to resonate at many frequencies. Different sized patches will give out electromagnetic radiation at their own unique frequencies. For example, a slot in the shape of a H can be interpreted as the combination of two folded dipoles. A dual-band X/Ku antenna is made in the article [12] by employing a modified MPA in the shape of a tulip, which may also be thought of as a leaf. The advantages of modified leaf shaped MPAs include, but are not limited to, high radiation performance, compact size, broad bandwidth or multi-band operating frequencies, and many more. The fact that it has such a complex structure makes it difficult to analyze its performance characteristics, which is a drawback. [13] also illustrates slots and uncommon shapes for utilization with a wide variety of frequencies. Everything in this location is ideal for Kuband multi-frequency operation, and consequently, satellite telephony. Because dual-frequency patches often have a narrow bandwidth and require a certain shape or slots in order to fit both frequencies, they are not very attractive for the antenna that is the subject of this thesis.

Utilizing parasitic patches makes it feasible to produce a great deal of resonance in a system. As can be seen in Figure 2.1, it is conceivable for the primary patch and the parasitic patches to be on the same plane (the patch that is directly supplied). One further choice is to overlay the parasitic patches on top of the primary patch, as seen in Figure 2.2. This is still another approach that may be used. The electromagnetic interaction between the primary patch and the parasite patches will cause the parasitic patches to radiate, and if they radiate at frequencies that are somewhat different from one another, the bandwidth will increase.

The utilization of layered patches in conjunction with the aperture feed strategy has the potential to considerably increase the bandwidth, as was previously mentioned. It is possible to generate a second tuning effect by positioning the tuning stub of the aperture-coupled structure in close proximity to the resonance point. According to the information presented in [8,] the factors that may be altered to increase bandwidth are as follows: the position of the parasite patches in respect to the main patch; the size of the parasitic patches; and the number of parasitic patches. Combining stacked and co-planar parasitic patches is one way to lessen the prole or the lateral size of a parasite. This may be accomplished by reducing the size of the parasite. According to reference 14, a multi-frequency Ku-band antenna may be built from three stacked patches. [Citation needed] This antenna has a bandwidth of approximately 10%, which applies to both the transmitting and receiving frequencies. Because of their low relative permittivity, foam layers are utilized in the spaces in between the patches in order to increase electromagnetic coupling. Increasing the thickness of the foam can help enhance bandwidth, but this comes at the price of increased electromagnetic contact with the patch.

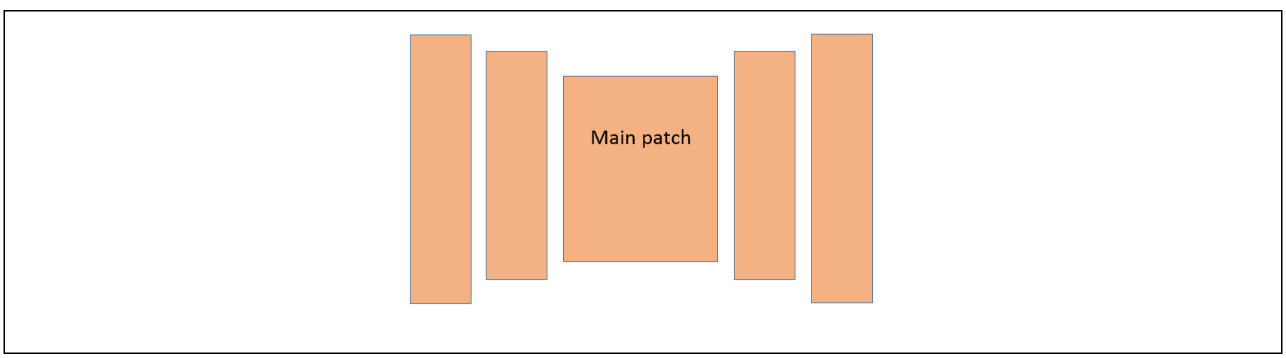

Figure 2.1: Collocated parasitic sores

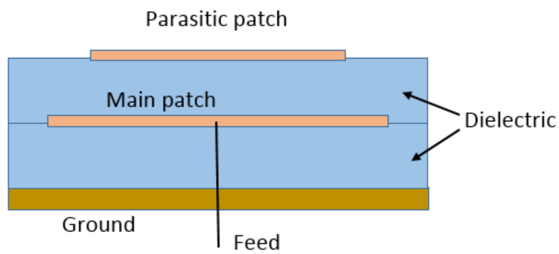

Figure 2.2: Layers of repair work

2.4 TECHNIQUES FOR FEEDING

When trying to send a signal to an antenna, it is really necessary to have a dependable technique for feeding the antenna. Considerable deliberation is required before settling on a feeding approach. The three ways that are used the most frequently for feeding a patch antenna are the transmission line feed/microstrip edge feed, the coaxial probe feed, and the electromagnetically connected feed. In light of the fact that vertical feeding methods lend themselves particularly well to the building of MPA arrays, this thesis will focus on those approaches.

2.4.1 Edge-fed microstrip circuitry

Figure 2.3 illustrates how a microstrip line has been connected to the edge of the patch in order to facilitate direct feeding. It's an easy method of feeding that doesn't require much in the way of technical components, so it's a good option for beginners. One of the advantages offered by the technology is the possibility of positioning both the feeding network and the patch on the same plane. Microstrip feeding offers a substantial problem for impedance matching since the input resistance is strongest around the patch's edge. Impedance matching may often be improved using one of two primary approaches. You have the choice of either utilizing a quarter-wave transformer in the space between the patch and the feed line or generating an inset depth at the location where the patch receives its signal. The existence of false and unwelcome radiations, on the other hand, is a common factor that makes this method less effective. The microstrip feeding approach known as edge feeding is not a vertical feeding method.

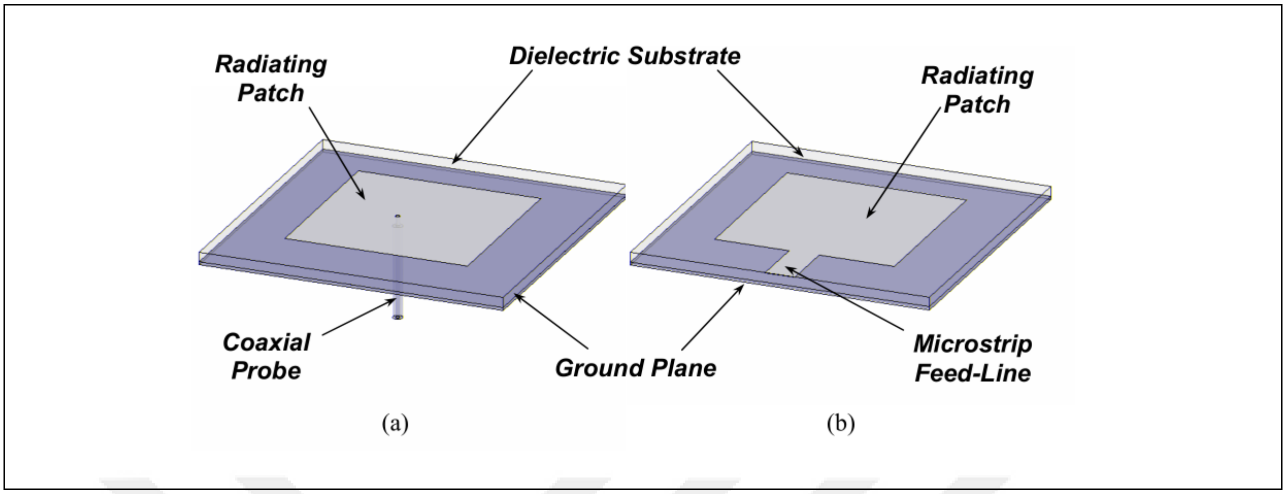

Figure 2.3: Di Different feeding techniques

2.4.2 Coaxial probe feed

If you want to feed the patch with a coaxial probe, you need to join the patch to the probe from below, going via the ground plane and the substrate. This information is depicted in a graphical way in figure 2.3. The input impedance is determined by the location where the feed is linked to the patch. When set up in this manner, the ground plane serves the purpose of a shield between the patch and the feed line. This feed may be built in a variety of different ways, each of which has the potential to enhance bandwidth while simultaneously reducing spurious radiation. According to [10], the fact that array construction uses a coaxial probe is less than optimal due to the vast number of soldering spots and coaxial lines. [Citation needed] When employing a probe feeding strategy, one may experience an amplification of unwanted surface waves and spurious radiation as a result.

When it comes to patch antennas, having a substrate that is thicker enables a larger frequency range. When fed using the coaxial probe feeding method, antennas with a thick substrate will see an increase in their input inductance. This is an outcome that should be avoided. In [8,] a number of different approaches are outlined that can be used to deal with the greater input inductance. Altering the shape of the feeding probe or etching slots into the patch are two viable solutions for reducing the amount of inductance produced by the patch. The feeding probe has a bend in the shape of an L, which provides capacitive reactance. Instead of being stimulated by the probe's physical contact, the patch will be aroused by the electromagnetic interaction it has with the probe. In order to carry out this method, one may substitute the usage of a probe with the use of a strip. The L-shaped feeding probe has the unanticipated effect of producing high levels of cross-polarization in the magnetic plane and a co-polarized polarization pattern in the electric plane. Both of these effects are caused by the probe. Attenuating cross-polarization can be accomplished by using two L-shaped feeding probes that are spaced apart by a half wavelength and positioned either face-to-face, as seen in Figure 2.4, or parallel to each other. A curved feeding probe that is bent in such a manner that it has two horizontal and three vertical parts constitutes the meandered probe feeding technique, which is an alternate method of feeding. This will result in a decrease in the amount of co-polarization that occurs as a consequence of the vertical arms generating unwanted radiation. However, developing various techniques of feeding that make use of probes with a variety of forms might be challenging. In [8,] a revolutionary method for chewing and swallowing food is described. [8] For vertical plate feeding, a vertical standing plate is utilized. This plate is responsible for transmitting the signal from the feeding probe to the patch. The feeding probe and the patch both have some kind of physical connection to the vertical plate. The calculations show that this method is capable of achieving a bandwidth of more than 65%, which makes it possible to make use of thick substrates.

An other type of probe-fed MPA is known as the Suspended Plate Antenna (SPA). A ground plane, a thick substrate with a low permittivity, a feed, and a patch are the components that make up this structure. In [10], in addition to the SPA itself, many approaches are shown for increasing bandwidth, enhancing radiation performance, and implementing SPAs in arrays.

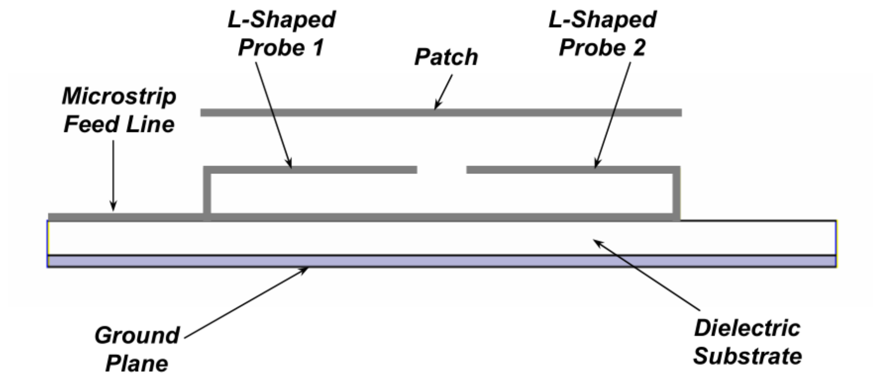

Figure 2.4: Two L-shaped probes

2.4.3 Coplanar waveguide feed

A microwave transmission line is referred to as a coplanar waveguide (CPW) if it has a ground plane on either side and an air gap in between them. CPW utilizes electromagnetic coupling as the means by which signals are transmitted between the feed and the patch. It is possible to achieve the desired impedance matching by not only cutting the waveguide in the ground plane but also etching a slot at the end of the CPW. An illustration of a CPW that has a slot is provided in figure 2.5. According to [10], the back radiation that is induced by slots in the ground plane can be reduced by using a loop at the end of the CPW. [Citation needed] Because of the short distance that exists between the transmission line and the ground, CPW is widely used in situations in which electronic components need to be integrated on the same layer. CPW architectures are particularly well suited for use in arrays due to the predominance of TM modes on coupled slot lines. In other words, slots that are close together will have magnetic currents that are out of phase with one another, which will result in less radiation coming from the feeding structure. Because it requires fewer layers than the aperture coupled feed does, the coplanar waveguide feed may be made smaller without compromising performance. There is evidence of this in [15], where dual-frequency operation is accomplished by using CPW feed with a crossed slot. However, because there are fewer variables to adjust, this method does not give the same degree of flexibility in terms of reaching a large bandwidth as aperture coupling offers. This is because there are fewer factors to adjust.

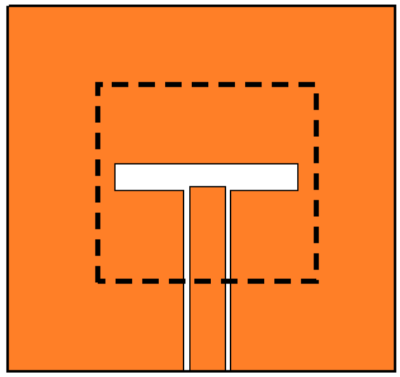

Figure 2.5: End-fed CPW feeder with a slot

2.4.4 Magnetically linked electromagnet feed

Electromagnetic coupling is a method that permits signal energy to be transferred from the feed to the patch even when there is no direct physical contact between the feed and the patch. This style of feed avoids the need for soldering wires and prevents cross-polarization, an issue that is created by microstrip and coaxial feed. According to [16], this type of feed also prevents cross-polarization. In this discussion, we will solely address feeding systems that include a vertical electromagnetic connection.

The patch is linked to a strapline that is located right below it and is separated by a dielectric layer in the method known as proximity linked feed. The electrical connection is made through the substrate that lies beneath the feeding strip. If the feed and patch are arranged in the correct manner, adding a second layer of dielectrics can increase bandwidth while maintaining the same level of performance. The evaluation of a structure becomes more difficult when additional layers are added to it, which leads to an increase in the overall cost of manufacture. This strategy, according to [16], will also result in an increase in surface wave losses. Out of all of the many feeding systems that were put to the test, the radiation performance of the proximity connected feed was the best [17].

According to [16], D. M. Pozar invented the aperture linked feed in 1985. Ever since then, it has been a typical way of feeding, particularly for the construction of patch antenna arrays. The construction of the aperture connected feed is depicted for us in Figure 2.6. The microstrip feed line that is positioned at the bottom of the feed substrate is what makes it feasible to implement an aperture connected MPA. In spite of the fact that it is technically a feed superstrate due to its location above the feed line, we will refer to it as a substrate for the duration of this study. A feed substrate, a ground plane with an aperture or slot, another dielectric layer that serves as the antenna's patch substrate, and finally the patch itself, which is responsible for the actual radiating, are the typical components that make up dielectric antennas. The electromagnetic coupling that occurs at the aperture allows power to be transferred from the feeding strip to the patch. Because of the ground layer that is located in the middle, any radiation that originates from the feed line is stopped before it can reach the patch. According to [18], it was possible to achieve a bandwidth of more than 50 percent using layered patches by employing an aperture-coupled feed on the antenna. This was accomplished. Aperture coupling was found to have the largest bandwidth out of all of the various feeding strategies that Kumar et al. (2013) investigated.

Adjustments may be made to a wide variety of design aspects in order to achieve the best possible performance from an aperture-coupled MPA. Because of the extensive [17] adjustment range, aperture-linked MPAs allow for a large variety of different customizations to be applied. The quality of the connection is determined by the contours and dimensions of the aperture. According to [17], a rectangular aperture offers approximately 10 times better coupling than a circular aperture. Furthermore, different types of apertures, such as dogbane and H-shaped apertures, can improve the coupling even further. Because this would cause radiation to be radiated from the antenna in a direction that is not desired, it is imperative that this phenomenon be avoided. Resonance of the aperture at the operating frequency would cause this. When contrasted with cross-polarization levels attained through the use of a probe or microstrip edge feed, those attained through the utilization of a centered aperture are superior. Because of their two-layered construction, aperture-coupled antennas are ideally suited for use in antenna arrays. This is because the architecture of the feeding network may be placed on a separate substrate layer, which frees up more space in the antenna for the architecture. The aperture connected feed has a problem with back-lobe radiation, but this issue may be solved by adding a second ground layer beneath the feeding network to function as a rector, as was suggested in [18]. Another downside of aperture coupled feed is that it is more difficult to build than single-layer devices, and it is also taller since there are more layers involved.

In reference [19], an aperture-coupled patch antenna designed for Ku-band frequencies is described. A polymer ring is employed as the support structure for this antenna because the patch substrate for this antenna is air. The maximum gain was 8.3 dBi, and the bandwidth was 19%.

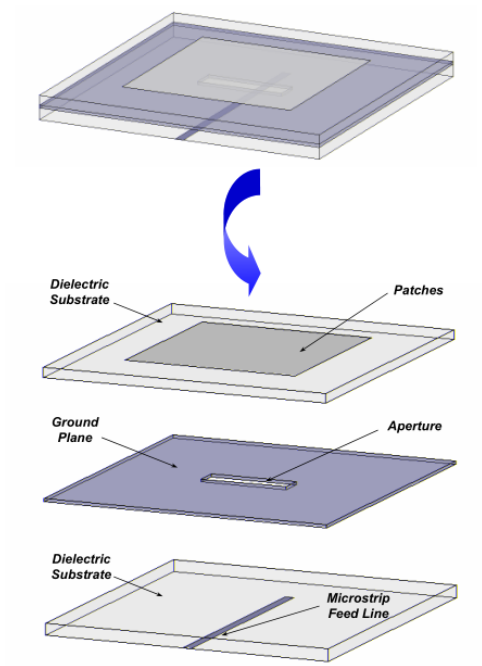

Figure 2.6: Maximum power point analysis with an aperture

2.5 POLARIZATION

According to [20], the polarization of an electromagnetic wave is the form that the tip of the electric field vector makes when it moves from one location to another in space. According to [20], dipoles and dipole arrays exhibit linear polarization, as do rectangular, circular, and triangular patch antennas. Linear polarization is also seen in dipoles. Because of the geometry of the antenna, certain antennas have the ability to be circularly polarized, while others have the ability to be dual polarized. An antenna with dual polarization will radiate two waves that are linearly polarized, but their phases will be 90 degrees off from one another. The frequency range where the input reflection coefficient is less than -10 dB and the axial ratio is less than 3 dB is the bandwidth for the axial ratio. The circularly polarized antenna will be useful in both of these situations since it will improve the axial ratio. In the case of fully circular polarization, the axial ratio is 0 dB, whereas in the case of perfectly linear polarization, the axial ratio is infinite. When moving away from the primary lobe of a circularly polarized antenna, the polarization pattern of the antenna often becomes more elliptical. Circular polarization is recommended over linear polarization in a number of scenarios, including those in which multipathing and fading present difficulties, as well as for ionospheric communication, as mentioned by Lee and Tong [21]. There are three different methods that may be used to create dual polarization in a patch antenna, and one of these methods can produce circular polarization. These techniques can be categorized as "single feed," "dual feed," or "sequentially rotated," depending on how the food is delivered.

The patch may be almost square or nearly circular; alternatively, its corners could be shortened, as seen in figure 2.

7's square patch or indentations, similar to those seen in Figure 2.7.

7's circular patch, all of which were done in order to accomplish circular polarization using a single feed structure. These geometries will give rise to two waves that are linearly polarized and orthogonal to one another. There is also the possibility of circular polarization being present in a slotted or stubbed patch. When there is just one feed, the circular polarization is dependent on the precise position of the feed. The single-feed setup will thus create two waves in phase quadrature at slightly different frequencies. These waves will be slightly offset from one another. Two of the most significant limitations are the effective circular polarization and the reduced bandwidth provided by the single feed. As demonstrated in [22], it is possible to construct a dual-band patch antenna with circular polarization by stacking two patches with asymmetric U-slots to generate a dual-band antenna. The probe's electromagnetic contact with the patch causes it to activate both the upper and lower regions of the patch. The top patch achieves an axial ratio bandwidth of 3.1%, while the lower patch achieves a bandwidth of 1.0%. Both patches are effective in this regard.

When contrasted with a structure with a single feed, a system with two feeds has the potential to give better bandwidth. The signal is provided by two spots on a symmetrical patch that are equally spaced apart, which cancels out the components that are cross-circularly polarized. The method may accommodate the usage of more than one feed at a time. If circular polarization with dual feed is required, the patch should be symmetrical; on the other hand, squared patches should be avoided since they produce a significant amount of cross-polarization. Aperture-coupled antennas may produce circularly polarized radiation patterns by using a split feed in conjunction with either an off-center aperture or an aperture composed of crossed slots. This combination of elements is called an aperture. A quadri-polarized aperture linked multi-pole antenna (MPA) is developed in [23]. Because of this, the antenna is able to utilize a total of four separate polarizations, including two distinct sets of circular polarization and two distinct sets of linear polarization that are orthogonal to one another. Figure 2.8 reveals that the ground plane contains four rectangular apertures, each of which is accessed by one of the four feeding lines that deliver food to the MPA. The feed is controlled by eight pin diodes, which enables the user to choose the polarization that is most suitable for their needs. Obtaining circular polarization is possible through the use of the successive rotation technique. The next step is to load a sequence into the individual members of an array. [24] describes the construction of broadband antenna arrays that have circular polarization. It's a grid with holes in square formation, and the size is 22. In spite of the fact that these slots have a circular polarization because of their design, the axial ratio can be improved by rotating them in series. Circular polarization will be the end outcome if both the spatial rotation of the slots by 90 degrees and the phase shift of the input by 90 degrees are carried out simultaneously.

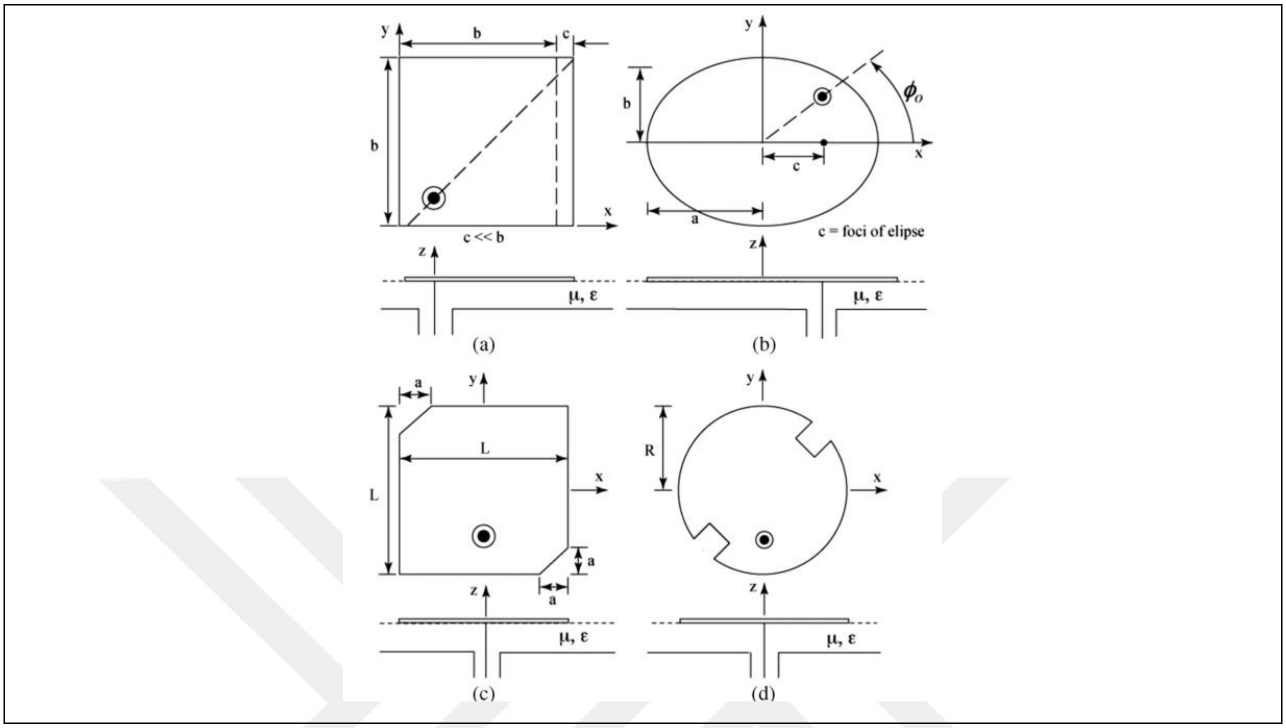

Figure 2.7: Patches with a single circular polarization feed

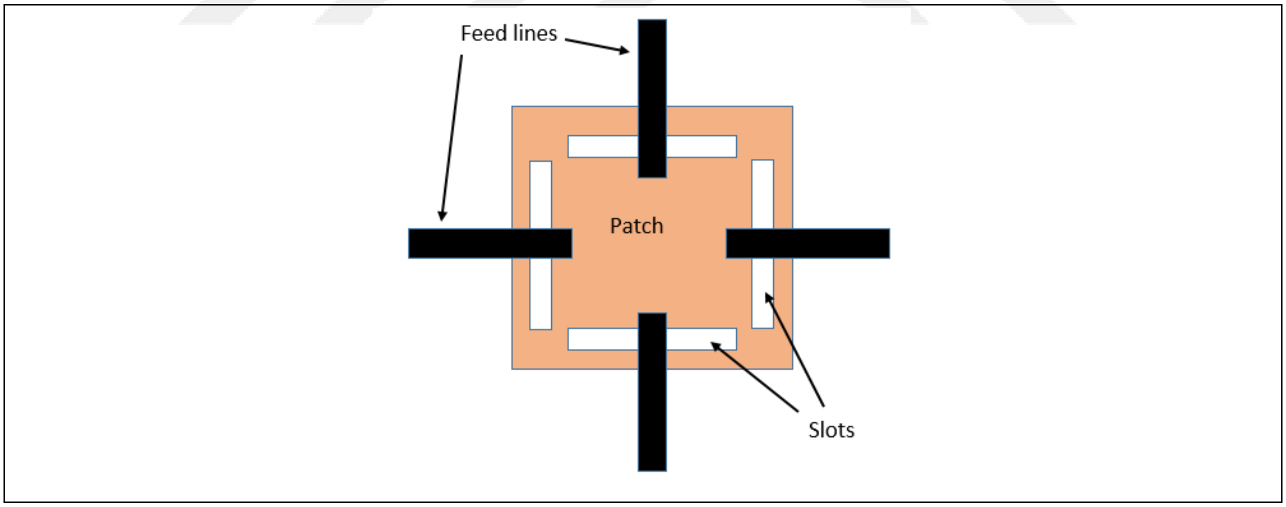

Figure 2.8: a Patch with four polarizations

2.6 SSFIP PRINCIPLE

The acronym SSFIP refers to a particular type of MPA structure known as a Strip-Slot-Foam-Inverted Patch. It was initially suggested in the paper [20] as a strategy for increasing the capacity of MPAs. The acronym describes the order in which the components are traversed by the signal as it moves through the system. A graphical illustration of the plan is shown in Figure 2.9. A portion of the base is designed in the form of an aperture-coupled multi-port antenna (MPA), which consists of a microstrip line that is buried beneath a feed-substrate and a ground plane that contains a slot. The substrate of the patch is a layer of foam, as the next step in the process. Foam is a great option for the substrate of the antenna since some varieties of foam have very low relative permittivity’s. This quality translates to less surface waves in the material. In addition, foams enable constructs of any thickness that are thin, making them an excellent choice for patch substrates. On surfaces that are friendly to the substrate, an inverted patch is implemented, with the substrate layer in the uppermost position. The antenna will be protected from the environment by this substrate, which may also be referred to as a radome or a superstrate. It should be robust enough to prevent damage, but it shouldn't be so cumbersome that it compromises the antenna's performance in any way. This is the ideal situation.

According to the research presented in [25], the SSFIP may be improved even further by positioning a reector in the form of a metal plane underneath the structure, as seen in Figure 2.9. The reflector's purpose is to reduce the amount of light that is reflected. It is situated a quarter of a wavelength below the aperture, which is the principal source of back radiation in the system. As a result of the fact that the wave is moving at a half wavelength and that its phase is shifted by 180 degrees when it is reflected, the radiation that is reflected will then contribute to the field in a constructive manner as it moves ahead. If the spacing were smaller, the signals would be cancelled out, and if it were larger, more directed lobes would be produced. Because of the reflector's limited size, some of the light that is reflected is still allowed to pass through.

In the paper referenced by number 6, the SSFIP approach is applied in order to generate a wide-band MPA array that operates at the Ku-band frequency. The VSWR of the single MPA is less than 2 at all frequencies between 10.27 GHz and 13.22 GHz. Because air is used rather than foam, the superstrate that is home to the patches is held up by holds that are situated in each of the four corners of the antenna. The resonant aperture is the primary factor responsible for the high bandwidth.

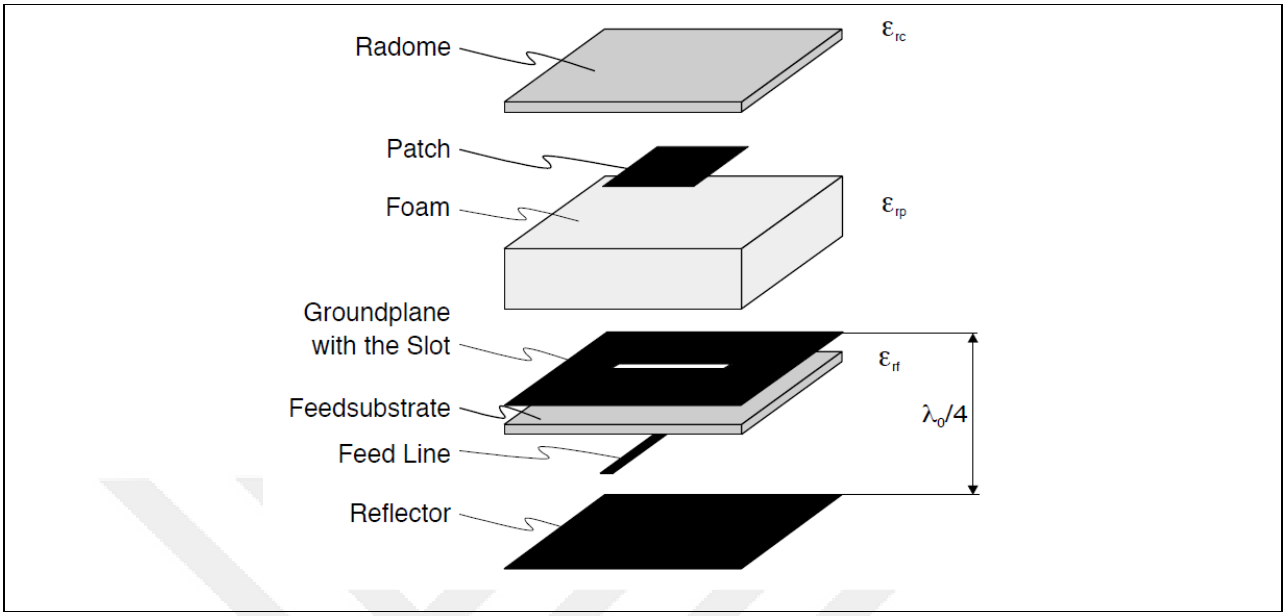

Figure 2.9: Constructed as an SSFIP with a reflector

2.7 APPLICATIONS

There is a wide variety of potential applications for MPAs, all of which are presented below. In the 1990s, improvements were made to the MPA's bandwidth, bringing it up to the point where it could successfully compete with other antennas in a number of different systems. These days, multiple programmable aggregators (MPAs) may be seen working in a broad range of communication infrastructures. The MPA's low profile and conformal qualities made it an excellent choice for use in fixed frequency/low bandwidth radar systems as well as in telemetry on missiles and other projectiles due to the fact that it could be mounted almost anywhere. When the MPA is put to use for military purposes, the constrained bandwidth might be an asset. As a consequence, it is better able to withstand attempts to jam its frequency and other forms of interference. There has been a noticeable increase in the number of commercial airlines that use MPAs to provide their customers access to satellite phones and the internet while they are in flight.

Due to their low weight and small size, multipurpose applications were initially implemented in a select group of satellites. MPAs started to take on a more major role in satellite systems during the middle of the 1990s, when newer arrays with wider bandwidths and better radiation performance were available. One well-known example of a system that makes use of MPAs is the Iridium communication system. [Citation needed] MPAs have recently become as the industry standard for satellites. MPAs are widely utilized as part of less expensive detection systems, such as those designed to avoid accidents. Due to the fact that microwave frequency systems do not require extensive channels, it is possible for them to be employed efficiently in this application. The tiny form factor of the MPA is well-suited to this application. The Mobile Packet Appearance (MPA) protocol is often implemented in base stations, where it is also present in mobile communication networks. Additional uses include radio frequency identification, wireless internet access, and global positioning system receivers in hospital settings (WiMAX).

3. METHODOLOGY

3.1 INITIAL ANTENNA DESIGN

The process of design needs to be founded on fundamental models and equations that come close to approximating the antenna's ideal shape. If a reasonable approximation of the antenna design has already been developed before the tuning technique begins, it will make the process much simpler. On the other hand, beginning with a design that is far different from any operating antenna is similar to shooting in the dark. Full-wave analysis is a strong tool, but because of the additional time and complexity it would add to the process, it is not necessary for the preliminary design work that is being done. It was determined that the most effective way for tuning is full-wave analysis. During the process of design, there was a significant reliance placed on pre-existing examples of antennas that possessed the desired qualities and structural similarities.

3.2 FEEDING TECHNIQUE

This thesis' production was launched off with a literature study on vertical feeding techniques and patch antenna design methodology. This research offered a firm platform upon which to build, so the production of this thesis could get underway. In the course of our literature study, we investigated the many ways in which previous researchers have attempted to solve the problem of MPAs. One of the more fascinating feeding approaches that we came across was called the aperture linked feed. This approach demonstrates a variety of favourable properties when it is applied to an antenna array, such as the one that is being used in this project. When constructing the feeding network, you have a lot of bandwidth and area to work with if you choose an aperture-coupled feed, which allows you to generate antennas with varied polarizations and gives you more creative freedom. Because of the flexibility of the feeding mechanism, aperture-linked antennas have a large variety of customisation choices available to choose from. The negative sides include the increased visibility and complexity that comes from the additional layers. The CPW feed is another intriguing option for feeding an antenna; it requires fewer layers than the aperture coupled feed, but it also has fewer options to change, which limits the design space somewhat. Although it requires fewer layers than the aperture coupled feed, it is still an intriguing option. It is believed that the bandwidth that is offered by the CPW feed is lower than that which is provided by the aperture coupled feed [26]. It was decided not to make use of probe feed since the coaxial variety requires an excessive number of soldering points, rendering it unsuitable for use with arrays. Because of this, an aperture-linked antenna was settled on as the primary aim for the initial design. The SSFIP was selected as the most promising structure because it has already been demonstrated to offer huge bandwidths through the utilization of aperture coupling. This was the primary focus of the study because it aimed to create a wide-band or dual-band MPA, and the SSFIP was chosen because it has already been demonstrated to offer huge bandwidths through the utilization of aperture coupling.

The fact that rectangular patches are the most prevalent type means that their characteristics are well known; hence, deciding to begin with them was a simple option. The construction of the original antenna was initially influenced by the one that was described by Aliakbarian et al. [6], and some dimensions were established by utilizing the antenna reported in that study as a foundation. Because it is likewise a wide-band antenna for the Ku-band and its construction is comparable to that of SSFIP, this antenna was used as a point of comparison. A resonant aperture would make the production of a wide- or dual-banded MPA a far less complicated operation. As a result, the MPA would need to incorporate not one but two resonances: one for the patch and one for the aperture. It was known that the operational frequency range of the antenna for the downlink was 10.7–12.75 GHz, and that the operating frequency range for the uplink was 14.0–14.5 GHz. In a manner that is analogous to the antenna in [7], the patch was designed to have a resonance at the midpoint of the uplink frequencies (14.25 GHz), while the aperture was designed to have a resonance at the midway of the downlink frequencies (11.7 GHz).

3.3 SUBSTRATES

For the construction of an aperture linked antenna, a single feed substrate and a single patch substrate are required. The substrate for the patch should be constructed of a material with a low permittivity, preferably air, although because of the necessity for extra support, this is not always practical. Foam is a decision that may be made given that there are robust foams available that also have a low relative permittivity. ROHACELL is a polyetherimide foam that was developed with the sole purpose of being utilized in antennas. At 10 GHz, the relative permittivity of this material is 1.046 and the loss tangent of this material is 0.0017; both of these numbers are exceedingly low. Because of its malleability, it may readily be built into the requisite thickness in order for it to be used as an antenna substrate. When it was first manufactured, the foam had a thickness of 3 millimetres, the same as the antenna substrate in [6]. Because it was considered that foam's relative permittivity was lower than air's, foam was used as the substrate for the antenna rather than air. Tuning is required to make adjustments to the thickness because there are no known methods for determining substrates. In order to attenuate surface waves, it is preferable for the feed substrate to have a low thickness (often between 0.01 and 0.02 lambda) and a high relative permittivity (within the range of 2 to 10). The free-space wavelengths for downlink antennas vary from 23.5 to 28.0 millimetres, and the uplink wavelengths range from 20.7 to 21.4 millimetres. It's possible that a feed substrate thickness ranging from 0.2 to 0.5 millimetres will be sufficient for both downlink and uplink frequencies. The Rogers Corporation provides a selection of different dielectrics that are appropriate for use in microwave circuits. The RO3035TM was chosen for this project because it is ideal for use as a superstrate and is available in layers that are as thin as 0.127 millimetres. It was decided that the feed substrate would have a thickness of 0.508 millimetres, which would be equivalent to the thickness of the feed substrate used in the antenna described in [6]. In that antenna, RO4003TM was used as the feed substrate because it has a nearly identical relative permittivity to RO3035TM. RO3035TM is not suitable for use as a superstrate for a device that is required to be entirely waterproof since it has a low water absorption rate.

3.4 MICROSTRIP PATCH ANTENNA

The emission pattern of the patch antenna, because of its broadside orientation, is well-suited for deployment in two-dimensional arrays, which is another benefit to add to the extensive list of advantages offered by the antenna. It is easy to manufacture, it has a low price tag, it has a tiny physical footprint, and it conforms to standards to a great degree. It is not difficult to set up probe feeding using either microstrip or coaxial. In a variety of settings, such as continuous partial wave (CPW) and strip line feeding, multilayer systems are utilized. Utilizing microstrip feeding allows for a straightforward realization of both linear and circular polarization excitation of the antenna [27].

The patch antenna is a microstrip-fed conventional planar antenna, as can be seen in Figure 3.1. The patch antenna is fed by a microstrip. The manner in which a patch antenna is fed will have an effect on the ripple, cross-polarization, and bandwidth of the antenna. Most microstrip-fed patches have bandwidths that are lower than 5% of their total. In addition to the use of multilayer manufacturing, various feed approaches, such as proximity coupling and aperture coupling, have been utilized in order to increase bandwidth. These methodologies include: Pozar is the person to talk to if you need any further information on this breakthrough (1992). However, by increasing the electrical thickness of the substrate, it is possible to reduce the Q-factor of the antenna cavity, which in turn will result in an increase in the matched bandwidth of the antenna. As a direct consequence of these adjustments, the bandwidth of the antenna will be narrowed. If, on the other hand, the radiation is produced as a result of the surface wave, then the radiation will be less effective, and the radiation pattern will be damaged as a result of the high levels of TM0 surface waves (which can occur at the edge of finite ground antennas). High-frequency antennas frequently run into the problem of the substrate being electrically thick when they are installed on substrates that have a high permittivity. Because of this problem, potentially significant volumes of TM surface waves will be created.

The input match may be achieved by inserting the microstrip feed into the antenna at a distance x, as illustrated in Figure 3.1. By selecting the right b dimension, it is possible to create a resonant cavity on the top plane of the design. This cavity will be formed by the conductor. As a consequence of this, radiation is released from the ends of the antenna, and this radiation may be observed as fringing fields. It is possible to utilize the model of the transmission line in order to conveniently and accurately duplicate the activity of the antenna. This model, when applied in the vicinity of the point where resonance occurs, provides a decent estimate of the resonant frequency and an acceptable approximation of the input impedance. Unfortunately, because the patch antenna has such a narrow bandwidth, it is not a good option for a first-pass design decision because it does not have sufficient reliability. However, it is important to note that the bandwidth does serve as a beneficial benchmark and source of data on the performance of the antenna. This is something that should be taken into consideration.

A view of the patch antenna as seen through its cross-section is seen here (Figure 3.2). According to this theory, standing wave type modes should arise within the cavity if the patch antenna is totally surrounded by walls composed of perfect magnetic conductor. This prediction is based on the fact that the cavity is completely enclosed (PMC). Because of the phenomena of the microstrip open-end, the cavity is significantly longer than the patch antenna (dimension b).

The fundamental resonance of the cavity that is produced by the patch antenna will take place at a frequency at which the effective length of the patch antenna, which is equal to b plus 2loc, is equal to half a guided wavelength in the microstrip cavity. This will take place at a time when the cavity is at its shortest length. The mathematical representation of this concept is seen in the equation 3.1 below.

$$f_r = \frac{c}{2\sqrt{\varepsilon_{re}}} . \frac{1}{b + 2\,\Delta l_{oc}} \qquad (3.1)$$

Remember that the speed of light in a vacuum is c = 3 108 meters per second, and that re is the effective permittivity of the microstrip. By describing the effective permittivity in terms of the characteristics displayed in Figure 3.1, Equation 3.2 provides a rather precise approximation of that quantity.

$$\varepsilon_{re} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r + 1}{2}\left(1 + \frac{10t}{a}\right)^{-\frac{1}{2}} \qquad (3.2)$$

The effects of fringing must also be considered, therefore a reasonable estimate of the effective length is required. In order to calculate the length of the fringing field, formulas like the one shown below are commonly used (equation 3.3).

$$\frac{\Delta l_{oc}}{t} = 0.412\ \frac{(\varepsilon_{re} + 0.3)\ ({}^{a}/_{t} + 0.264)}{(\varepsilon_{re} -\ 0.258)\ ({}^{a}/_{t} + 0.813)} \qquad (3.3)$$

The resonance frequency of a patch antenna may be tuned by adjusting the antenna's size according to the aforementioned calculations. Generally speaking, the model's accuracy is on the order of a few percentage points. This could not be accurate enough for first-pass design since the bandwidth of a microstrip-fed patch is of the same order.

It would be helpful to have some idea about the antenna's input impedance as well. The patch antenna's transmission line model provides the most elementary and direct method of estimation. In this diagram, the antenna appears as a microstrip transmission line with the same dimensions as the patch antenna. The loc and a values determine the width and length of the two radiating slots, respectively. A coaxial probe or inset feed allows the feeding to be placed anywhere along the antenna's length.

3.5 DESIGN

The desired frequency in ku-band is between 11 and 12 GHz. Frequency equal to 11.2 GHz is chosen basing on it is useful applications, such as CMOS, radiometers, and radio telescope etc…

A simple shape of microstrip antenna with a small notch on the feed line is chosen. The design is shown in figure 3.1.

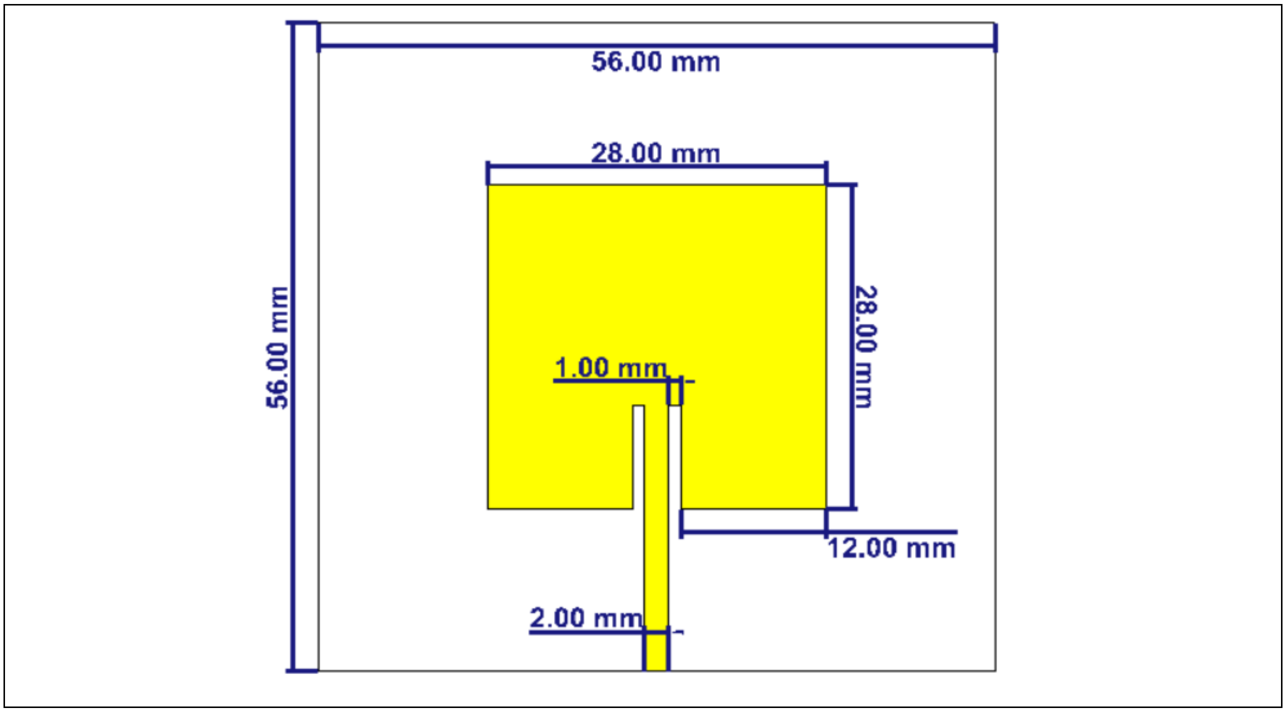

Figure 3.1: Proposed design

4. DESIGN AND RESULTS

4.1 CST STUDIO SIMULATION

The CST Studio Suite® is a high-performance 3D electromagnetic analysis software suite that may be used for the development, evaluation, and improvement of electromagnetic (EM) components and systems.

CST Studio Suite gives users access to electromagnetic field solvers across a wide variety of electromagnetic (EM) applications through the use of a common interface. Because the solvers may be integrated for use in hybrid simulations, engineers now have more flexibility than they've ever had before when it comes to studying complicated systems that are made up of a wide array of components. Co-design with other SIMULIA solutions allows for the integration of electromagnetic (EM) simulation into the design flow and early process driving.

Common topics of research in the subject of electromagnetics include electromagnetic compatibility and interference (EMC/EMI), human exposure to electromagnetic fields, electro-mechanical effects in motors and generators, and thermal effects in high-power equipment.

CST Studio Suite is relied on by leading technology and engineering companies located all over the world. It makes it possible to have shorter development cycles and reduced expenses, which are both big benefits in terms of getting things to market much more quickly. The use of simulation allows for the creation of digital models that function as prototypes. It is possible that one of the outcomes will be the optimization of device performance, the early identification and resolution of potential compliance difficulties, the reduction in the requirement for physical prototypes, and the reduction in the likelihood of test failures and product recalls.

4.2 MAIN ANTENNA DESIGN

The design shown in figure 4.1 was simulated using CST studio software. It shown all the main dimensions taking into consideration the expected range of frequency. All the calculation was done using MATLAB.

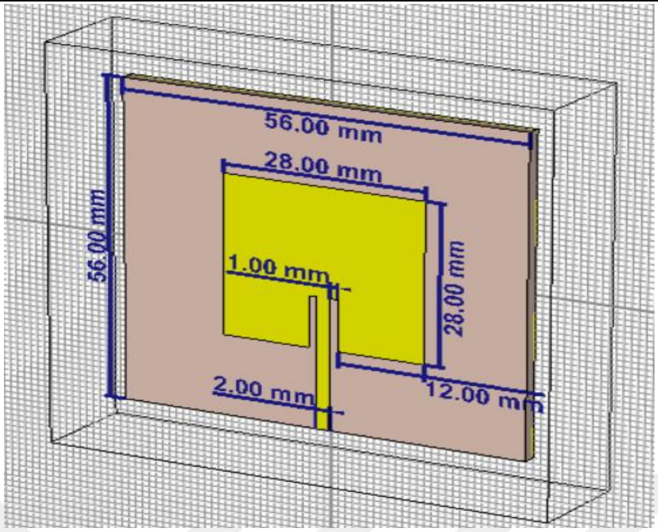

Figure 4.1: Main Antenna Design dimensions

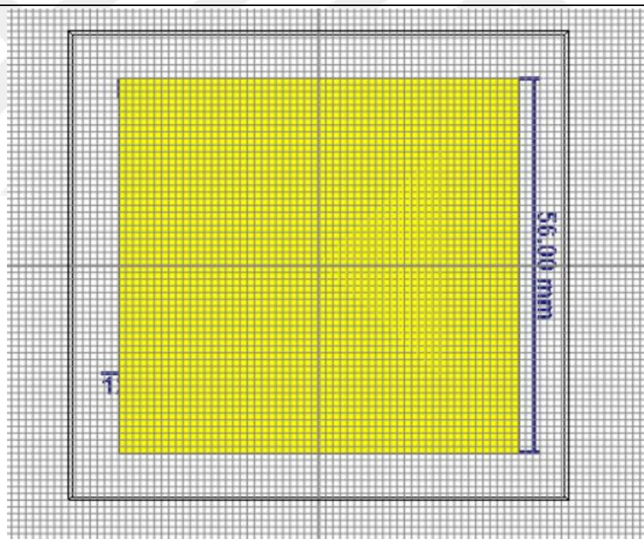

Figure Continue 4.1

4.3 RESULTS AND EFFECTS OF PARTS

4.3.1 Substrates

During the early phases of the development process, choices were taken about the substrates and the thicknesses of those substrates. The resonant frequencies will increase with a feed substrate that is thicker, whereas they will decrease with one that is thinner. Because the thickness of the feed substrate is confined to the range of thicknesses that are accessible from the manufacturer, increasing the thickness of the feed substrate is unfortunately not possible. The dielectric material can be changed, but the new material should have electrical characteristics that are comparable to those of the old material. This will allow the tuning procedure to be repeated with the least amount of difficulty possible. Therefore, it is essential to make sure that you consistently employ the same feed substrate in all of your simulations.

You are able to modify the thickness of the FR-4 (lossy) patch substrate in order to fine-tune the performance of the antenna. Because of the thinner patch substrate, the patch resonance shifts downward, while the aperture resonance shifts somewhat upward, resulting in a narrower bandwidth. This is because the patch substrate is thinner. When the foam is thicker, the reverse phenomenon takes place; however, there is a limit to how much the bandwidth can be expanded before the resonances become too spaced apart and the band between them becomes too highly reflective. As can be seen in Figure 4.4, the coupling quality noticeably improves whenever there is a decrease in the substrate thickness of a patch. When the substrate was made thinner, the gain at the patch resonance increased, but the gain at the aperture resonance fell. On the other hand, when a patch substrate with a larger thickness was tested, the results were reversed. We were able to achieve a broad frequency range, employ a superstrate of any thickness, and fine-tune our system with a reasonable amount of ease thanks to the use of foam as the substrate.

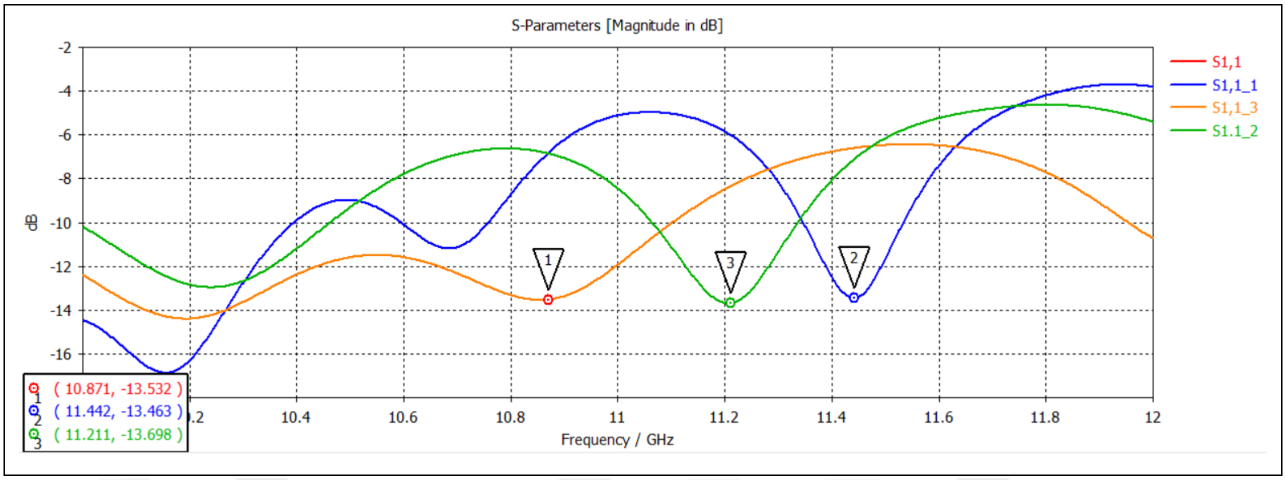

Figure 4.2 Return loss response for different substrate thickness

Table 4.1: Substrate thickness responses

Substrate thickness (mm)	Frequency (GHz)	Return loss (dB)
1	11.442	-13.464
2	11.211	-13.698
3	10.871	-13.532

4.3.2 Feedline

In the simulations, the length of the feed line has an effect on the radiation pattern, but it has no impact on the frequency responses. If you increase the feed length along the y-axis, the beam width along the x-axis will get narrower. This has taken place as a direct consequence of radiation coming from the feed line. When connecting the feed network and the antenna elements, it is essential to conduct a thorough inspection of the length of the feed line. This is because the length of the feed line is dependent on the feed network and where it will couple to the feed line.

The tuning process was successful in preserving, for the most part, the breadth of the feed, which changes depending on the substrate. Nevertheless, the frequencies can be changed down by making the feed line wider, or up by making it thinner. This is accomplished by changing the width of the feed line. Figure 4.3 illustrates the return loss of the antenna at a range of feedline widths to compare the results (table 4.2).

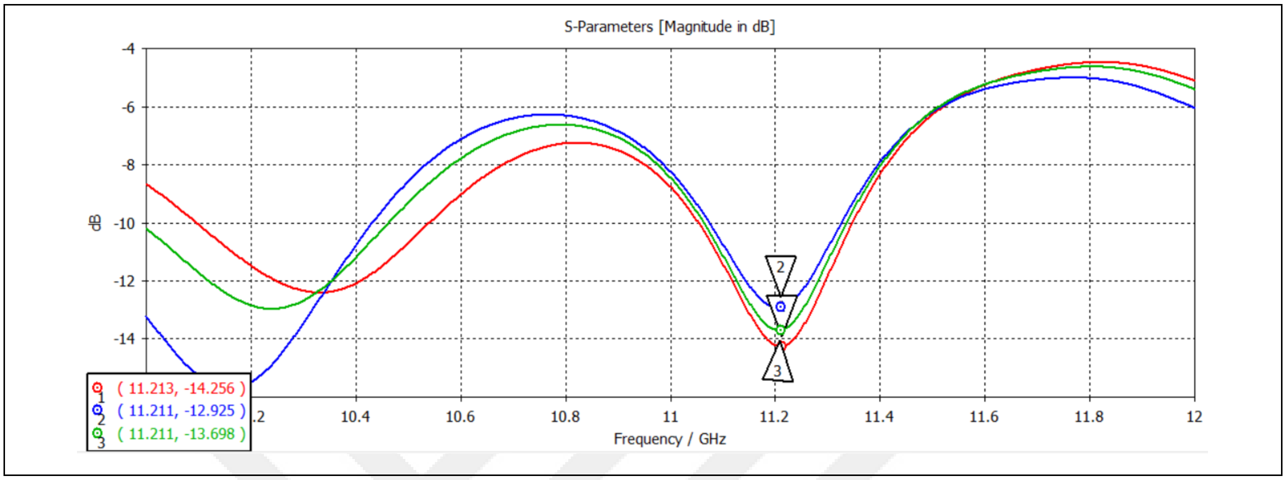

Figure 4.3 Return Loss Response for Different feedline width

Table 4.2: Return Loss Response for Different feedline width

Feedline width (mm)	Frequency (GHz)	Return loss (dB)
1.5	11.2	-14.256
2	11.2	-12.925
3	11.2	-13.668

4.3.3 Patch size

The frequency response changes depending on the patch's length. The center frequencies of both the patch and the aperture are lowered as the patch length increases. It's easier to hear higher frequencies when the patch is smaller. This may be seen in the S11 reading in Figure 4.4. The influence of frequency on patch width is similar to that of patch length, although less pronounced. For the same frequency shift as would occur with a 0.2 mm change in length, a 1 mm shift in breadth is required.

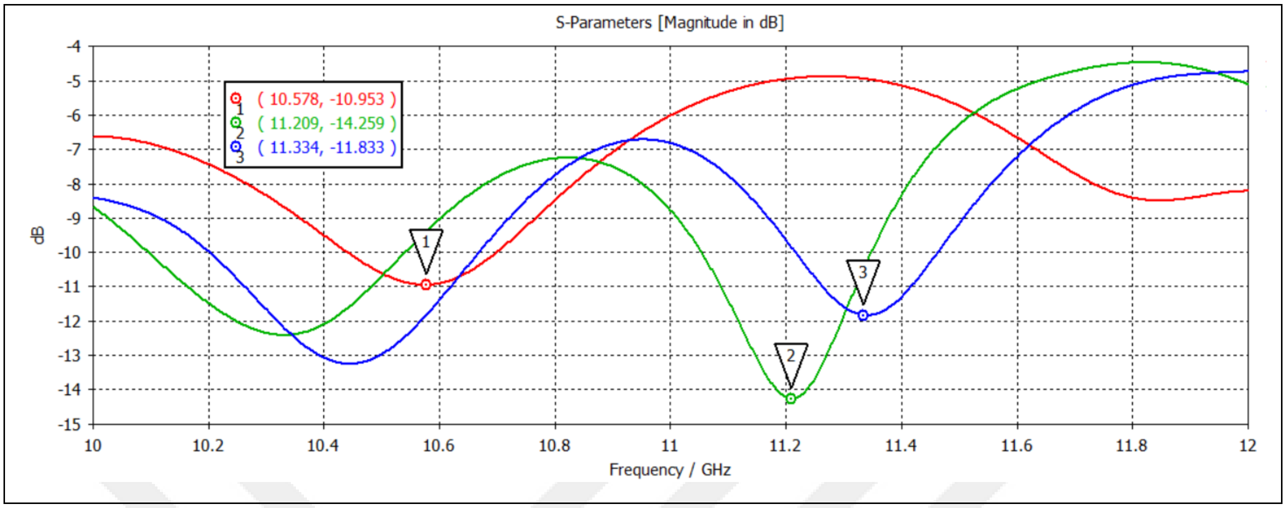

Figure 4.4: Return Loss Response for Different patch size

Table 4.3: Return Loss Response for Different patch size

Patch (mm)	Frequency (GHz)	Return loss (dB)
28 x 28	11.2	-14.259
27 x 27.8	11.334	-11.833
28 x 27.6	10.578	-10.953

4.4 FINAL DESIGN AFTER TUNING

After checking and comparing all results, dimensions of the design is specified to get the best return loss at 11.2 GHz (figure 4.5). The thickness of the substrate is 2 mm.

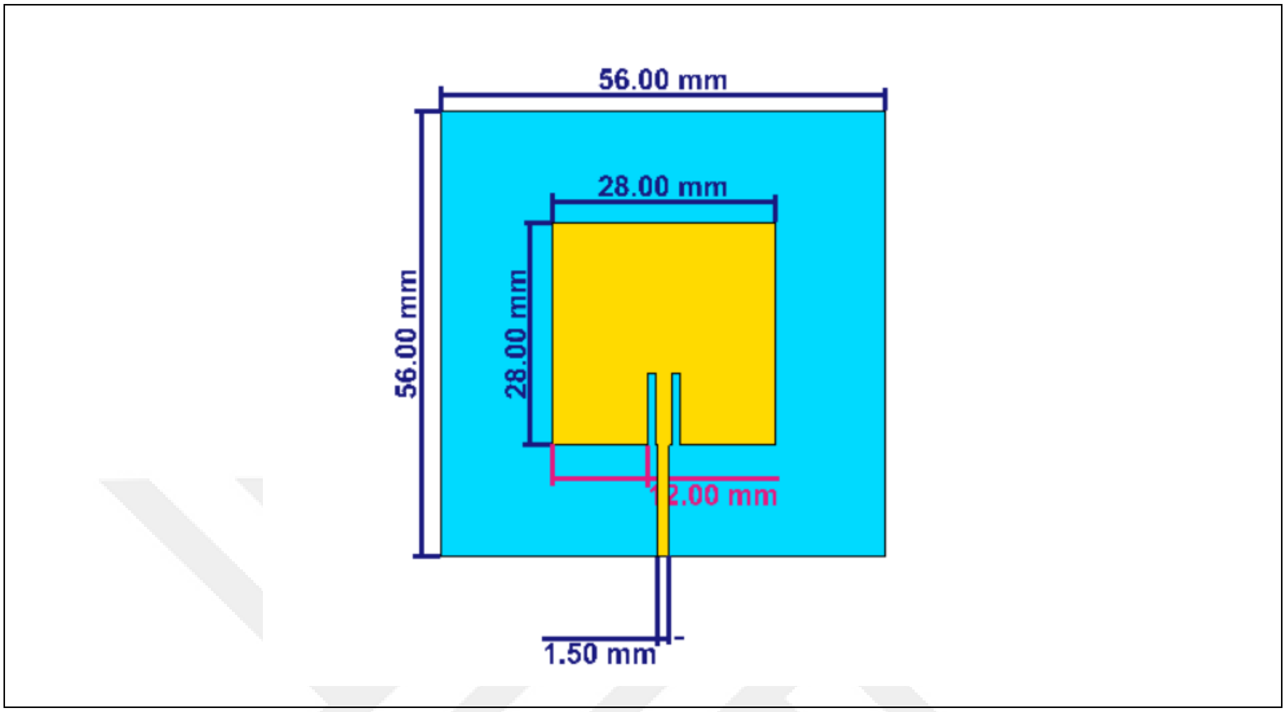

Figure 4.5: Final Design

4.5 RESULTS

Figure 4.6 shows the return loss of the antenna. Figure 4.7 represents the VSWR results which is less than 2. Figure 4.8, 4.9, 4.10 and 4.11 represents the 3d results for gain, directivity, realized gain and the power flow of the antenna respectively.

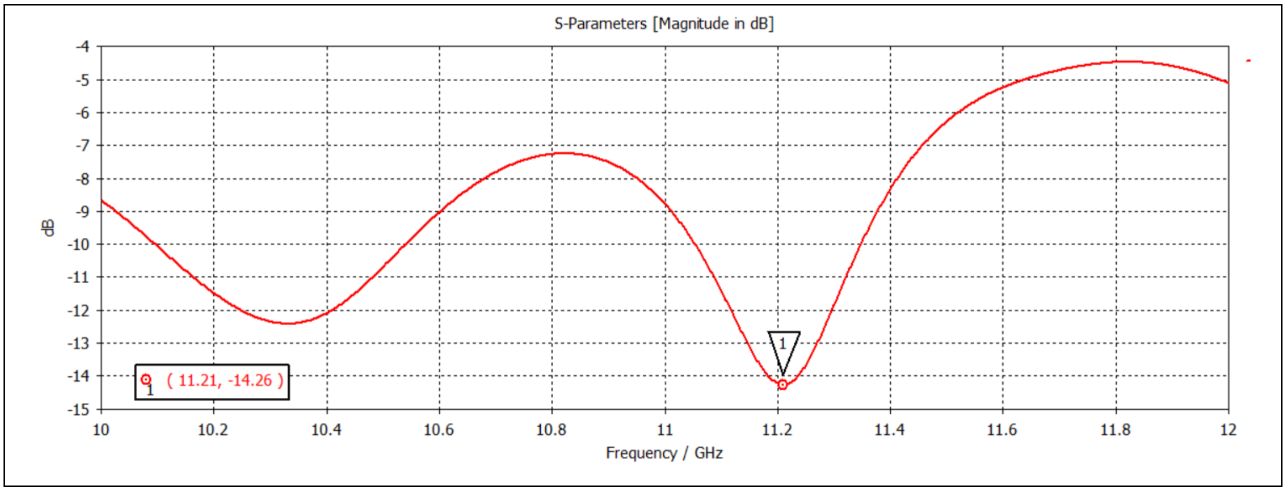

Figure 4.6: Return loss

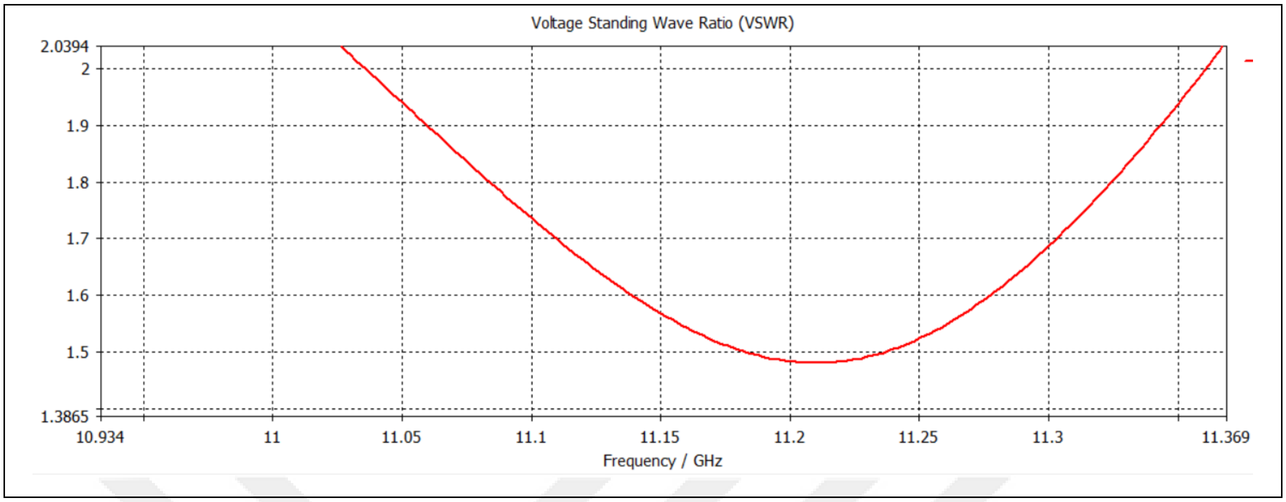

Figure 4.7: VSWR

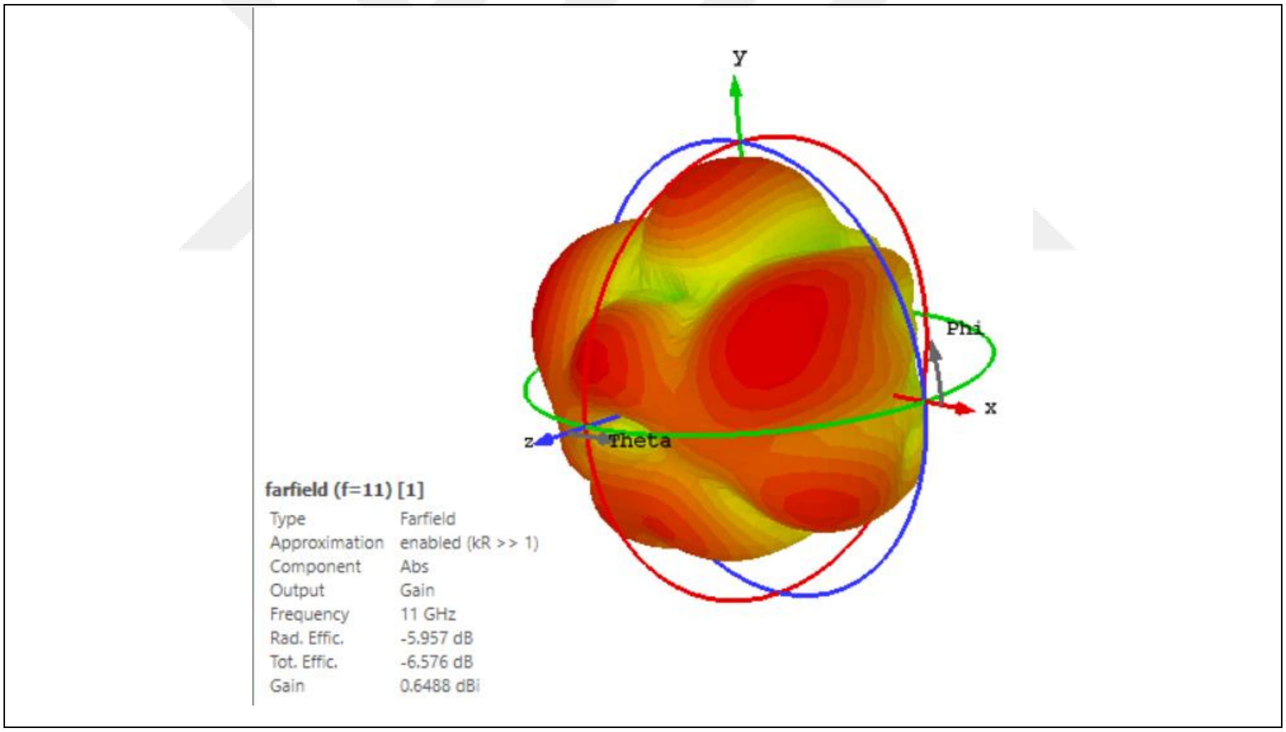

Figure 4.8: Gain

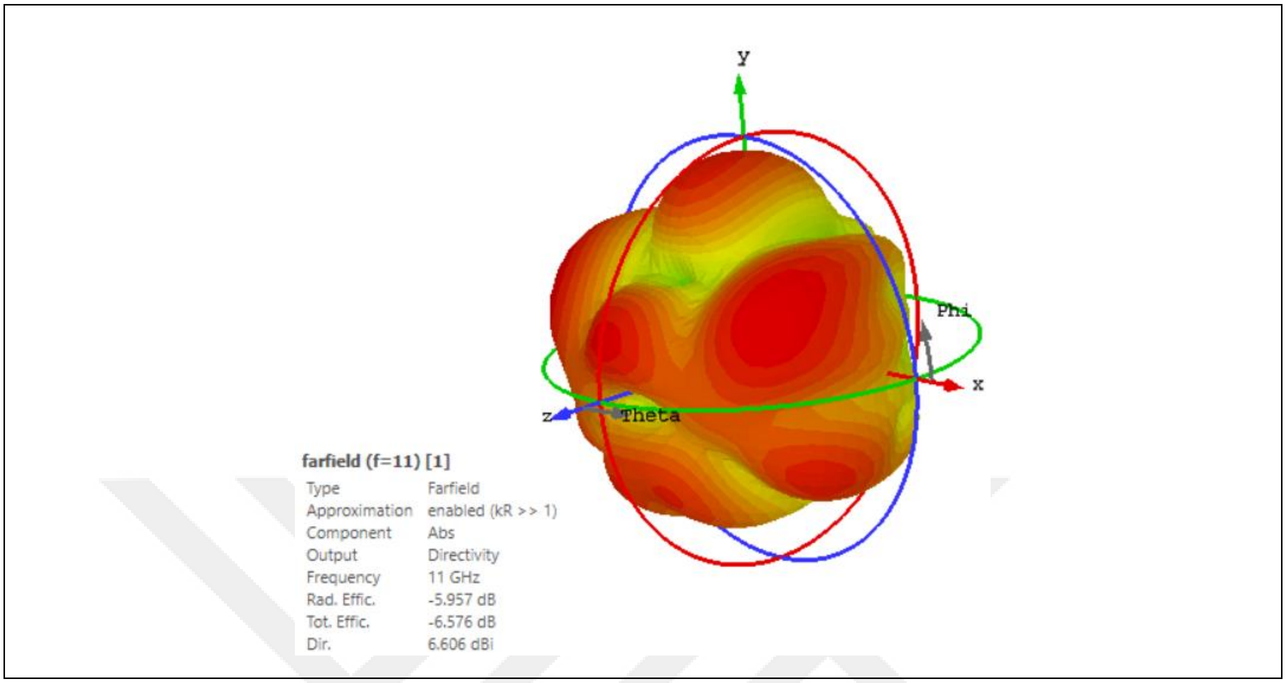

Figure 4.9: Directivity

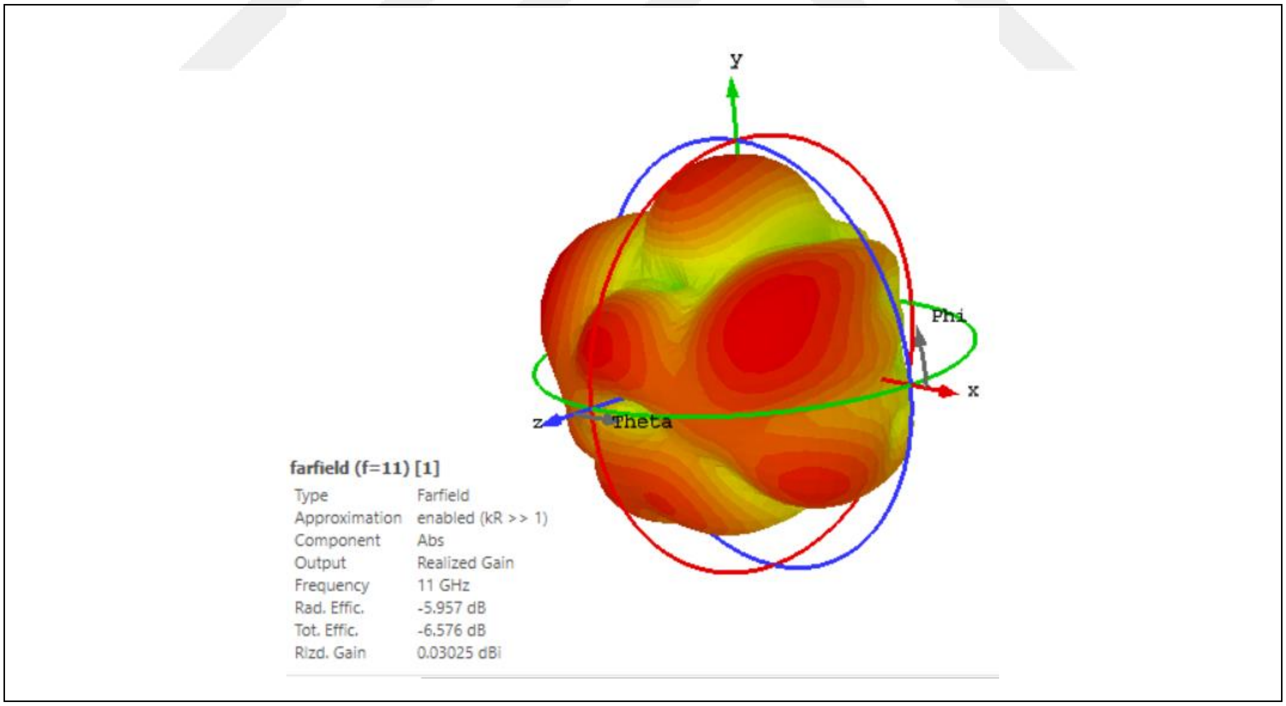

Figure 4.10: Realized gain

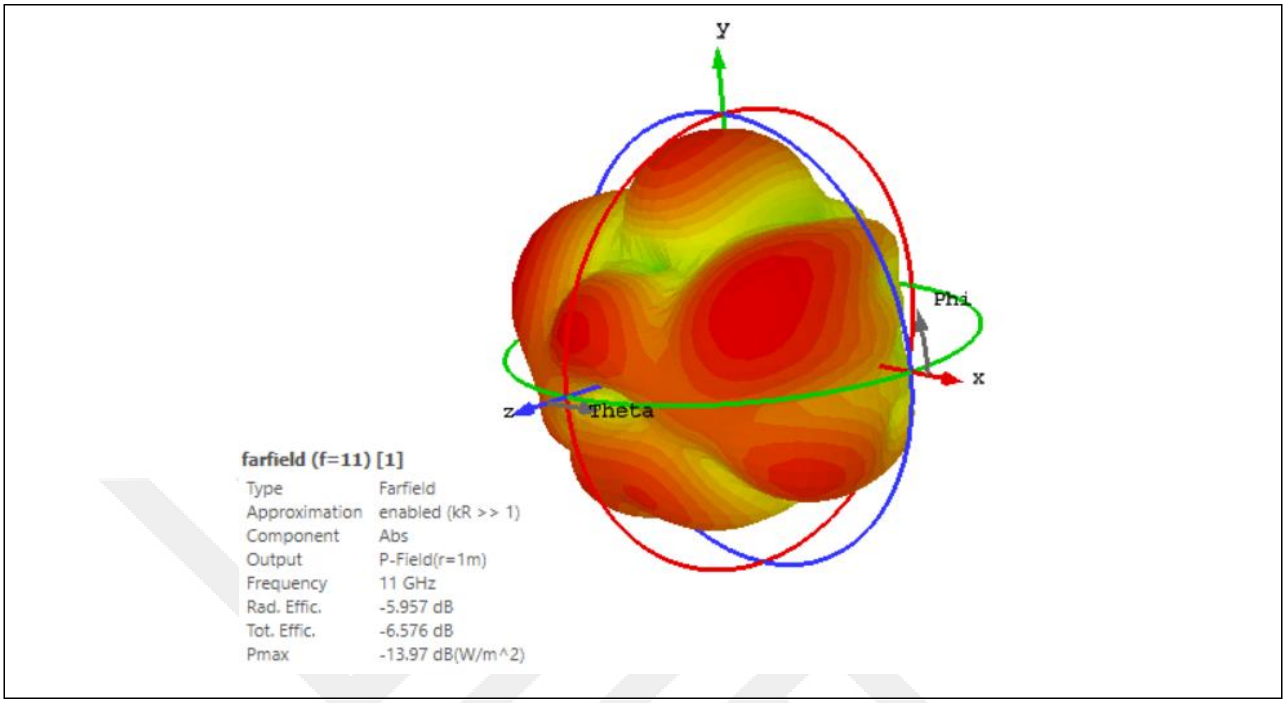

Figure 4.11: Power flow

5. CONCLUSION

In order to produce and evaluate a large selection of patch antenna designs for the Kuband (Kurtz-under-band) frequency range, simulations were run in CST studio. The frequency range that falls between 10.7 and 12.75 gigahertz is referred known as the "Kurtz-under-band," or simply "Kuband."

When constructing an MPA array for satellite communication, it is important to give careful consideration to a number of important factors, including the architecture of the array's patch components, the number of frequencies that will be utilized, whether wide-band or multiple-frequency operation will be utilized, and the type of polarization that will be utilized. The following are some additional things to take into account; nevertheless, this list is not exhaustive.

If the patch is going to be compatible with this infrastructure, its frequency range will need to be modified such that it operates in the Ku band. Because the use of a horizontal feed might potentially add complexity to the building of an antenna array, a vertical feed is almost always utilized instead. It is necessary to make a decision on the feeding mechanism in advance in order for the antenna to properly operate throughout a broad frequency range. It is necessary for the antenna to be able to handle both downlink and uplink Ku-band communications. What we're talking about here is a range from 10.7 to 12.75 GHz in terms of frequency (14 to 14.5 GHz). It is essential to give careful consideration to both the polarization of the antenna as well as its capability of switching polarizations. When assessing the electromagnetic properties, the complexity of the manufacturing process is an important factor to take into consideration.

For the purpose of evaluating the patch antenna design, a mathematical model of the patch element and the feed that is associated with it is necessary. At this point, it should be possible to acquire a comprehensive electromagnetic description of the antenna. It is essential to take into consideration potential migrations to new frequency bands in the future while planning the antenna feed and tuning methods for a wide-band or dual-band patch antenna. The skills that were acquired throughout the process of constructing and optimizing the multi-purpose antenna for the Ku-band might be applied to the creation of new antenna designs that are optimized for usage at a number of other frequencies.

This thesis may be broken down into five primary sections. The purpose of the first chapter is to provide an overview of the motivation for the study, the methodology, and the expected conclusions.

The literature evaluation of pertinent earlier work takes up the majority of the second part of the paper. The results of this study provide a foundational understanding of the potential uses of laser radar systems. In great detail, the following topics are covered in the thesis: antennas; microstrip circuits; electromagnetic theory; the coordinate system; and nomenclature.

In the next part, we will go even further into the strategy. In the third chapter, we will analyze whether or not these objectives can be accomplished by utilizing this strategy. The design and simulation program has a number of capabilities, and some of these functions are discussed. In Chapter 3, not only are the parameters of the tuned antenna described, but also the parameters of the design and the results of the simulation.

The findings of the research are discussed in Chapter 4. In this section, we will present the results and discuss what those results signify. The modeling results for the antenna element that was fitted with a patch rector are presented. Following an analysis of how the myriad antenna components interact with one another, Chapter 4 delves into the process of designing and adjusting the antenna.

The conclusion of the narrative and a recap of its events are presented in the fifth and final chapter. In this article, we discussed the difficulties associated with project management as well as the responsibilities performed by a variety of individuals and organizations.

A microstrip rectangular patch antenna is proposed and simulated within the scope of this thesis. Both the gain and the efficiency are rather remarkable, and the return loss is lower than -14 dB.

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APPENDIX A

APPENDIX TITLE

Paragraph. You must include an appendix within your thesis document, if you are including supplemental material in your submission, such as: overall description of the subject matter; materials that help clarify your research, but do not belong in the main text; questionnaires you have created; detailed information on surveys, interviews, etc.; tables, figures, or instruments that do not belong in the main text; copies of relevant letters and forms (permission letters to reproduce or adapt images, instruments for research, or other copyrighted materials, approval document issued by the ethical committee); any further information that is not immediately needed to prove your argument can be included in an appendix. Data displays should be presented in the appendix following the same order they first appear in the main text. If appendices include tables or figures, they should be treated as they would be in the main text. The appendices must comply with all formatting requirements you have followed with your thesis.

A.1 APPENDIX FIRST-LEVEL SUBHEADING

Paragraph.

A.1.1 Appendix Second-Level Subheading

Paragraph.