**Ministry of Higher Education and Scientific Research**

**University of Babylon**

**College of Engineering**

# EFFECT OF PATCH SHAPE ON PROPERTIES OF MICROSTRIP ANTENNAS

**A project**

**Submitted to the College of Engineering/University of Babylon as Partial Fulfillment of the Requirements for the Degree of Higher Diploma in Engineering/Electrical Engineering.**

***By***

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**2022 A.D.** **1443 A.H.**

بسم الله الرحمن الرحيم

نَرْفَعُ دَرَجَاتٍ مَّن نَّشَاءُ وَفَوْقَ كُلِّ ذِي عِلْمٍ عَلِيمٌ

صدق الله العلي العظيم

سورة يوسف – آية ( 76)

# *Supervisor Certificate*

I certify that this project entitled **"Effect Of Patch Shape On Properties Of Microstrip Antennas"** was prepared by **Wael Hamid Jadoa Abdallah** under my supervision at the Department of Electrical Engineering, College of Engineering, University of Babylon, as a partial fulfillment of the requirements for the degree of Higher Diploma of Science in Electrical Engineering .

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## Examining Committee Certificate

We certify that we have read this project entitled **"Effect Of Patch Shape On Properties Of Microstrip Antennas"** and as an examining committee examined the student **Wael Hamid Jadoa Abdallah** in its contents and that in our opinion it meets standard of a project for the degree of Higher Diploma Science in Electrical Engineering.

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**Date: / / 2022**

# *Dedication*

*To my mother ... source of my courage and*

*inspiration.*

*To  my family …who always give me support and*

*love .*

*To my friends... who share my sadness before my joy.*

*To my professors …who gave me knowledge.*

*To the students of science ... in all parts of the world.*

*To all those ,I dedicate this work.*

*WAEL*
*2022*

# *Acknowledgements*

*Foremost, I will repeat my lonely prayer "please, my Allah don't left my hand even if I left your hand". I would like to express my gratitude and thanks to* ***ALLAH****, who answered my prayers and bestowed upon me abundant blessings, including the ability to complete my study.*

*I wish to express my deepest thanks to my supervisor,* ***Asst. Prof. Dr. Haider Sahib Al-Mumen*** *for the guidance and invaluable information he provided to me and continuous encouragement during the preparation for this research.*

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*Finally, I owe a special thanks and sincere gratitude to my family who was behind me and prepared all the conditions that would help me study without hesitation, especially* ***my FATHER****, who was always the watchful eye that guard me.*

***WAEL***

***2022***

# Abstract

Conventional microstrip antennas have a conducting patch printed on a grounded microwave substrate, they also have the attractive features of low profile, light weight, easy fabrication, and conformability to host surface. However, micro strip antennas (MSA) inherently have a narrow bandwidth, and bandwidth enhancement is usually demanded for practical applications. In addition, applications in present-day mobile communication systems usually require smaller antenna size in order to meet the miniaturization requirements of mobile units. Thus, size reduction and bandwidth enhancement have been basically taken into consideration for practical applications of microstrip antennas design.

The analytical models of the rectangular microstrip antenna and the theoretical calculate computer simulation technology (CST) program have been presented. Also the effect of the parameters of the conventional rectangular microstrip antenna on microstrip antenna characteristics have been studied; these parametric studies have been done using CST software at operating frequency 2.4GHz

Simulations were performed on (Flame Retardant) FR4 substrate patches in rectangular and circular shapes. the substrate was preserved at the same thickness of 1.6 mm throughout All of the MSAs' simulation results were compared, including bandwidth, efficiency, return loss curves, and radiation patterns. All simulated microstrip antennas have a resonance frequency of 2.4 GHz.

The most efficient antenna was a circular microstrip antenna with return loss about (-18.7dB) in single element. The biggest realized gain was likewise found in the same MSA. The MSA was found to be capable of operating at 2.4 GHz. Other than the forms utilized in the study, additional

shapes can be investigated, such as an elliptical quarter circle. Higher gain can be achieved by using substrates with a lower directivity. A substrate having a high dielectric constant, such as silicon, can be used to minimize the size of a microstrip antenna. Array of antenna patches of these shapes should also be studied because they produce the higher overall gain.

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# List of Symbols

| | |
|---|---|
| $t$ | Thickness of Metallic Strip (Patch) |

| | |
|---|---|
| $\lambda_0$ | Free Space Wavelength |
| $h$ | Thickness of Substrate Material |
| $L$ | Length of Element (Patch) |
| $W$ | Width of Element (Patch) |
| $\lambda_d$ | Wavelength in Dielectric (Substrate) |
| $\varepsilon_r$ | Dielectric Constant of Substrate |
| $f_r$ | Resonant Frequency |
| $\tan\delta$ | Dielectric Loss Tangent |
| $\varepsilon_{re}$ | Effective Dielectric Constant |
| $c_0$ | Speed of the Light |
| $\Delta L$ | Extension in Element Length |
| $L_e$ | Effective Length of the Patch |
| $\mu$ | Permeability |
| $\varepsilon$ | Permittivity |
| $\gamma$ | Propagation Constant |
| $\alpha$ | Attenuation Constant |
| $\beta_d$ | Dielectric Phase Constant |
| $Z_0$ | Characteristic Impedance |
| $Y_0$ | Characteristic Admittance |
| $Y_S$ | Self-Admittance |
| $G_S$ | Self-Conductance |
| $B_S$ | Self Sucepetance |
| $\beta_0$ | Free Space Phase Constant |
| $G_m$ | Mutual Conductance |
| $g_m$ | Normalized Mutual Conductance |
| $J_0$ | Zero order Bessel Function |
| $Y_m$ | Mutual Admittance |
| E | Electric Field Density |
| H | Magnetic Field Density |
| k | Wave Number |
| $\omega$ | Angular frequency |
| AF | Array Factor |
| $V_0$ | Voltage across the Slot |
| $D_0$ | Maximum Directivity |
| $D_{AF}$ | Directivity of Array Factor AF |
| $U_0$ | Radiation Intensity of an Isotropic Source |
| $U_{\max}$ | Maximum Radiation Intensity |
| $P_{rad}$ | Average Power Radiated by an Antenna |
| $e_r$ | Radiation Efficiency |

| | |
|---|---|
| G | Gain of Antenna |
| $\theta_{BE}$ | Half-power Beam Width in E-plane |
| $\theta_{BH}$ | Half-power Beam Width in H-plane |
| $R_r$ | Radiation Resistance |
| Q | Quality Factor |
| $\sigma$ | Conductivity |
| $\Delta f$ | Frequency Deviation |
| R | Resistance |
| $\rho$ | Resistivity |
| $\Gamma$ | Reflection Coefficient |
| $Z_{in}$ | Input Impedance |
| $\eta$ | Antenna Efficiency |
| $L_g$ | Length of Antenna Ground Plane |

# List of Abbreviations

| | |
|---|---|
| RMSA | Rectangular microstrip antenna |
| BW | Bandwidth |
| FEM | Finite Element Method |
| FR4 | Flame Retardant |
| GPS | Global Positioning of Satellite |
| GSM | Global System of Mobile Communication |
| CST | Computer  Technology |
| MSA | Microstrip Simulation  Antenna |
| MSC | Mobile Satellite Communication |
| MPA | Microstrip Patch Antenna |
| PCB | Printed Circuit Board |
| TEM | Transvers Electric Mode |
| VSWR | Voltage Standing Wave Ratio |
| WLAN | Wireless Local Area Network |
| WiFi | Wireless Fidelity |

# CHAPTER ONE

# INTRODUTION

## 1.1.Introduction:

An antenna is a component of a transmitting and receiving system[1]. Either receiving or radiating electromagnetic waves can be done using the same system. antenna is a device that converts transmission line signals into electromagnetic field space, which is composed to opposing magnetic & electric field patterns [2].

When the velocity of charge increases or decreases as a result of a time-varying current, radiation occurs. Radiation happens when charges is moving at a non-uniform rate along conductor.

If the conducting wire is curved, electrons are traveling at a constant pace, radiation will occur , radiation happens when a charges oscillated within time in a straight conductor [3] .

Figure 1.1 shows how to connect a voltage source to two conducting wires on the transmission line to make an antenna work**.**

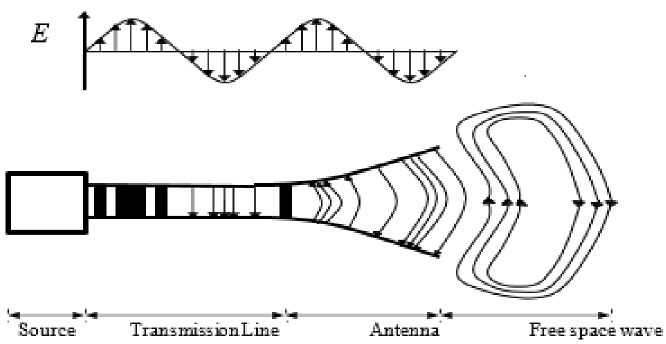


**Figure 1.1:** Radiation of an Antenna

When a sinusoidal voltage is placed in a transmission line, a sinusoidal electric field is formed. The line of force refers the strength of the magnetic field. electrons in wire occur by this electric line of force. Charge flow results in current, which creates magnetic field. Electromagnetic waves are created by flow of time-varying magnetic and electric fields in conductor. When waves come close to an open area, they form free waves, As a result, the field line's open ends are joined [3].

As electromagnetic waves inter space, the charges inside the line and antenna keep them going Before interring space efficiency is highly determined by the characteristics of the receiving and transmitting antennas. MSA provide several advantages over other antennas, as size, weight, and simple to integration with other communication devices, making MSAs ideal for wireless communication systems [4]. Kumar and Ray in(2003) are [5] mention the following benefits:

- Planar and non-planar surfaces can be conformed to.
- When put on stiff surfaces, it is mechanically durable.
- They can polarize in both linear and circular directions.
- Dual and triple frequency capabilities are available.

The MSA on the other hand, has a wide bandwidth calculated by increasing thickness of substrate. Because of the lowest dielectric constant are chosen the microstrip patch emits the most radiation, substrate [5]. Because it is easier to find and obtain beam scanning from the patch, the most common shapes are round, square, and rectangle[6].

## 1.2 Objectives

- To create and test MSA for use in 2.4 GHz applications.
- Analyses CST software were used to model and simulate, circular, and rectangular (MSA).
- To adjust the frequency and construct the best simulation results microstrip antenna (MSA).

## 1.3 Advantages and Disadvantages of MSA

The microstrip antennas have several advantages compared to the conventional microwave antennas, some of the principal advantages of the microstrip antennas compared to the conventional microwave antennas are [8]:

• The microstrip antennas lightweight, low volume and thin profile configuration make them easily incorporated into any package.

• The low profile planar configuration of the antennas can be easily made conformal to host surface.

• The low fabrication cost of the microstrip antenna it easy to manufactured in large quantities.

• The microstrip antenna support both the linear as well as the circular polarization.

• They can be easily integrated with the microwave integrated circuits (MICs).

• They can be made compact for personal mobile communication

• Capable of dual and triple frequency operations and provides flexibility to be constructed in any shape.

• Mechanically robust when mounted on rigid surfaces.

However, the microstrip antennas also have some limitations compared to conventional microwave antennas [7]. These limitations are mentioned bellow:

- Narrow bandwidth and associated tolerance problems,
- Somewhat lower gain (~6dB),
- Large ohmic loss in the feed structure of array,
- Most microstrip antennas radiate into half-space,
- Polarization purity is difficult to achieve,
- Poor end-fire radiator,
- Extraneous radiation from feeds and junctions,
- Lower power handling capability (~100W),
- Excitation of surface waves,

There are ways to minimize the effect of some of these limitations. For example, the bandwidth can be increased by using special technique , and surface wave excitation may be suppressed or eliminated by exercising care during design and fabrication.

**The following are some of their key drawbacks:**

- Limited bandwidth
- Ineffectiveness.
- Gain is minimal.
- Power handling capacity is limited.
- Excitation by surface waves.

## 1.4 Applications

The performance and durability of MSA are well-known. MSA are used in a variety of sectors, including medicine, satellites, and military equipment such as rockets, aircraft, and missiles, among others. Due to the inexpensive cost of the substrate material and manufacture, they are already blooming in the commercial realm. A microstrip patch antenna can be used in a variety of situations. The following are some of these applications:[9]

### 1.4.1 Application for mobile and satellite communication:

Small, low-profile, low-cost antennas are required for mobile communication. A variety of MSA had devised for use in systems for mobile communication, and they meet all of the requirements. Circular polarization is necessary for satellite and can be achieved using a square or circular patch as shown in figure(1.2) **[9]**

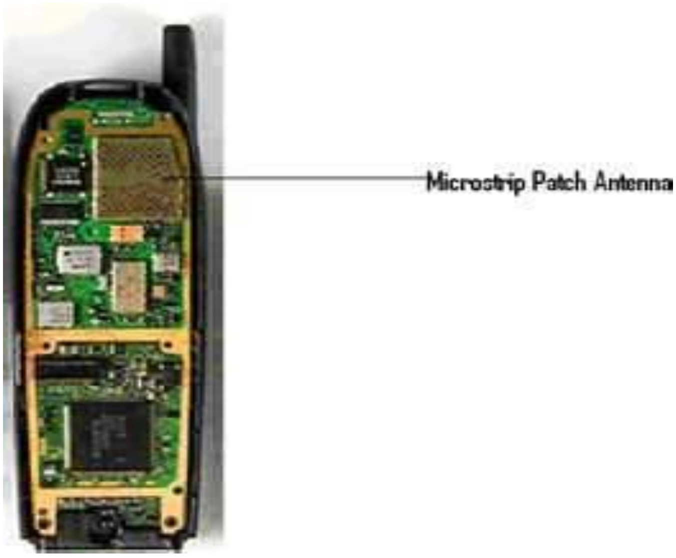


Figure (1.2) MSA for Mobile

### 1.4.2 Applications for global positioning systems

For the global positioning system, MSA with a high permettivity sintered substrate material are used (GPS). These circularly polarized antennas are small and lightweight as shown in figure(1.3)[9]**;**

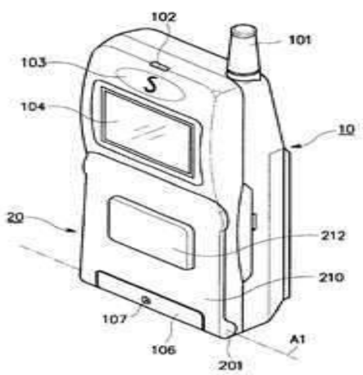


**Figure 1.3:** GPS system, a microstrip antenna.

### 1.4.3 RFID stands for radio frequency identification.

RFID is employed in a variety of applications, including mobile communication, logistics, manufacturing, transportation, and healthcare. RFID systems use frequencies ranging from 30 Hz to 5.8 GHZ. transponder and reader are the basic components of an RFID system as shown in figure(1.4)[9]

**figure(1.4)** in RFID, a microstrip antenna is employed**.**

### 1.4.4 Microwave access (WiMax) interoperability:

The IEEE 802.16 standard is referred as WiMax. It has a theoretical range of 30 miles and a data rate of 70 megabits per second. MSA produce three resonant types of mode at 2.7, 3.3, and 5.3 GHz, allowing them to be used in Wi Max-compliant communication equipment as shown in figure(1.5)[9]

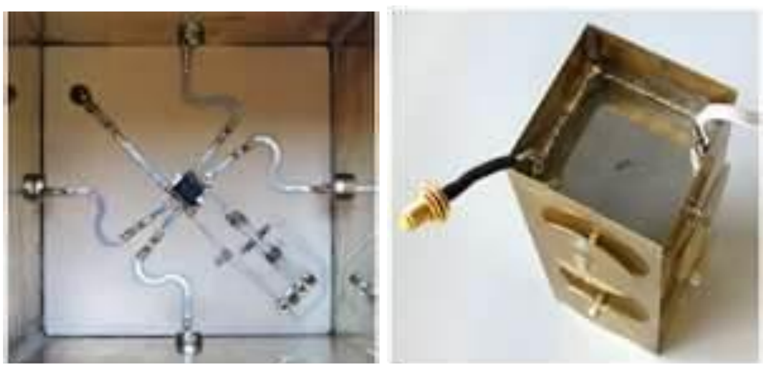

**figure (1.5)** : MSA used in Wi max

### 1.4.5 Radar application:

Moving targets, such as people and automobiles, can be detected using radar. MSA are an excellent option. comparison to conventional antennas, photography-based manufacturing technology allows for the mass manufacture of MSA with reproducible performance at a little cost and time frame as shown in figure(1.6)[9]

**Figure 1.6**: MSA used in radar

### 1.4.6 Reduced size MSA for Bluetooth Applications:

In this case, the MSA operates in the ISM Band from 2400 to 2484 MHZ. Despite the presence of an air substrate, MSA occupies a modest volume of 33.36.60.8mm3 as shown in figure(1.7)[9]

**figure 1.7**: MSA utilized in Bluetooth has been reduced in size.

### 1.4.7 Wireless communication with a broadband S shaped MSA :

This is a broadband S-shaped MSA with a single patch. A coaxial feed is used to feed a microstrip S-shaped patch antenna. The antenna is made by putting two slots into a rotated square patch, which resembles the letter 'S' in English. The antenna's bandwidth is improved due to the slots and thick substrate as shown in figure(1.8) [9]

**figure (1.8)**: As a Broadband Antenna ,a Microstrip Antenna is employed

## 1.5 Literature Review

[33] Ahmed et al. (2017) designed a Microstrip antenna using a RO4350B hydrocarbon ceramic laminates substrate. The dielectric constant of the substrate was 3.66. The gain of MSA was 3.08 dB. RMSA was fed using a microstrip line feed approach.

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## 1.4.Outlines of the Study:

The present investigation comprises of five chapters and the overview of all the chapters are as below:

Chapter 1 gives an introduction, advantages and disadvantages, applications, and the literature review.

Chapter 2 presents the analysis of the rectangular microstrip antenna and circular patch , the theoretical calculation of the basic parameters, and their effects on the characteristics of the antenna.

Chapter 3 deals with the study, the design, and the implementation of rectangular microstrip antenna and circular patch with the simulation in CST software .

Chapter 4 deals with the study, the design, and the implementation of the rectangular microstrip antenna and circular patch with the simulation and the experimental results.

Chapter 5 includes some concluding remarks of the present work and some suggestions for future work.

# CHAPTER TWO

# Basic Concept of Microstrip Antenna

## 2.1. Introduction:

patch is an antenna produced by printed an element pattern in a metal vestige attached on insulating dielectric substrate, such as a printed circuit board (PCB), with a continuous metal strata bound on the other back face. The most popular MSA shapes are elliptical, rectangular, square, and circular. The dielectric constant, loss tangent, and substrate thickness are the key elements that influence the microstrip antenna's performance. Thick substrates radiation power become high, impedance bandwidth, cross polarization, and conduction loss because they are mechanically strong. Antenna efficiency is reduced due to high tangent loss, which increases dielectric loss. The bandwidth and gain value of a substrate decrease when dielectric constant substrate high.

## 2.2 Antenna Fundamental

### 2.2.1 Radiation Pattern

A depiction of an antenna's far field radiation characteristics as a function of the spatial coordinates given in rising angle and azimuth angle defines antenna's radiation pattern. This pattern plot is create using spatial coordinates. Radiation intensity is defined as the proportion of radiated power to the unit solid angle [3]. Isotropic antenna is a type of antenna that radiates evenly in all directions. The power density S is provided by formula 2.1 in any direction;[3]

$$s = \frac{\mathrm{P}}{4\pi r^2} \qquad (2.1)$$

where p is isotropic antenna's total energy radiated and the sphere radius r . Radiation intensity for isotropic antenna *Ui* is given by formula (2.2);

$$Ui = r^2\, S = \frac{P}{4\pi} \qquad (2.2)$$

Although an isotropic antenna is impossible to achieve. Practical antennas are directional, which means antennas radiate more energy in certain directions and less energy in others. Fig2.1 depicts a directional antenna's radiation pattern plot.

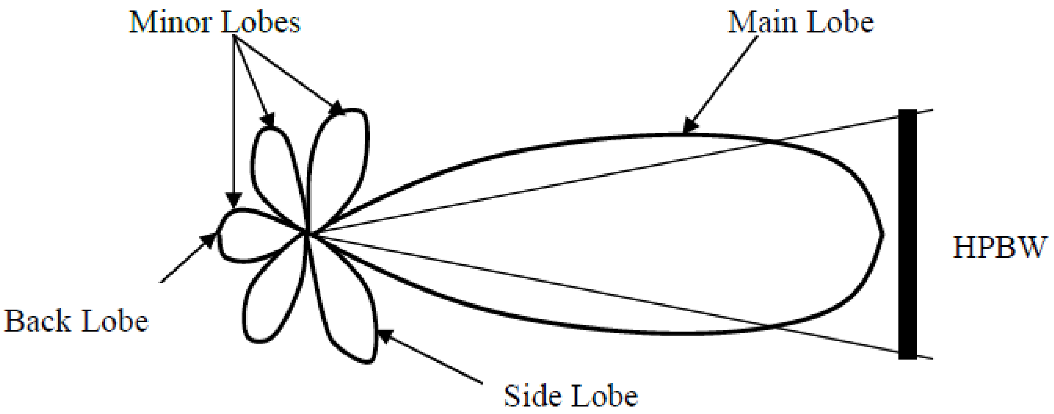



**Fig 2.1:** Directional Antenna's Radiation Pattern

From fig 2.1 we observe ;

• The angle subtended 1/2 power of the lobe where we have the maximum radiation 1/2 power beam width.

• The main lobe is one with the most powerful radiation direction.

• Mainer segment other than the primary lobe that signify radiation in undesirable directions.

• The rear lobe is located directly opposite of the major lobe .

• Side lobe is the smallest of the minor lobes and located adjacent to main lobe.

• Minor lobes are un-desirable in wireless systems,

### 2.2.2 Directivity

According to Balanis in 1997 [3], The ratio antenna's radiation strength in one direction to the main radiation intensity is referred to directivity. The directivity for omnidirectional source is the ratio of the radiation intensity towards a specific direction or position to that of an isotropic source. The equation(2.3) for directivity is :

$$D = \frac{4\pi U}{P} = \frac{U}{Ui} \qquad (2.3)$$

D signifies the directivity of an antenna and P denotes the energy radiated, Ui The radiation intensity of an isotropic source is denoted by, and the radiation intensity (U). The maximum intensity can be calculated using the equation if the direction of the highest intensity is known (2.4)[3] :

$$D_{max} = \frac{\mathrm{U_{max}}}{\mathrm{U}_i} = \frac{4\pi U_{max}}{\mathrm{P}} \qquad (2.4)$$

Dmax : highest directivity for antenna and, Umax : maximum radiation intensity for antenna, directivity of an antenna is independent of its orientation because ratio of tow intensities for particular radiation. directivity is measured in decibels. The radiation pattern of an antenna can be used to assess its directivity. antenna with a tiny main lobe has stronger directivity and is hence more directive than one with a broad main lobe.

### 2.2.3 Input Impedance

The impedance of an antenna at its terminals, or the voltage to current ratio at the pair of terminals, Balanis(1997) [3] defined it . Input impedance is ratio of the appropriate components of the electric and magnetic field in the location. Input impedance is calculated using the following formula(2.5):[3]

$$Z_{in} = R_{in} + JX_{in} \qquad (2.5)$$

The antenna input impedance is represented by Zin, the antenna resistance is represented by Rin, and the antenna reactance is represented by X in. The near-field power stored in the antenna is represented by X in, which is the imaginary component of impedance. resistive component for input resistance, produced loss and radiation resistance, is denoted by Rin. The power squandered in the loss resistance is lost as heat in the antenna due to dielectric or conducting losses, whereas power associated with radiation resistance will radiated from antenna.

### 2.2.4 Voltage Standing Wave Ratio

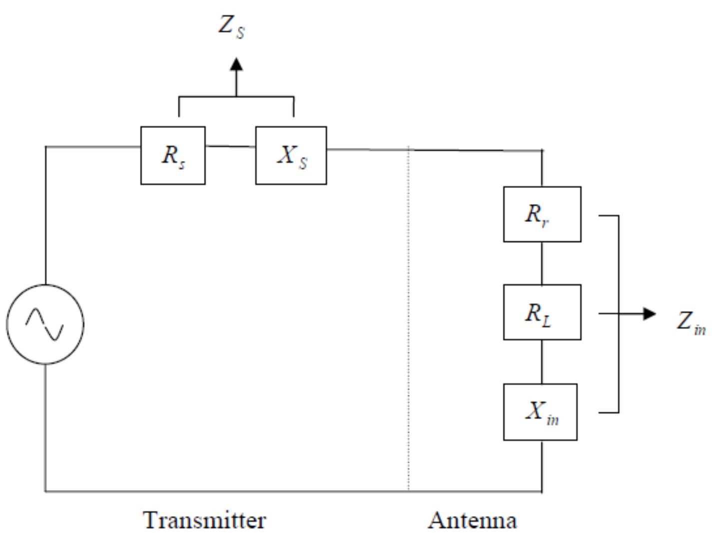



**fig 2.2** circuit of transmitting antenna

A maximum flow of power between antenna & transmitter is required for an antenna to be efficient. when antenna & transmitter impedances matched well, energy will transmit. most power is delivered when transmitter impedance is complex conjugate of the antenna impedance. Equation( 2.6) gives the condition:[11]

$$Z_{in} = Z_s^* \qquad (2.6)$$

Zin = Rin + jX in and ZS * = RS + jX S

standing waves are formed When electricity is reflected owing to a mismatch. gives equation for VSWR to characterize standing waves (2.7);[11]

$$VSWR = \frac{1+\Gamma}{1-\Gamma} \qquad (2.7)$$

Where

Γ is reflection coefficient,

VSWR is a measurement of the impedance mismatch between the antenna & transmitter. When the VSWR high , this means mismatch also high , and when the VSWR is unity, there is a perfect match. VSWR limitation lower 2 in order for it to radiate and transmit effectively.

## 2.2.5 Return Loss

measurement of what percentage of energy is missed in load, (return loss not reflected). When there is a mismatch between antenna and transmitter, the reflected wave causes a standing wave to occur. The return loss demonstrates how the antenna and transmitter were method. formula 2.8) is used to express the RL;

$$\mathrm{RL} = -20\log_{10}\Gamma \qquad (2.8)$$

The RL= ∞ This signifies that there is no power being returned or reflected. According to Nakar(2004) [12], a VSWR of 2 is permissible for an antenna to function adequately because it produces a return loss of -9.54dB.

## 2.2.6 Antenna Efficiency

Antenna Efficiency is a metric that takes in to account the losses that occur at the antenna's terminals as well as the structure. Balanis explains it thus way [3]. The efficiency factor accounts for wave reflection owing to mismatch, as conduction and dielectric losses.

The antenna's total efficiency is provided by equation (2.9);[3]

$$e_t = e_d \, e_c \, e_r \qquad (2.9)$$

Where $e_c$ conduction efficiency,

$e_r$ reflaction efficiancy ,

$e_d$dialectic efficiancy.

The conduction efficiency and reflection efficiency are from antenna radiation efficiency $e_{cd}$ which is defined as to radiation resistance$R_r$ to energy delivered to $R_L$ and $R_r$ expresed by the relationship (2.10)

$$e_{cd} = e_d \, e_c = \frac{R_r}{R_r + R_L} \qquad (2\ .10)$$

## 2.2.7 Antenna Gain

The antenna directivity is related to the antenna gain. The capacity of an antenna to radiate (E)significantly in one proffered direction relative to other directions is known as directivity. Because the gain is equal to the antenna's directivity, the efficiency of an isotropic radiator is 100 percent. an antenna gain is calculated using Equation (2.11)[3]

$$\boldsymbol{G}\ \Theta, \emptyset = \boldsymbol{e_{cd}}\ \boldsymbol{D}\ \Theta, \emptyset \qquad (\mathbf{2.11})$$

**G ; Gain**

## 2.2.8 Polarization

According to Balanis in 1997 [3], An electromagnetic wave's polarization is a property that indicates the direction of change ever time and is proportional to the magnitude of the electric field vector. Polarization of the field vector is another name for antenna polarization. The polarization of a wave is also determined by the direction and position of field with respect to the earth ground. Linear and circular polarization are two different kinds of polarization. Linear polarization is depicted in Figure 2.3.

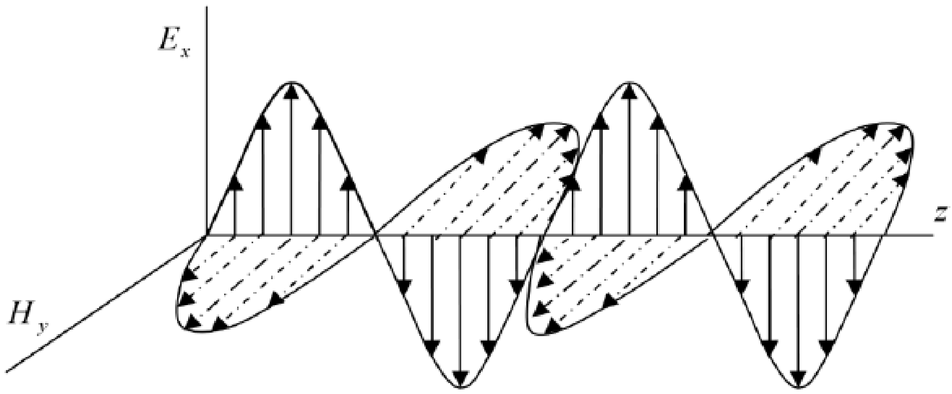



**figure 2.3** : Linearly Polarized

When vector of electric field travels buck and for long the line, it is said to be linearly polarized. When wave is circularly polarized, on the other hand, the electric field vector rotates along a circular direction while the length remains constant. As shown in figure 2.4, a wave is right hand circular polarized while moving clockwise and left hand circular polarized when moving anticlockwise.[3]

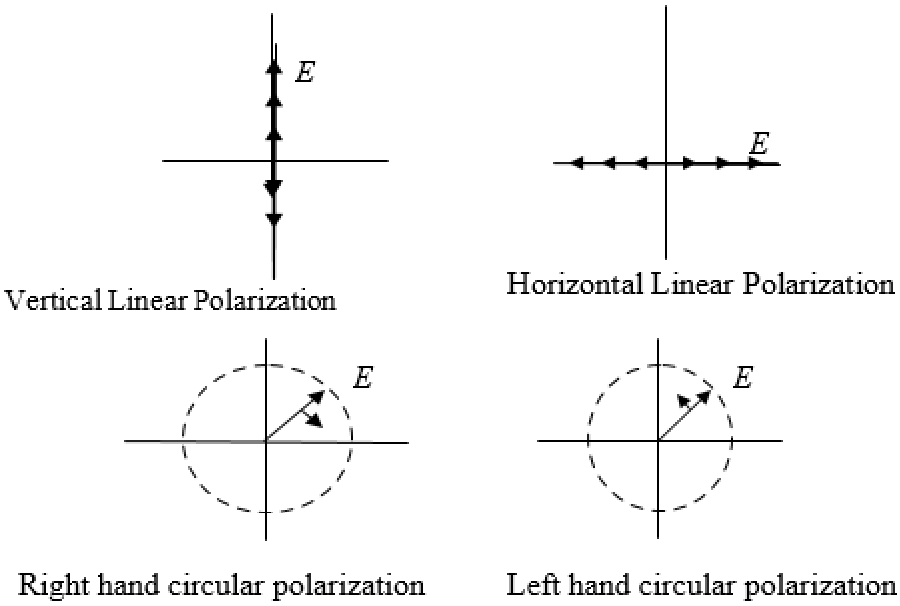



**figure 2.4** polarization scheme

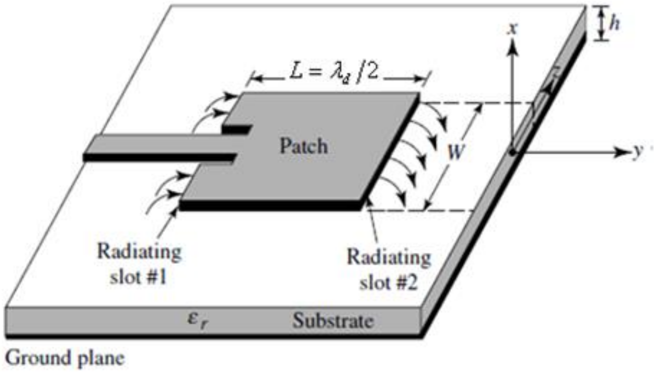
## 2.2.9 Bandwidth

range of electromagnetic frequencies throughout which antenna can effectively receive or transmit electromagnetic waves. Also known as bandwidth, it is a range of frequencies on either side of the resonant frequency with similar radiation patterns, input impedance, polarization, beam width, and gain value. VSWR is used to determine an antenna's efficiency. An antenna with a VSWR of 2 or less can perform well because the return loss is about -9.54dB .[3]

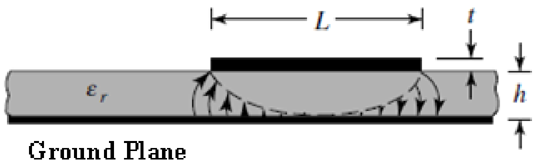
## 2.3. Basic Characteristics of MSA:

Microstrip antennas are made out of an extremely thin ( $t<<\lambda_0$ ) metallic mounted on a small friction of a wavelength ($h \gg \lambda_0$ , $usually\ 0.003\lambda_0 \leq h \leq 0.05\lambda_0$ ) above a ground plane, as shown in Figure 2.1(a)

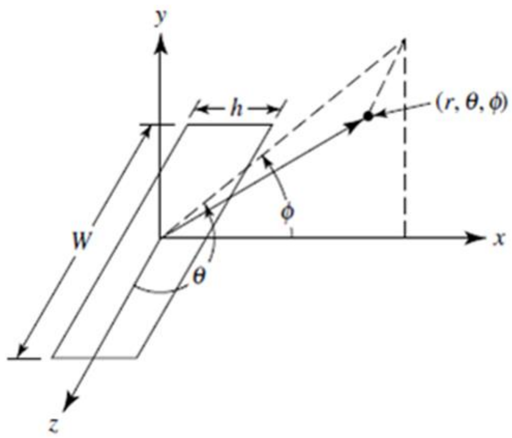
The pattern on the microstrip patch is designed to be as normal to the patch as possible (broadside radiator). [3]




(a) The microstrip antenna




(b) Side view




(c) Coordinate system for each radiating slot

**Figure 2.5.** The microstrip antenna and coordinate system

dielectric substrate, the radiating element and fed line are normally photo etched. any other shapes is possible for the radiating patch. The most frequent designs are square, rectangular, dipole (strip), and circular for two reasons: (1) their easy of analysis and manufacture, (2) appealing radiation properties, particularly low cross polarization radiation [10].

## 2.4. Microstrip Antenna Feed Technique:

Many ways used to feed the MSA. These approaches can be divided as: contacting method and non-contacting method. connecting element such as a micro strip line or a coaxial probe to feed RF power directly to the radiating patch, whereas the latter uses electromagnetic field coupling to transmit energy between the microstrip line and patch. The four must common fed techniques are microstrip line, coaxial prob. (touching), aperture coupling, and proximity coupling (non-contacting) [8].

### 2.4.1. Microstrip Line Feed:

As shown in Figure 2.6, a conducting strip is linked directly to the edge of patch in this sort of feed approach. The conducting strip is narrower than the patch, and The advantage of this form of feed arrangement is that the feed can be etched on the same substrate , resulting in a planer structure. patch's inset cut is used to math the impedance of the fed line to the patch without the usage of any additional matching devices. The inset feed is carefully managed to achieve this. As a result, this is a straightforward feeding system in terms of manufacturing, modeling, and impedance matching. Surface waves and spurious fed radiation increase as the thickness dielectric substrate used increases, limiting the antenna's bandwidth. The fed radiation can also produce cross-polarization[8].

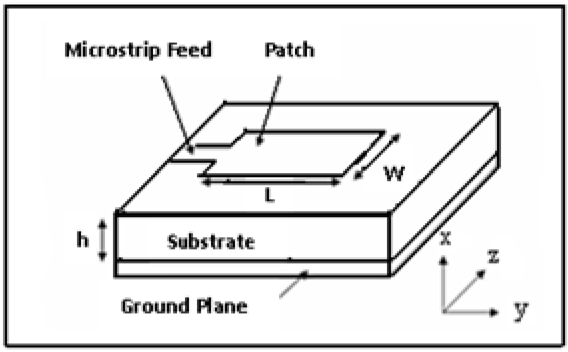



**Figure 2.6** Microstrip line feed

### 2.4.2. Coaxial Probe Feed:

A common way of feeding MSA is the caoxial feed, often known as the probe fed. As illustrated in Fig2.7, The caoxial connector's inter conductor passes through the dielectric and connects of radiating patch, where the outer conductor connects to the ground plane. fed system is simple to build and emits very little harmful radiation [8].

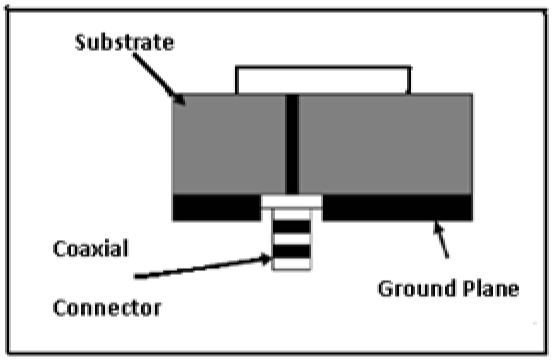



**Figure 2.7.** The probe fed RMSA

### 2.4.3. Aperture Coupled Feed:

The ground plane protects the radiating patch from the micro strip fed line, Fig(2.8). The patch is connected to the fed line via a slot or aperture in the ground plane. The coupling aperture is usually centered under patch due to the symmetry of the design, As a result, cross polarization is reduced. The form, size, and location of the aperture affect the amount of coupling .to maximize patch radiation, a thick, low dielectric constant material is utilized for the bottom substrate and a thin, high dielectric constant material is used for the top substrate. The main downside of this fed technology that it is difficult to manufacture because to the many layers, which also add to the antenna thickness. This feeding system likewise has a limited bandwidth [8].

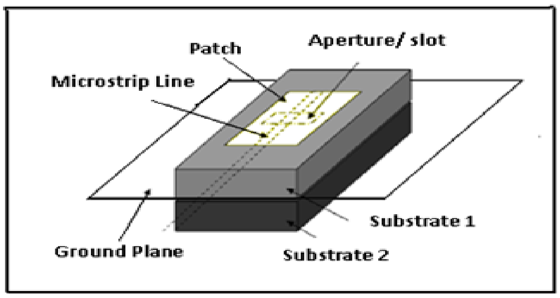



**Figure 2.8.** Rectangular MSA with aperture linked feed

### 2.4.4. Proximity Coupled Feed

The electromagnetic coupling strategy is feed technique. Figure (2.9) depicts the use of two dielectric substrates with the feed line running between them and the radiating patch on top of the upper substrate This feed technique prevents spurious feed radiation while simultaneously offering high bandwidth due to the overall increase in thickness of MSA . This approach also allows for the use of(2) dielectric media, one for the patch and the other for the fed line, to improve individual performance. Controlling the feed line length and the patch's width-to-line ratio allows for better matching. Because of the two dielectric layers that must be aligned properly, this feed system has a significant disadvantage in terms of fabrication. In addition, the antenna's overall thickness has increased [8].

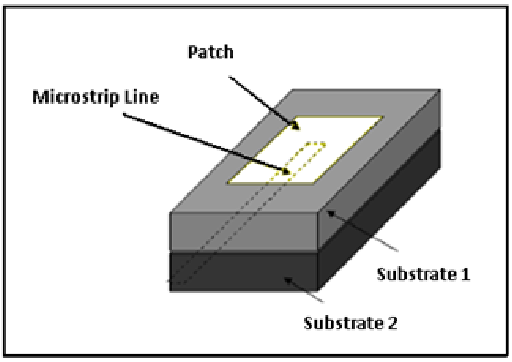



**Figure 2.9.** The proximity-coupled feed scheme

The characteristics of the various feed strategies are summarized in table (2.1);

**Table (2.1)** A comparison between different feed techniques

| Characteristics | Microstrip Line Feed | Coaxial Feed | Aperture Coupled Feed | Proximity Coupled Feed |
|---|---|---|---|---|
| **Spurious Feed Radiation** | More | More | Less | Minimum |
| **Reliability** | Better | Poor due to soldering | Good | Good |
| **Ease of Fabrication** | Easy | Soldering and Drilling is needed | Alignment Required | Alignment Required |
| **Impedance Matching** | Easy | Easy | Easy | Easy |
| **Bandwidth (Achieved with Impedance Matching)** | 2-5 % | 2-5 % | 2-5 % | 10-13 % |

The feed line approach was utilized in this study because it is simple to construct .

## 2.5 Transmission line model

Microstrip antenna is represented in this form by two slots of height (h) and width(W) separated by a transmission line of specific length. Some of field lines in figure(2.10) are in air, whereas the remainder travel through dielectric substrate.**[13]**

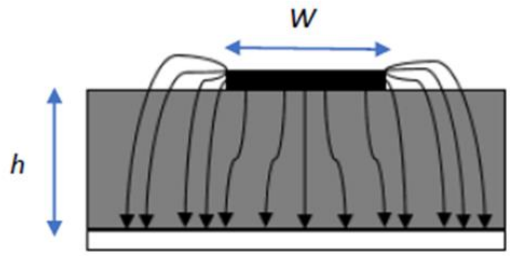



**Figure (2.10)** Electric Field Lines

Because of the phase velocities in the dielectric substrate and an air are different, the transmission line does not supported solely in the transverse electric magnetic mode of transmission. In this scenario, transmission mode is quasi transverse electric. in Figure (2.10) εreff which is calculated using formula (2.1) [13].

$$\varepsilon_{reff} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2}\left(1 + 12\frac{h}{w}\right)^{\frac{-1}{2}} \qquad (2.12)$$

when εreff is the constant of effective dielectric constant, h is substrate height , εr is the constant of dielectric substrate and W is width of patch . The dimensions of the patch along its length have now been extended on each end by a distance ΔL [14] as:

$$\Delta L = 0.412h\frac{\left(\varepsilon_{reff} + 0.3\right)\left(\frac{W}{h} + 0.264\right)}{\left(\varepsilon_{reff} - 0.258\right)\left(\frac{W}{h} + 0.8\right)}\,\varepsilon_{reff} \qquad (2.13)$$

The effective length of the patch L eff now becomes:

$$L_{eff} = L + \Delta L \qquad (2.14)$$

For a given resonance frequency fo , the effective length is given by [10] as:

$$L_{eff} = \frac{c}{2f_0\sqrt{\varepsilon_{reff}}} \qquad (2.15)$$

For a rectangular Microstrip patch antenna, the resonance frequency for any (TMmn) mode is given by [18] as:

$$f_0 = \frac{c}{2\sqrt{\varepsilon_{reff}}}\left[\left(\frac{m}{L}\right)^2 + \left(\frac{n}{W}\right)^2\right]^{1/2} \qquad (2.16)$$

Where m and n are modes along L and W respectively.

For efficient radiation, the width W is given by [19] as:

$$w = \frac{c}{2f_0\sqrt{\frac{(\varepsilon_r+1)}{2}}} \qquad (2.17)$$

## 2.6 Specifications for Design

The patch of MSA with the best characteristics was selected through comparison based on the simulated results from the CST software.

### 2.6.1 Determination of Rectangular Shaped MSADimensions

Rectangular patch as shown in figure(2.11);

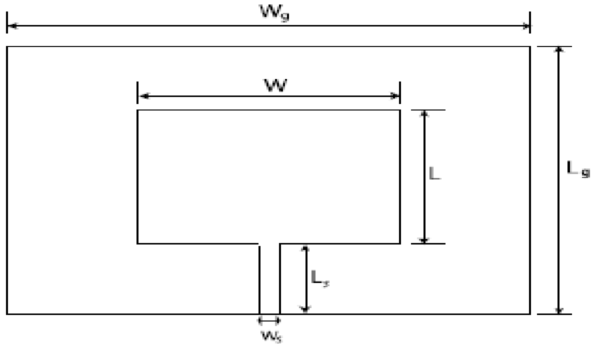



**Figure (2.11)** Rectangular Micro strip Patch Antenna

Equation (2.18) is used to calculate the patch's width (w) [20] .

$$W = \frac{1}{2f_r\sqrt{\mu_0\varepsilon_0}}\sqrt{\frac{2}{\varepsilon_r + 1}} \qquad (2.18)$$

The top view of Figure (2.12) depicts the effective length of patch, which includes electro-magnetic waves that extend beyond the patch's actual length.

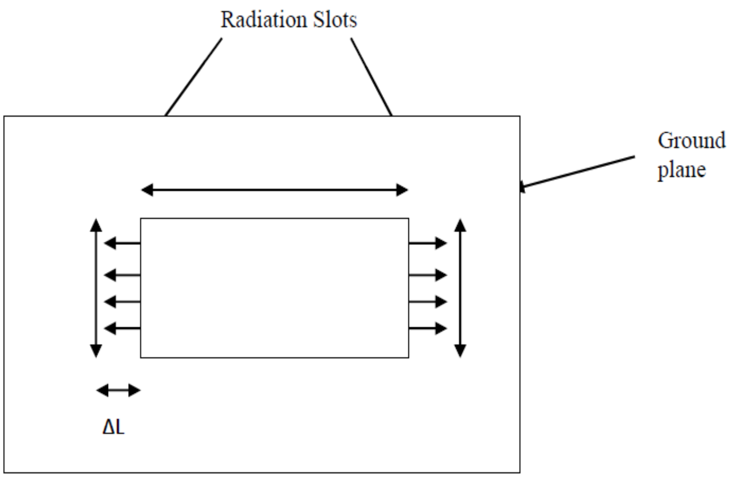



**Figure (2.12):** Effective Length diagram

The patch effective length is calculated using equation 2.13, which is the sum of the patch's actual length(l) and (Δl) the length owing to the field radiating from the radiating patch.[20]

The side view and movement of electromagnetic waves are shown in Figure (2.13), where h is the patch thickness.

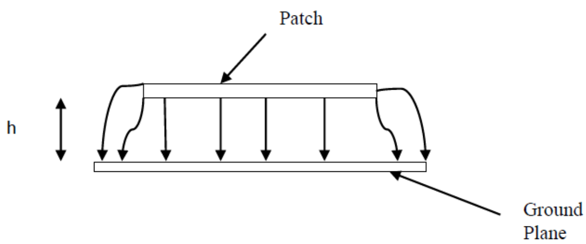



**figure (2.13)**: The Patch from the Side view

For another types of rectangular MSA as (rectangular feed inset and their arrays) the same formula or equation are follows as above equations.

### 2.6.2 Calculating the Ground Plane Dimension

In terms of practical considrations, finite ground plane is consederd. To achieve the same results for finite and infinite ground planes, the ground plane size must be approximately six times that of the patch dimensions all around the periphery [21].the length of ground plane is given by formula (2.19), while width of the ground plane is given by formula (2.20);[21]

$$L_g = 6h + L \qquad (2.19)$$

$$W_g = 6h + W \qquad (2.20)$$

### 2.6.3 Determination of Circular MSA Dimensions

Circular patch as shown in figure (2.14)

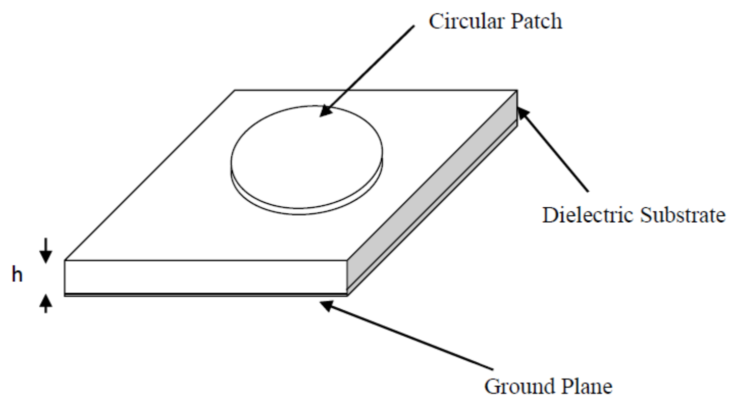



**Figure (2.14):** Circular Patch MSA

Equation (2.21) **a** is used to calculate the patch's real radius [13] .

$$a = \frac{F}{\left(1 + \frac{2h}{\pi \varepsilon_r F} \ln \frac{\pi F}{2h} + 1.7726\right)^{1/2}} \qquad (2.21)$$

where εr is the substrate's dielectric constant, h is the patch's thickness, and fringing effect is (F) as calculated by formula (2.22) [13] ;

$$F = \frac{8.791 \times 10^{9}}{f_r \sqrt{\varepsilon_r}} \qquad (2.22)$$

sum of actual radius ($\alpha$)& radius ($\Delta\alpha$) owing to fringing, which provided in formulas (2.23) and (2.24), is the effective radius $\alpha_e$ [13];

$$\alpha_e = \alpha + \Delta\alpha \qquad \textbf{(2.23)}$$

$$a_e = a\left(1 + \frac{2h}{\pi \varepsilon_r a} \ln \frac{\pi a}{2h} + 1.7726\right)^{1/2} \qquad \textbf{(2.24)}$$

Relation between the frequency (*fr*) and the effective radius (*ae*) of the circular shape patch is given in equation (2.25)[13] :

$$f_r = 1.8412 \times \frac{c}{2\pi a_e \sqrt{\varepsilon_r}} \qquad (2.25)$$

# CHAPTER THREE

# Material and Methods

## 3.1 CST Microwave Studio :

CST microwave studio is a specialized tool for high-frequency component 3D EM simulation. CST MWS' unrivaled performance has made it the preferred option of technology leading R and D departments. CST microwave studio allows for the rapid and accurate analysis of high frequency (HF) devices.

The shapes below are designed in CST and there dimensions are shown in table (3.1);

| parameter | Rec. | Rec.inset | Cir. | Cir.inset | Rec.arra | Rec.inset.arr. |
|---|---|---|---|---|---|---|
| $\varepsilon_r$ | 4.3 | 4.3 | 4.3 | 4.3 | 4.3 | 4.3 |
| H(mm) | 1.6 | 1.6 | 1.6 | 1.6 | 1.6 | 1.6 |
| Lg(mm) | 59 | 40 | 54 | 60 | 70 | 60 |
| Wg(mm) | 76 | 60 | 54 | 60 | 106 | 100 |
| Lp(mm) | 28.6 | 29 | - | - | 28.5 | 29.5 |
| Wp(mm) | 50 | 38.076 | - | - | 29.1 | 30 |
| T | 0.035 | 0.035 | 0.035 | 0.035 | 0.035 | 0.035 |
| A | - | - | 17.3 | 18 | - | - |

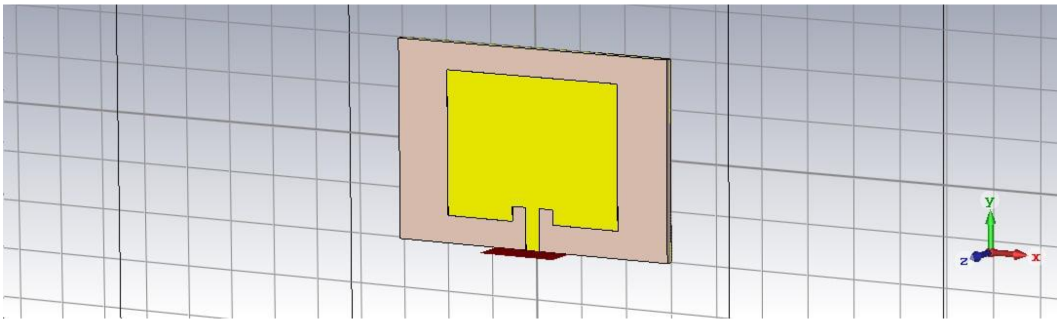


**Figure 3.1** rectangular feed inset MSA

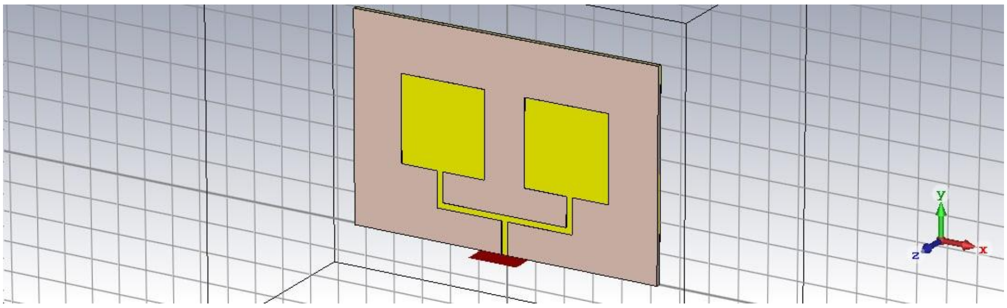


**Figure 3.2** (2 × 1) array rectangular MSA

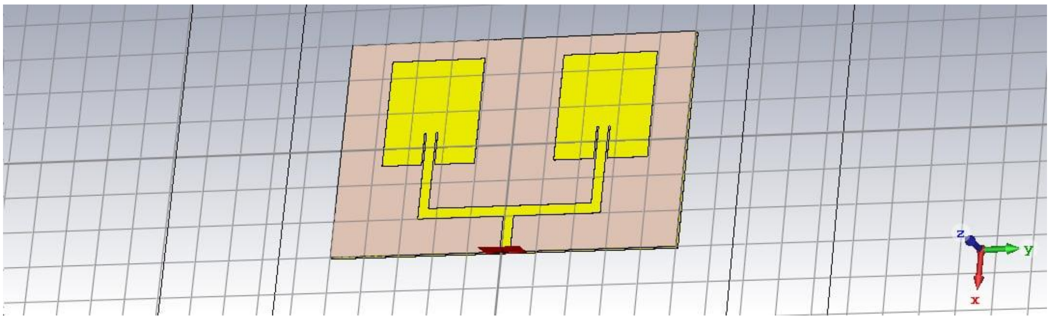


**Figure 3.3** (2 × 1) array rectangular feed inset MSA

There is another type as circular feed inset MSA shown below;

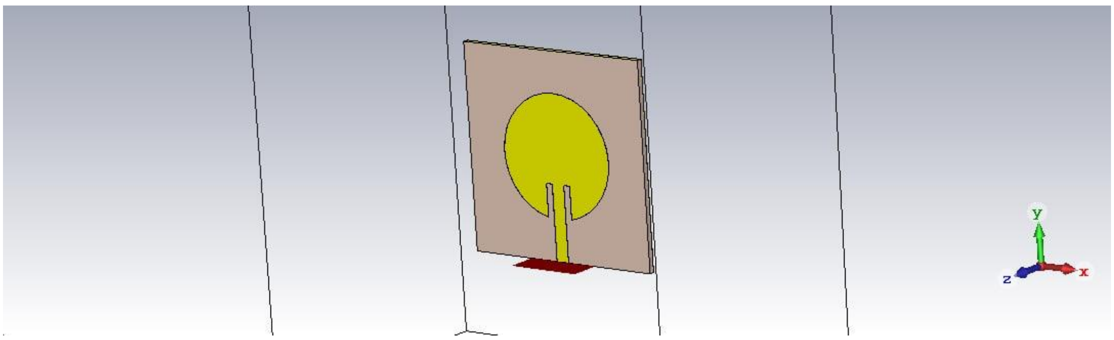


**Figure 3.4** circular feed inset MSA

## 3.2 Resonance Frequency Selection

The frequency of operation in this investigation was 2.4 GHz, which is widely utilized in wireless fidelity (Wi Fi), sensors network, & (WLAN).

## 3.3 Simulation Process

Depending on the form to be used, the parameters of rectangular, rect. feed inset.arrays, and circular MSAs were determined using (CST) software. The characteristics of a rectangular shape micro strip patch antenna employing FR4 as a substrate were investigated using CST while maintaining a frequency of 2.4GHz constant.

# CHAPTER FOUR

# Results & Discussions

## 4.1 Outcomes

This chapter includes simulations, experimental, and a summary of work that has been completed. The findings of the simulation were acquired using high frequency simulation software.

### 4.1.1 Frequency VS. Return Loss

The return loss of a circular patch microstrip antenna is plotted against frequency in Figure 4.1. The MSA has a 2.4GHZ resonant frequency, as shown in Figure 4.1. The power returned at this frequency is -18.7034dB. Because the losses of these frequencies in return less than the practically viable recognized return losses of -9.54dB, this may efficiently transmit or receive a signal at frequencies ranging from2 .3454 to 2.4312.

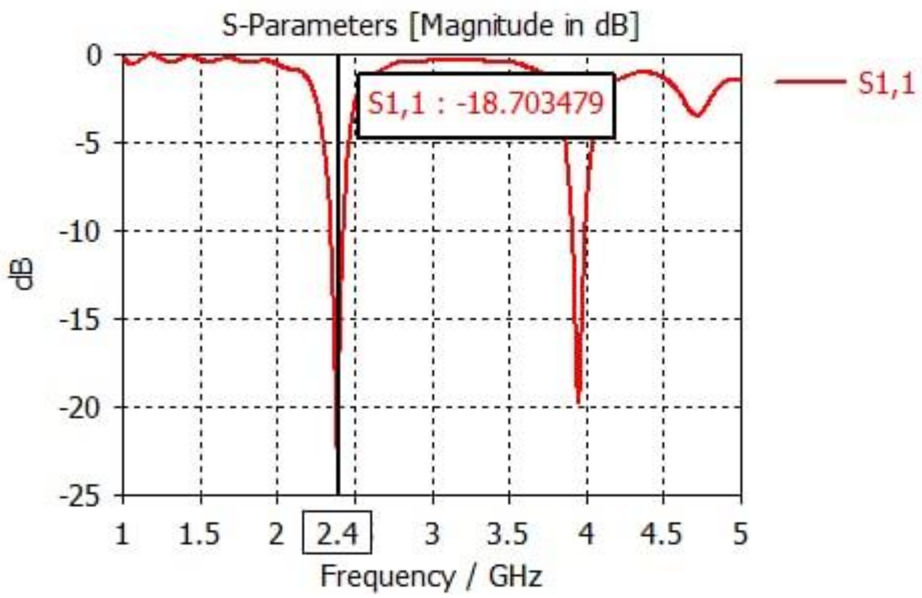



**Figure 4.1**: Graph of Circular Patch Microstrip Antenna Return Loss vs. Frequency.

The power returned at 2.4 GHz is -13.8154GHz this type can transmit or receive signals at frequencies ranging from 2.3612 GHz to 2.4424 GHz as shown in fig.(4.2);

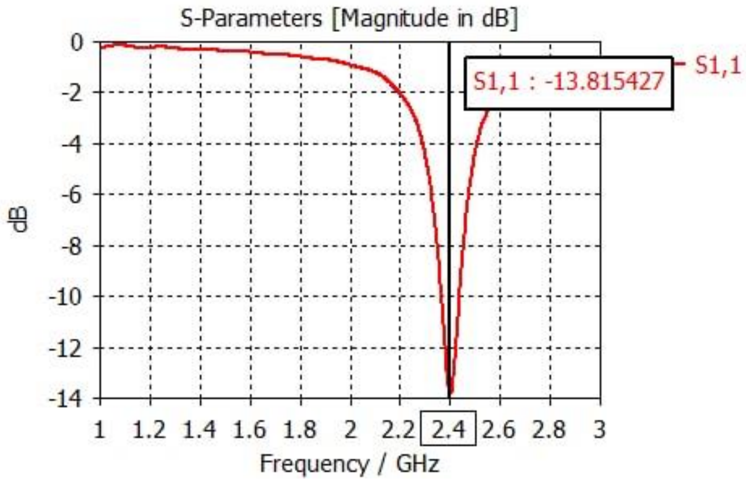



**Figure 4.**2 Graph of a Circular feed inset Patch Microstrip Antenna's Return Loss vs. Frequency.

The power returned at 2.4 GHz is -17.406GHz this type can transmit or receive signals at frequencies ranging from 2.3625 GHz to 2.4433 GHz as shown in fig.(4.3);

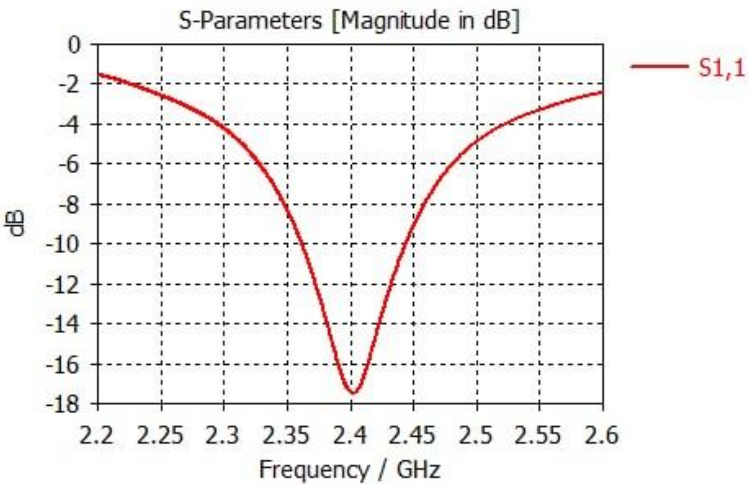



**Figure 4.3:** Graph of a Rectangular Patch Microstrip Antenna's Return Loss vs. Frequency.

The power returned at 2.4 GHz is -12.9511 GHz this type can transmit or receive signals at frequencies ranging from 2.3747 GHz to 2.4424 GHz as shown in fig.(4.3);

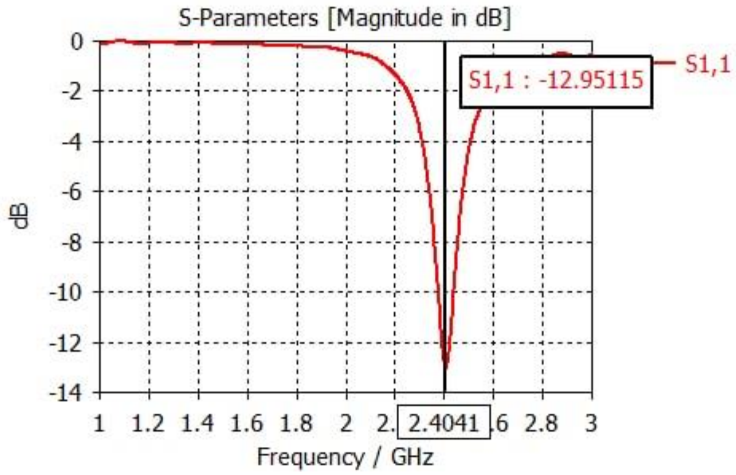



**Figure 4.4:** A Rectangular feed inset Patch Microstrip Antenna's Return Loss vs. Frequency graph.

The power returned at 2.4 GHz is -22.8291 GHz this type can transmit or receive signals at frequencies ranging from 2.3606 GHz to 2.4373GHz as shown in fig.(4.5);

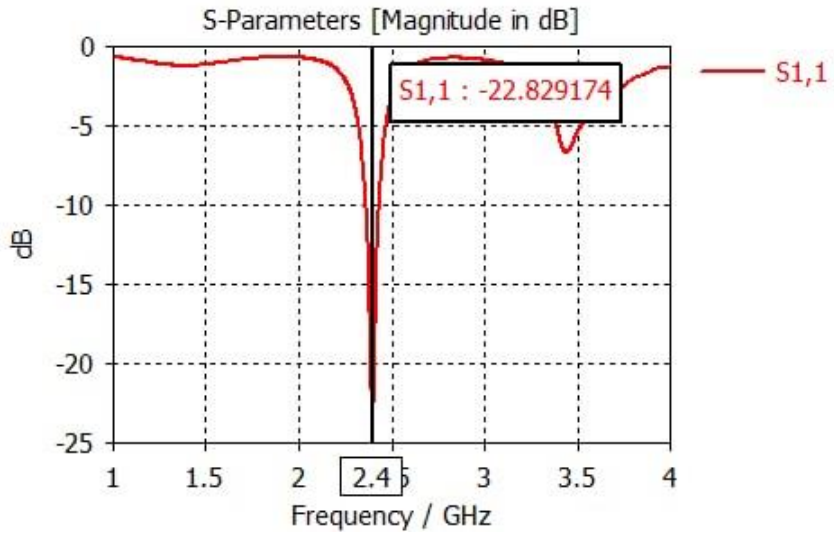



**Figure 4.5:** A Rectangular array Patch Microstrip Antenna's Return Loss vs. Frequency graph.

The power returned at 2.4 GHz is -21.16799 GHz this type can transmit or receive signals at frequencies ranging from 2.3583 GHz to 2.4427 GHz as shown in fig.(4.6);

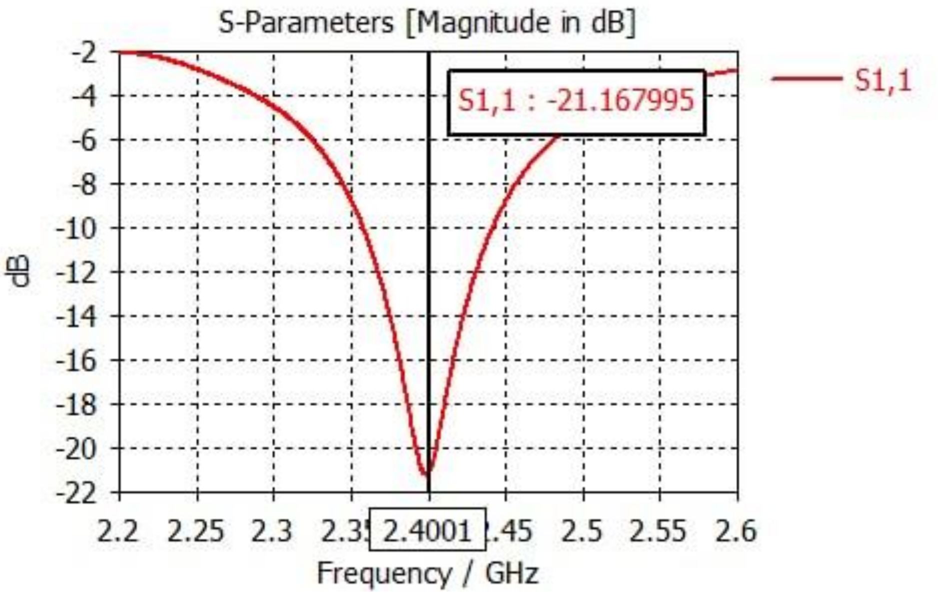



**Figure 4.6** Graph of a Rectangular feed inset array Patch Microstrip Antenna's Return Loss vs. Frequency**.**

table 4.1: Return Loss and Frequency Table

| Type Shape | frequency (GHZ) | return losses(dB) |
|---|---|---|
| Circular patch | 2.4 | -18.7034 |
| Circular inset | 2.4 | -13.8154 |
| Rectangular MSA | 2.4 | -17.406 |
| Rectangular inset MSA | 2.4 | -12.951 |
| Rec.array MSA | 2.4 | -22.8291 |
| Rec.feed inset array | 2.4 | -21.16799 |

All of the microstrip antennas in Table 4.1 radiate at **2.4GHZ**. The circular MSA has lowest Return losses, which means it reflects the least amount of power of all the antennas. The return loss of the rectangular patch microstrip antenna is the second best.

Because of all of the return loss is less than the acceptable limit -9.54dB, the two microstrip antennas can be utilized commercially.

The circular MSA has a wider band width than the rectangular MSA, and it can operate at a wider frequency range than the others.

### 4.1.2 Radiation Pattern

Figures below shows that patch is better at directing input power in radiations in one direction than other shapes. MSA can properly broadcast or rece**i**ve signal in The direction with greatest ga**i**n.

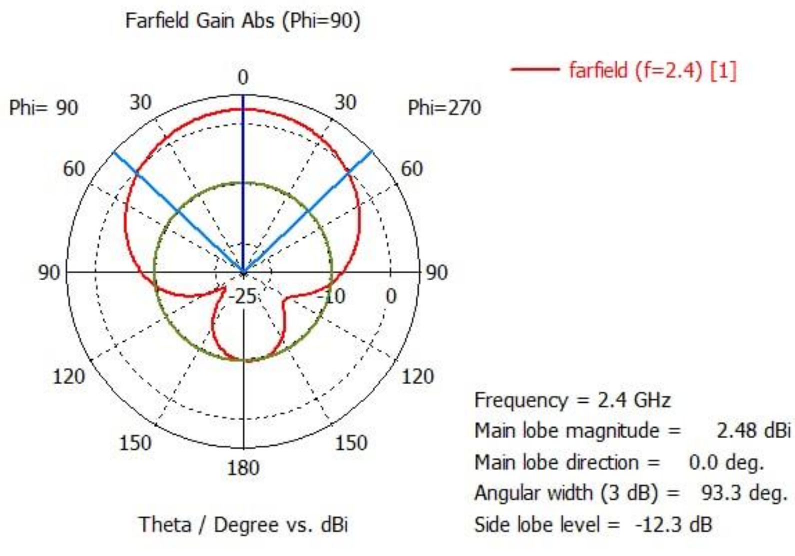



**Figure 4.7** Circular MSA radiation pattern.

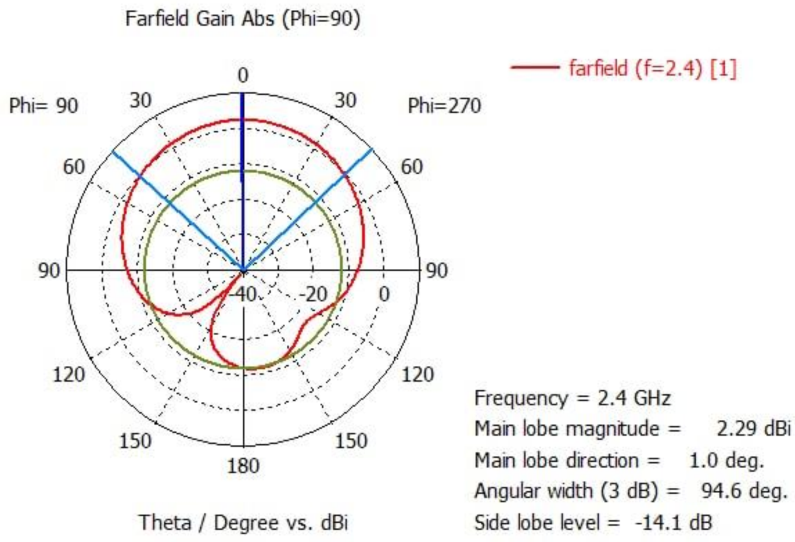



**figure4.8** circular feed inset Patch Microstrip Antenna radiation pattern.

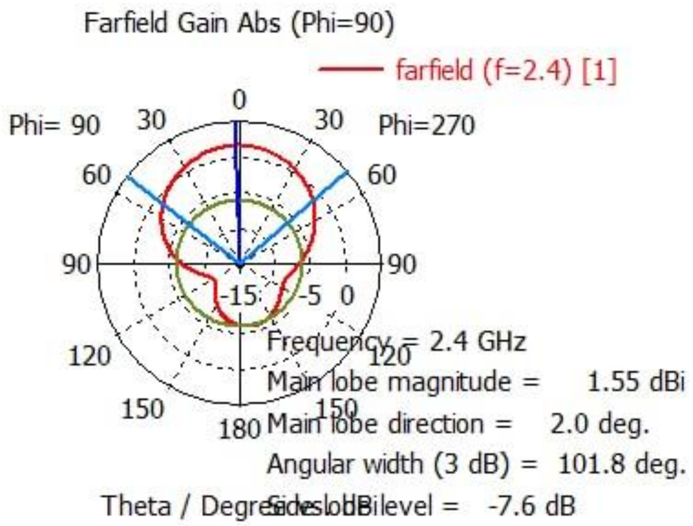



**figure 4.9** Microstrip Antenna radiation pattern with rectangular Patch

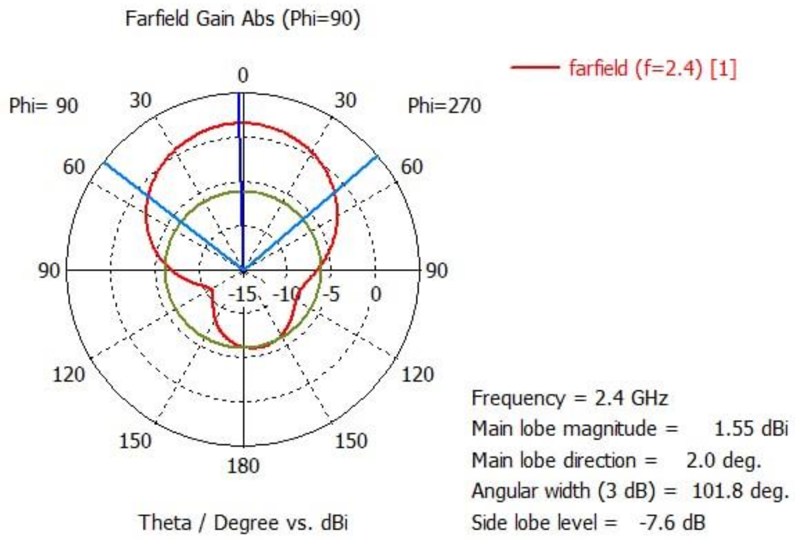



**figure 4.10** Patch Microstrip Antenna with rectangular feed insert and radiation pattern.

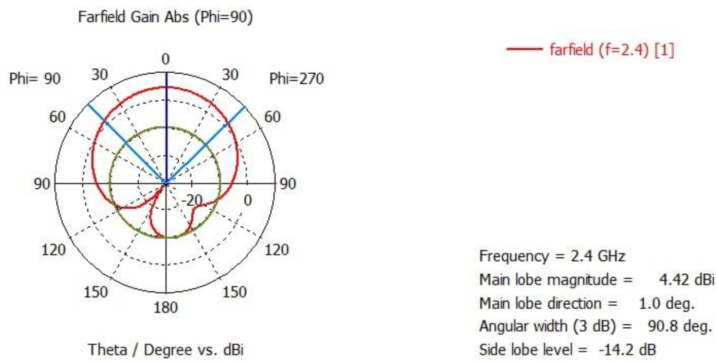



**figure 4.11** Patch MSA with Rectangular Array Radiation Pattern

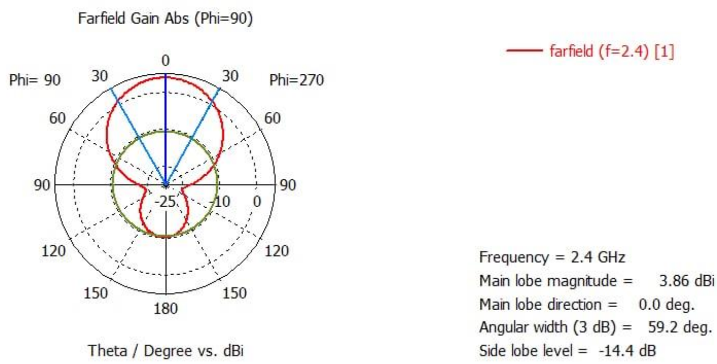



**figure 4.12** MSA with Rectangular Feed Inset Radiation Pattern.

### 4.1.3 Polar in 3D

The microstrip antenna has a peak gain of 2.481 dB at the 2.4 GHz frequency. MSA can properly receive or transmit signal in the direction with the greatest gain.

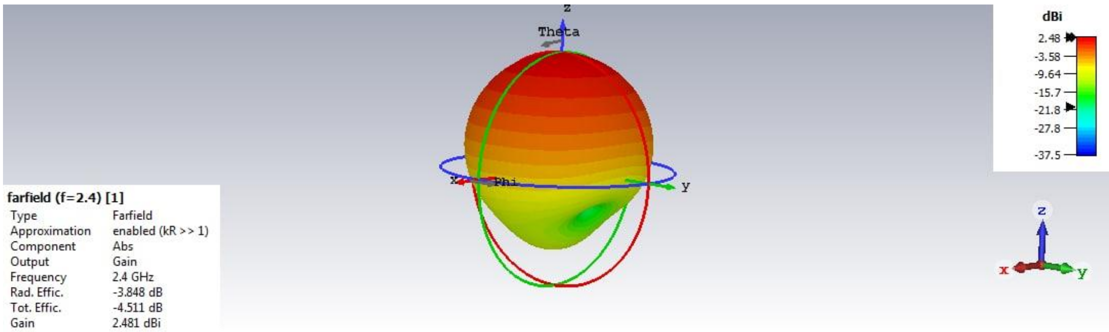



**figure 4.13**: Circular Patch Microstrip Antenna in 3D Polar

Peak gain in fig.(4.14) is 2.293dB;

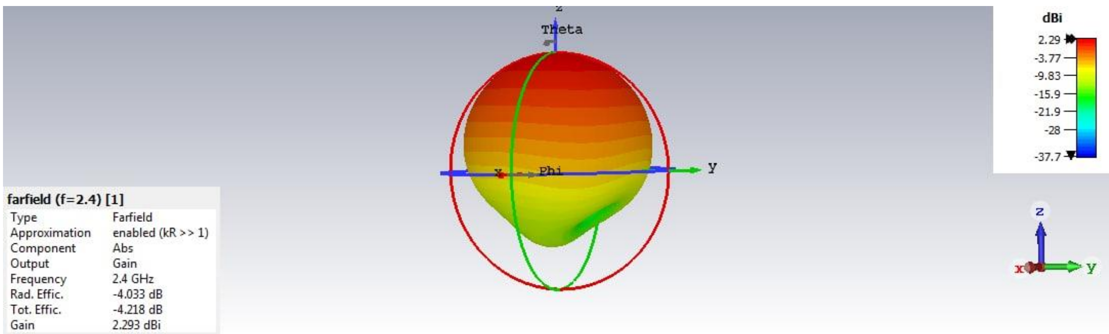



Figure 4.14: Patch Microstrip Antenna with Circular Feed in 3D Polar

Peak gain in fig.(4.15) is 3.426dB;

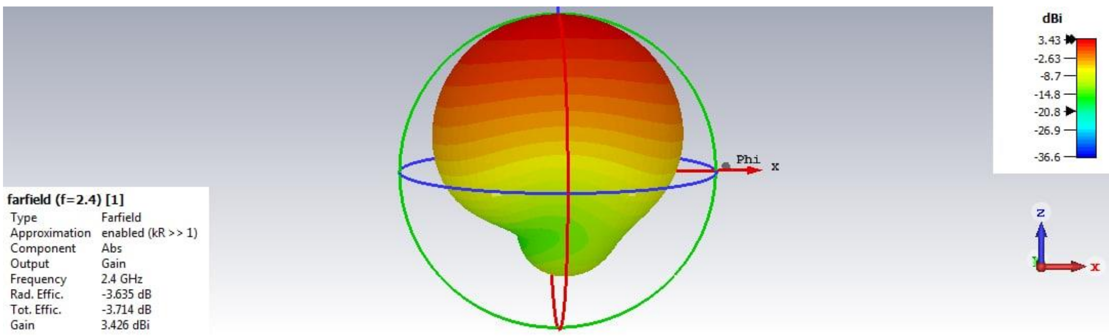



**figure 4.15:** Rectangular Patch Microstrip Antenna in 3D Polar

Peak gain in fig.(4.16) is 1.545dB;

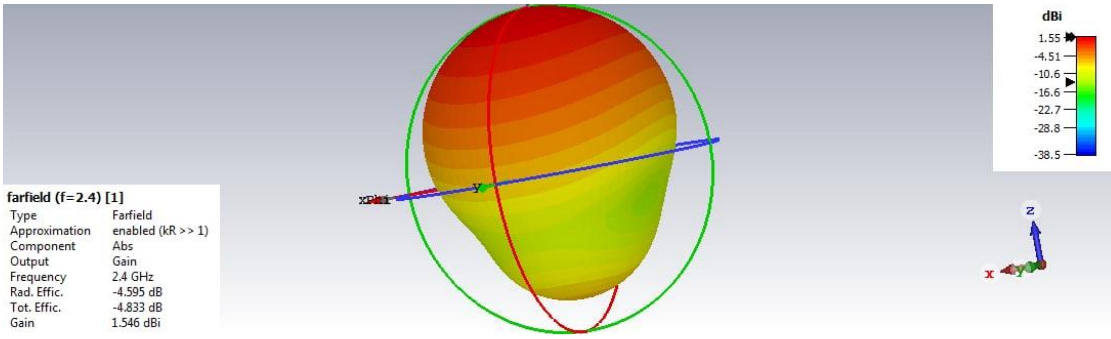



**Figure 4.16:** Rectangular feed inset Patch Microstrip Antenna in Polar 3D

Peak gain in fig.(4.17) is 4.435dB;

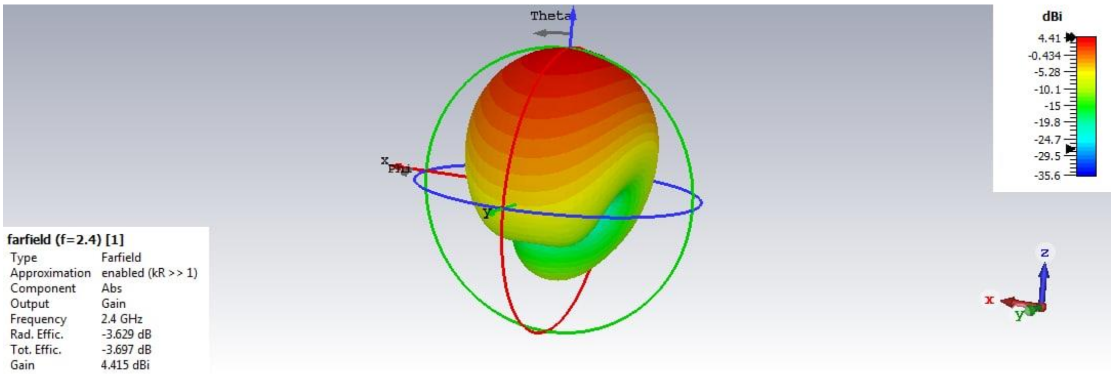



**figure 4.17:** Rectangular array Patch Microstrip Antenna in 3D Polar

Peak gain in fig.(4.18) is 3.857dB;

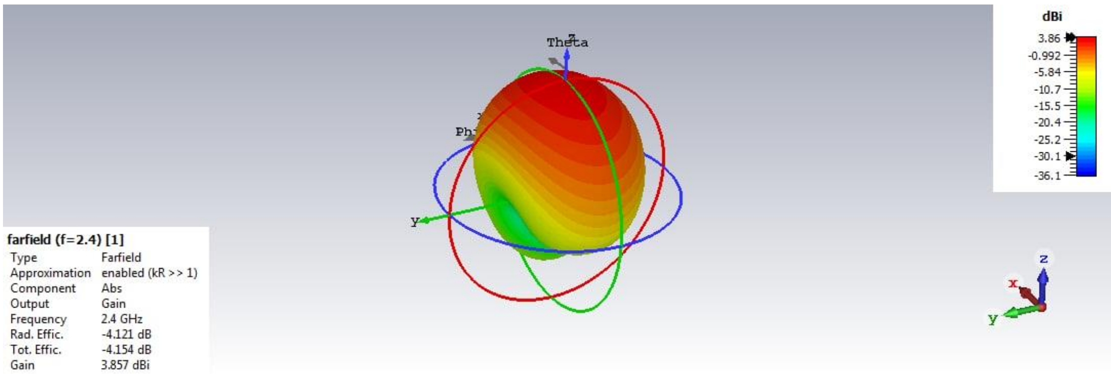



**figure 4.18:** Rectangular feed inset array Patch MSA in 3D Polar

## 4.1.4 (VSWR) Voltage Standing Wave Ratio

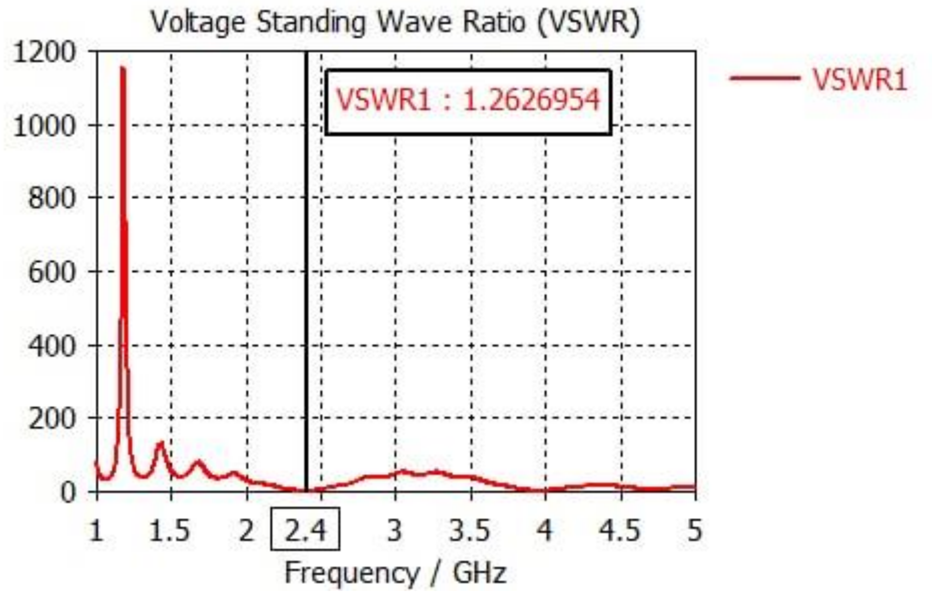



**Figure 4.19** VSWR for circular patch MAS

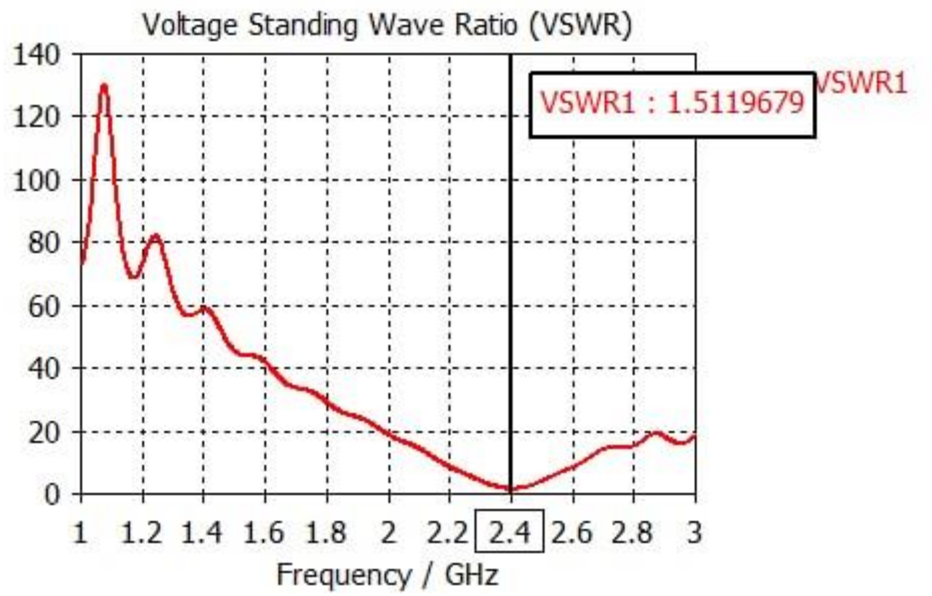



**Figure 4.20** VSWR for circular feed inset patch MAS

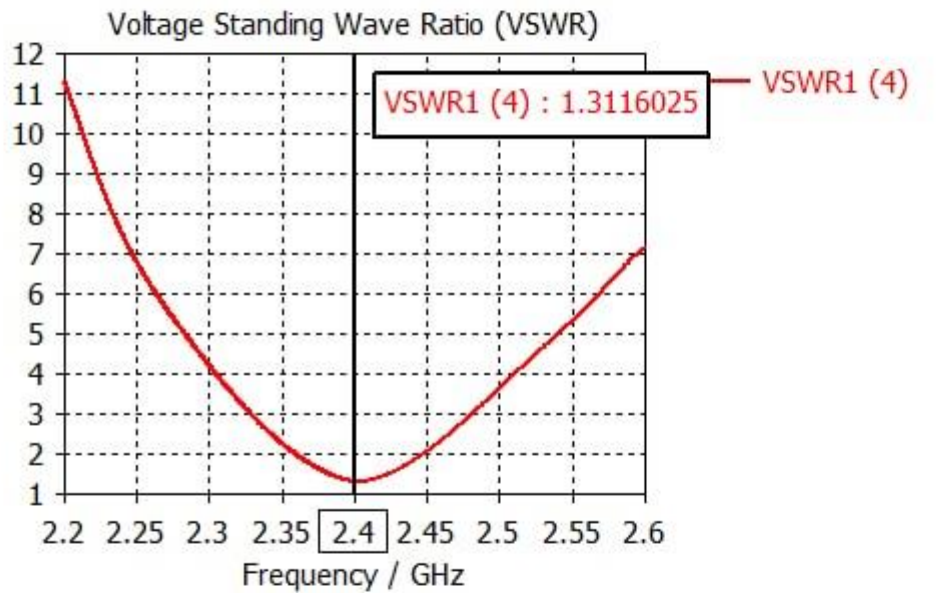



**Figure 4.21** VSWR for Rectangular patch MAS

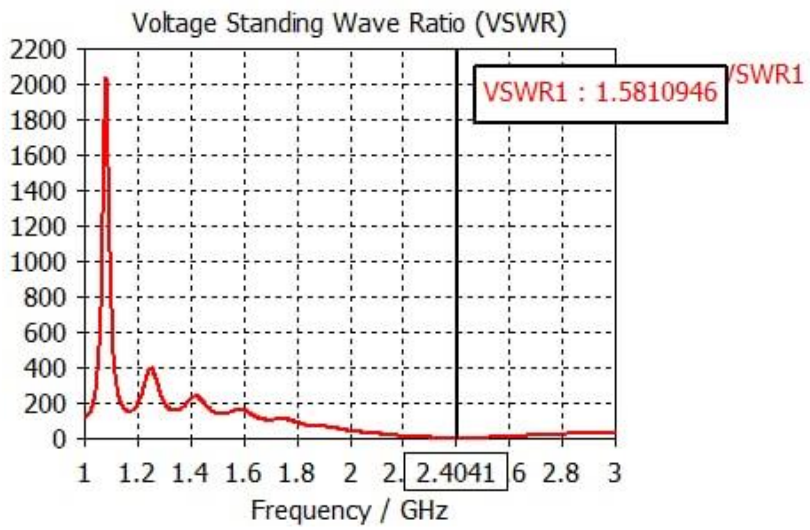



**Figure 4.22** VSWR for Rectangular feed inset patch MAS

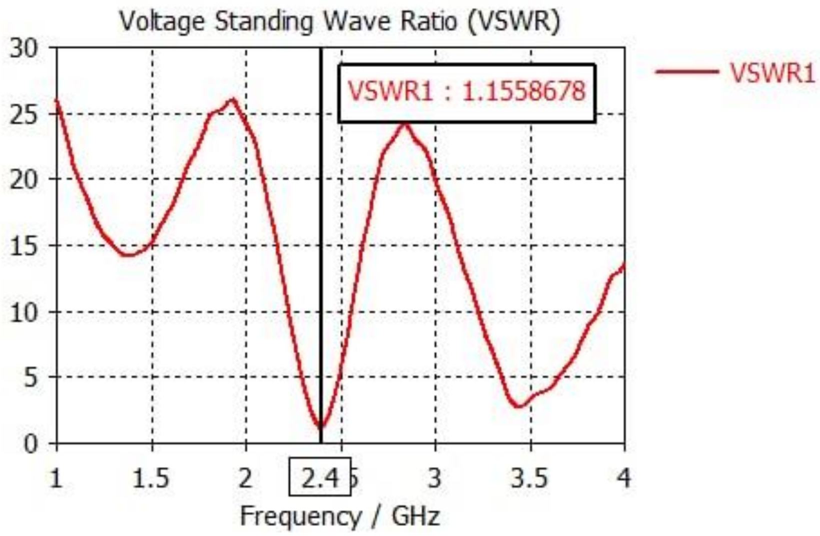



**Figure 4.23** VSWR for Rectangular array patch MAS

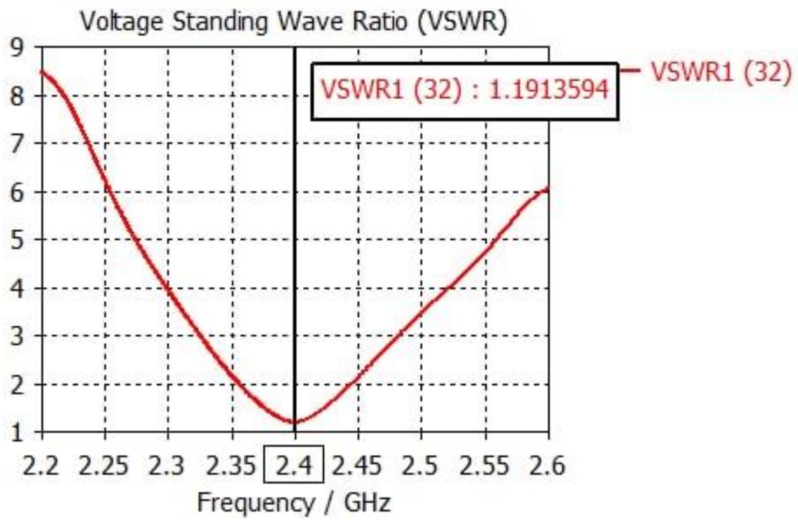



**Figure 4.24** VSWR for Rectangular feed inset array patch MAS

# CHAPTER FIVE

# Conclusions and Future Work

## 5.1 Conclusions

Despite having varied areas, circular, rectangular, their insets, and rec. arrays patch microstrip antennas resonated at the same frequency in this study ;

- In single element, the circular patch microstrip antenna had the best realized gain of 2.481.
- The rectangular patch microstrip antenna had the maximum directivity, followed by the circular patch antenna. Because of the huge surface area of the copper patch, the lower the directivity, this fluctuation is produced by antenna size.
- The circular patch microstrip antenna has the most bandwidth, followed by the rectangular microstrip antenna.
- The realized gain of the circular microstrip antenna was the highest, while the realized gain of the rectangular patch microstrip antenna was the lowest.
- The circular patch microstrip antenna has the lowest losses, whereas the rectangular patch microstrip antenna has the greatest.

## 5.2 Future Work

Microstrip line feed, proximity coupling, and aperture coupling are some of the feeding methods that can be used to feed microstrip antennas. These can all be tested to see if the realized gain can be enhanced further. Other than the forms utilized in the study, additional shapes can be investigated, such as an elliptical quarter circle. Higher gain can be achieved by using substrates with a lower directivity. A substrate having a high dielectric constant, such as silicon, can be used to minimize the size of a microstrip antenna. The usage of an array of these kinds of antenna patches should also be investigated because they produce the highest overall gain.

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## الخلاصة

تحتوي الهوائيات التقليدية ذات الشريحة الدقيقة على رقعة توصيل مطبوعة على ركيزة ميكروويف مؤرضة ، كما أنها تتميز بخصائص جذابة تتمثل في الانحدار المنخفض والوزن الخفيف وسهولة التصنيع والتوافق مع سطح المضيف. ومع ذلك ، فإن هوائيات **microstrip** بطبيعتها لها نطاق ترددي ضيق ، وعادة ما يكون تحسين النطاق الترددي مطلوبًا للتطبيقات العملية. بالإضافة إلى ذلك ، تتطلب التطبيقات في أنظمة الاتصالات المتنقلة الحالية عادةً حجم هوائي أصغر من أجل تلبية متطلبات تصغير الوحدات المتنقلة. وبالتالي ، فقد تم مراعاة تقليل الحجم وتحسين عرض النطاق بشكل أساسي للتطبيقات العملية لتصميم هوائيات **microstrip**.

تم إجراء عمليات محاكاة على بقع ركيزة **FR4** في أشكال مستطيلة ودائرية. تم الحفاظ على الركيزة بنفس السماكة **1.6** مم خلال جميع نتائج محاكاة **MSAs** التي تمت مقارنتها ، بما في ذلك عرض النطاق الترددي والكفاءة ومنحنيات خسارة العودة وأنماط الإشعاع .

كان الهوائي الأكثر كفاءة هو هوائي **microstrip** الدائري مع خسارة عودة تقارب (**-18.7dB**) في عنصر واحد. تم العثور بالمثل على أكبر مكسب تم تحقيقه في نفس **MSA**. تم العثور على **MSA** لتكون قادرة على العمل عند **2.4** جيجا هرتز. بخلاف الأشكال المستخدمة في الدراسة ، يمكن التحقيق في أشكال إضافية ، مثل دائرة ربع بيضاوية الشكل. يمكن تحقيق مكاسب أعلى باستخدام ركائز ذات اتجاهية أقل. يمكن استخدام الركيزة التي لها ثابت عازل مرتفع ، مثل السيليكون ، لتقليل حجم هوائي **microstrip**. يجب أيضًا دراسة مجموعة بقع الهوائيات من هذه الأشكال لأنها تنتج مكسبًا إجماليًا أعلى.



**وزارة التعليم العالي و البحث العلمي**

**جامعة بابل**

**كلية الهندسة**




# تأثير شكل التصحيح على خصائص هوائي الشريحة الصغير

**مشروع مقدم الى كلية الهندسة في جامعة بابل كجزء من متطلبات نيل درجة الدبلوم العالي في الهندسة / الهندسة الكهربائية.**

**رسالة تقدم بها**

**وائل حامد جدوع عبدالله**

**بإشراف**

**الدكتور حيدر صاحب المؤمن**

**1443 هـ** **2022 م**