Design and Performance Analysis of Frequency Scanning Microstrip Array Antenna for Vehicular Adhoc Network

Marta Tesema Gelan

A Thesis Submitted to

The Department of Electronics and Communication Engineering

School of Electrical Engineering and Computing

Presented in Partial Fulfillment of the Requirement for the Master of Science Degree in Electronics and Communication Engineering

Office of Graduate Studies

Adama Science and Technology University

September, 2021

Adama, Ethiopia

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APPROVAL PAGE OF M.SC THESIS

We, the advisors of the thesis entitled "Design and performance analysis of Frequency Scanning Microstrip Array Antenna for Vehicular Adhoc Network" and developed by Marta Tesema Gelan hereby certify that the recommendation and suggestions made by the board of examiners are appropriately incorporated into the final version of the thesis.

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We, the undersigned, members of the Board of Examiners of the thesis by Marta Tesema Gelan have read and evaluated the thesis entitled "Design and performance analysis of Frequency Scanning Microstrip Array Antenna for Vehicular Ad Hoc Network" and examined the candidate during open defense. This is, therefore, to certify that the thesis is accepted for partial fulfillment of the requirement of the degree of Master of Science in Electronics and Communication.

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DECLARATION

I hereby declare that this Master Thesis entitled “Design and Performance Analysis of Frequency Scanning Microstrip Array Antenna for Vehicular Adhoc Network’’ is my original work. That is, it has not been submitted for the award of any academic degree, diploma or certificate in any other university. All sources of materials that are used for this thesis have been duly acknowledged through citation.

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Marta Tesema Gelan		

RECOMMENDATION

We, the advisors of this thesis, hereby certify that we have read the revised version of the thesis entitled “Design and performance Analysis for Frequency Scanning Microstrip Array Antenna of Vehicular Adhoc Network” prepared under our guidance by Marta Tesema Gelan submitted in partial fulfillment of the requirements for the degree of Mater of Science in Degree in Electronics and Communication Engineering, Therefore, we recommend the submission of revised version of the thesis to the department following the applicable procedures.

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Co Advisor	Signature	Date

ACKNOWLEDGEMENT

First and foremost, my deepest and greatest thank goes to the almighty God and sent virgin marry. For all of their protections and blessings throughout my life .nothing is impossible without them. My parents; who are always there for me during the time of any good or bad circumstances happening in my life, Their impact in me ; to make me is unpredictable. I am so great full to have them. Also I would like to show my ultimate gratitude to my main adviser, **Dr. Rajaveerappa Devadas** and Co Advisor **Dr. Demisse Jobir** for their invaluable support, patience, assistance and especially their inspiration while I am doing this thesis particularly during the period when I most needed them.

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LIST OF ABBRIVATIONS

AU	Application Unit
CML	Corrugated Microstrip Line
CPG	Coplanar Wave Guide
CST	Computer Simulation Technology
dB	Decibel
DSRC	Dedicated Short Range Communication
EM	Electromagnetic
FACS	Flexible Access Common Spectrum
FSA	Frequency Scanning Array
FSMAA	Frequency Scanning Microstrip Array Antenna
HF	High Frequency
HPBW	Half Power Beam Width
IEEE	Institute of Electrical and Electronics Engineer
KCC	Korea Communications Commission
LWA	Leaky Wave Antenna
MANET	Mobile Adhoc Network
MEMS	Micro-Electromechanical Systems
MLWA	Microstrip Leaky Wave Antenna
OBU	On-Board Unit
OFDM	Orthogonal Frequency Division Multiplexing
OSB	Open-Stop Band
RL	Return Loss
RSU	Road Side Unit
SIW	Substrate Integrated Waveguide
UWB	Ultra Wide Band
VANET	Vehicular Adhoc Network
VCU	Vehicle Control Unit
VSWR	Voltage Standing Wave Ratio
WAP	Wireless Access Point
WLAN	Wireless Local Area Networks
WMN	Wireless Mesh Network
WSN	Wireless Sensor Network

ABSTRACT

For wireless communication system it is impossible to think a system without antennas because it is the one to enable the transformation of energy between a guiding device and the free-space. Antennas come in variety of shape, size and type. In order to achieve increased performance array of antennas are implemented. They bring benefits such as high gain, bandwidth, efficiency etc. specially beam forming and beam steering are their major advantage. Typical adhoc network, VANET (Vehicular Adhoc Network) works with the beam forming and steering technologies .Currently VANET is using Omni directional antenna. That means improvement in overwhelming signals is highly demanded .This can be achieved by beam steering and beam forming techniques. The shifting of beam mainly is achieved by either by using phase shifters or FSA (Frequency Scanning Antenna). This thesis work presents rectangular frequency scanning Microstrip patch array with a resonant frequency of 23 GHz for Vehicular Adhoc network application.23 GHz is recently allotted for dedicated short range communication (DSRC) by Korea Communications Commission (KCC).Which makes it ideal for VANET applications. Multi port feeding configuration combined with inset feeding has been used, the direction of the beam is swept or scanned by changing the frequency of the each element in the array, meaning beam steering is done by changing the frequency of the system .Change in the frequency of the system can be achieved in many ways. Mainly, by changing the path length of the each radiating element or using LWA (leaky wave antennas) the first approach is used in this work. That is the steering of the antenna beam by varying the frequency of each radiating element fit to the antenna is given focus. Computer Simulation Technology (CST) is used for designing, testing and Matlab for analytical modeling. Accordingly taking frequency range from 22.5GHz to 23.5GHz with steps of 0.125GHz, steering angle of 90 degree from-45.and 45 has been accomplished as result frequency sensitivity (scanning range/BW) of 90 degree has been obtained. Single, 2x1, 4x1, 6x1, 8x1 FSA antennas have been designed and compared with most relate FSA designs. A gain of 10.32dBi, angular beam width of 23.55dB, Side lobe level of -23.1, Radiation and total efficiency of 60% and 55.8% has been attained at the center frequency.

KEYWORDS: FSA, Array antenna, CST, VANET, Beam Steering, KCC, DSRC, LWA

CHAPTER ONE

1 INTRODUCTION

1.1 Background of the study

The antenna, often known as an aerial, is defined by the IEEE Standard Definition of Terms for Antennas (IEEE Std 145–1983) as "a tool used in a mechanisms for emitting or receiving radio waves." also the antenna serves as a transitional structure between empty space and a guiding device, it can be line which coaxial.it is used for delivering EM energy from sending antenna to receiving source or vice-versa. A transmitting antenna is present in the first scenario, whereas a receiving antenna is present in the second. Antennas are one of the most crucial components of wireless communication systems. An antenna with a suitable design can reduce system requirements while also improving overall performance. A television, for example, can benefit from the use of a high-performance antenna to increase overall broadcast reception. The antenna performs the same role for a communication system as eyes and eyeglasses do for a person [1].

Even though the concept of electromagnetic induction in a sealed/closed conductor produces a fluctuating field, this has no use in transmitting and receiving signals .that means only swinging of the field happens around the source, there is no propagation of electromagnetic field in this case. The working analogy of the antenna begins by considering two opposite charges placed in a distance apart. They obviously produce an electric field in between of their path the velocity will be at the higher tip and at the ends of their paths the velocity will be zero. because of this velocity variation the charged particles experience continuous acceleration and deceleration .this creates electric field .but as this process goes on due to memory effect the wave front formed starts to create a field [1].

The wave front finishes at a single place after a quarter of a time period. Following that, separation and propagation takes place. This causes the electric field strength fluctuation with distance in wave propagation to be sinusoidal. The wavelength of the propagation so created is exactly two fold that of the dipole's length. This variable electric field will generate a variable magnetic field perpendicular to it automatically. This is precisely what is required from an antenna. In short, arranging positive and negative charges to oscillate will only result in electromagnetic propagation [1].Therefor electric Current is generated by the oscillation of charges charge movement, which in turn generates a magnetic field. The time-varying magnetic and electric fields that flow through the conductor form electromagnetic waves. When waves approach open space, they create free waves, resulting in a connection between the field line's open ends. Electric disruption and electromagnetic waves are also produced by the source. Before open space radiation, propagation begins with the transmission line and antenna.

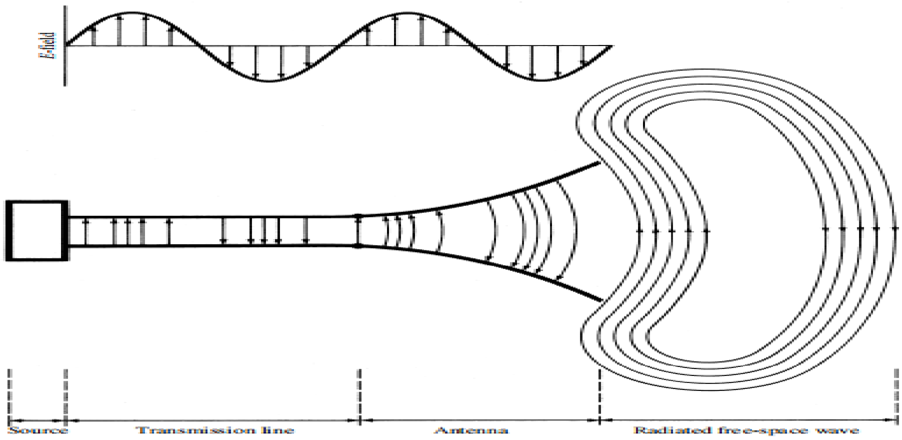


Figure 1.1 Demonstration for working principle of antenna [1]

As they enter free space, the electromagnetic waves are sustained by the charges inside the transmission line and antenna. Before entering free space, the waves form closed loops. As shown in the Figure 1.2

1.2 Antenna parameters

The efficiency and ability of a certain antenna is measured depending on different parameters used to characterize its basic properties .some parameters are discussed below.

1.2.1 Radiation Pattern

It's a representation of the antenna's radiation properties as a function of spatial coordinates, either graphically or mathematically. It is mostly evaluated as a function of directional coordinates in the far field areas. The amplitude field pattern is a representation of the received electric or magnetic field at a constant radius. But an amplitude power pattern is a graph showing the spatial fluctuation of the power density with a constant radius

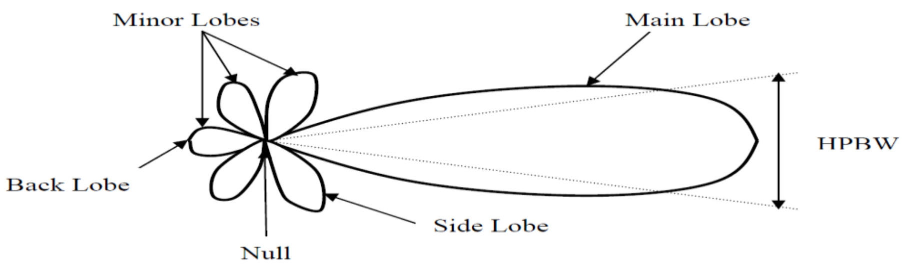


Figure 1.2 Radiation Pattern [1]

1.2.2 Radiation Power Density

It is mainly described by the Poyting vector ‘W’.

$$W = E * H \tag{1.2}$$

Where W denotes instantaneous Poynting Vector (W/m2), E refers to instantaneous Electrical field intensity (V/m) and H designates instantaneous Magnetic field intensity (A/m).The Poynting vector is power density and the total power crossing over a closed surface is obtained by integrating the Poynting vector over the closed surface given as:

$$p = \oiint ds * w \tag{1.3}$$

Where P = instantaneous total power (Watts) [1].

1.2.3 Radiation intensity

Radiation intensity U of antenna is power radiated per unit angle. It is measured in watts per steradian. As the distance gets larger the radiation intensity becomes independent of distance. The relationship with radiated power density is as follows.

$$u = r^2 \ w \tag{1.4}$$

1.2.4 Directivity

The ratio of an antenna's radiation intensity in a given direction to the average radiation intensity in all directions is known as Directivity. It is inversely related to the beam width of the main lobe. That means the wider the beam width the lower the Directivity and vice versa.

$$D = \frac{U}{U_0} \tag{1.5}$$

$$D = \frac{4\pi ru}{p_{rad}} \tag{1.6}$$

Where D signifies Directivity and P_{rad} represents Total radiated power (Watts).

1.2.5 Gain

Describes the antenna's ability to radiate strongly in any direction in free space .Though it is very similar to antenna Directivity; gain considers the efficiency as well as its directional capabilities of antenna. Formally, the absolute gain of an antenna is the ratio of the antenna's radiation intensity to the radiation intensity obtained by the antenna's input power.

$$G = \frac{4\pi ru}{p_{in}} \tag{1.7}$$

Where; Pin is the input power to the antenna.

1.2.6 Input Impedance

Is The impedance existing at the terminals of the antenna or the voltage-current ratio at the pair of terminals or the ratio electric and magnetic fields components at a point is called input impedance is written as

$$z_{in} = \mathrm{R_{in}} \times \mathrm{jx_{in}} \tag{1.8}$$

Where, z_{in} designates the antenna impedance at the terminals,$\mathrm{R_{in}}$ represents the antenna resistance at the terminals and $\mathrm{x_{in}}$ defines antenna reactance at the terminals .The imaginary portion, and $\mathrm{x_{in}}$ denotes the power stored in the antenna's near field. The receiver component $\mathrm{R_{in}}$includes the radiation resistance R_r and the loss resistance R_l. The power spent in the loss resistance is lost as heat in the antenna owing to dielectric or conducting losses, whereas the power spent in the radiation resistance is the actual power transmitted by the antenna [1]

1.2.7 Antenna Efficiency/Radiation Efficiency

An antenna's total antenna efficiency is determined by the antenna's ohmic losses through the dielectric material, conduction losses, reflecting losses at the input terminals, and losses inside the antenna structure [1].

$$e_0 = e_r e_c e_d \tag{1.9}$$

Where, e_0= Total antenna efficiency (dimensionless)

e_r= Reflection efficiency (dimensionless)

e_c= Conduction efficiency (dimensionless)

e_d= Dielectric efficiency (dimensionless

1.2.8 Voltage standing wave ratio (VSWR)

Maximum power transmission between the transmitter and the antenna is required for the antenna to perform efficiently. Only when the antenna's impedance (Z_{in}) is matched to the transmitters can maximum power transmission occur (ZS). According to the maximum power transfer theorem, maximum power can only be transferred if the transmitter's impedance is a complex conjugate of the antenna's impedance, and vice versa. As a result, the matching criteria is,

$$Z_{in} = Zs \text{ Where } Z_{in} = R_{in} + jX_{in} \text{ and } Z_s = R_s + jX_s \tag{1.10}$$

If the matching requirement is not met, part of the power may be reflected back, resulting in the formation of standing waves, which is measured using a metric called Voltage Standing Wave Ratio (VSWR) [2].

1.2.9 Return loss (RL)

The Return Loss of an antenna is a parameter that shows how much power is spent on the load but does not return as a reflection. When the transmitter and antenna impedances do not match, waves are reflected, resulting in the development of standing waves, as detailed in the prior section. As a result, the RL is a metric comparable to the VSWR that indicates how well the transmitter and antenna have been matched [2].

1.2.10 Antenna Bandwidth

The antenna bandwidth is defined as the range of frequencies with in which the antenna conforms to the specific standard with respect to some characteristics [1]. input impedance, radiation pattern, Beam-width polarization, side lobe level or gain are some of the determining characteristics to bandwidth .The bandwidth in the case of broadband is determined as the ratio of upper to lower frequencies. The antenna bandwidth can be defined as the proportion of the frequency variation across the central frequency for narrowband antenna types.

$$BW_{broadbamd} = \frac{\mathrm{fh}}{\mathrm{f_l}} \tag{1.11}$$

$$BW_{narrowbamd}\ \% = [\frac{\mathrm{fh} - \mathrm{f_l}}{\mathrm{f_c}}] * 100 \tag{1.12}$$

fh represents upper frequency, f_l shows lower frequency and f_c describes center frequency.

1.2.11 Beamwidth

The beamwidth of an antenna, which is defined by the antenna's direction and radiation distance, determines the predicted signal strength. It is determined by a number of factors, including antenna type, design, orientation, and radio frequency. The beam width is the area where the majority of the power is emitted. In the effective radiated field of the antenna, half power beam width is the angle at which relative power is more than 50% of peak power. It might be horizontal (azimuth) or vertical (elevation). Beamwidth is a valuable analytical metric for a lot of practical application, Identifying whether adjacent antennas will interact with one another

For various uses, many antenna types have been used. This is owing to their diverse properties, which allow them to be employed in a variety of applications [2].Among the very well-known types, Wire antennas (dipole antennas) were the first antennas to be utilized. Where a single conductor or transmission wire functions as a radiating element in this form, they are applicable everywhere on automobiles, ships, air crafts, spaceships, and so on due to their ease of manufacture. On the other hand, Aperture antennas are the most common at microwave frequencies [3].The region, pointed normal to the direction of an incoming electromagnetic wave, that would intercept the same amount of power provided by the antenna receiving which is called as an aperture. The horn antenna can be viewed as one type aperture antenna. To find its radiation characteristics, the same equivalent principle, techniques used in aperture antenna can be utilized. They are constructed by flaring (gradually becoming wider at one end) of wave-guides to increase the directivity due to increased cross sectional area of the flaring and improved impedance matching between free space and wave-guides. Due to its directional property it can be utilized for long distance communication applications. They are often employed in radio astronomy, satellite and terrestrial communications, and plasma diagnostic [4] .The other category is reflector antenna which is highly directive antenna consisting of one or more reflecting surfaces [5]. It's utilized with satellites and other long-distance communication systems.it basically consists of active antenna which acts as the feeding element to other antennas and parasitic antennas which acts as the reflector. The feed antenna of reflector is used to illuminate the reflector to give the desired energy distribution. On the other hand lens antenna incorporates electromagnetic lens with feed. it converges spherical wave front in to planner wave front and planner wave front to focus at the feed. Less blockage, higher gain, low noise and can receive more electromagnetic wave relative to reflected antenna are its advantage over reflector antenna .However, as compared to reflector antennas, they are heavier, more difficult to construct, and expensive [6]. The other most popular, easiest to use and directional antenna is the Yagi-uda antenna, which is made up of numerous parallel components in a line. It has a high gain and directivity.it is the most common form of television antenna. Typically, two types of constraints are used: active (driven) and parasitic (primarily reflector antennas) [7]. They have a greater gain, front to rear ratio, are lighter, and less expensive. However, larger antenna is required to have grater gain.

Unlike the previous types, due to their a availability of good substrates with lower loss tangent, attractive thermal and mechanical properties, improved photo lithographic techniques, and better theoretical models they have become important topic since the seventies of last century [8]. Their numerous benefits, including as light weight, compact volume, low cost, and interoperability with integrated circuits, made them appealing in a wide range of applications spanning from 100 MHz to 100 GHz. Furthermore, array configurations can be used to circumvent some of their shortcomings, such as low gain and low power handling capabilities. Today it is almost impossible to thick smart wireless system without Microstrip patch antenna. Satellite applications, microwave imaging systems synthetic aperture radars, and wireless power transfer are only a few of uses of Microstrip patches that exist today. Their numerous advantages, such as, for example, light weight, small volume, low cost, compatibility with integrated circuits, made them attractive in Many applications ranging approximately from 100 MHz to100 GHz. Furthermore, some of their limitations, such as low gain and low power handling capabilities, can be overcome by making use of array configurations [1]. there are several applications of antenna arrays using Microstrip radiators such as, satellite applications, microwave imaging systems, synthetic aperture radars, and wireless power transmission [9-13].

Even if a single antenna is 100 % efficient in every aspect ,there are some features which cannot be achieved by a single antenna such as increased gain ,increased bandwidth more over beam forming and beam scanning. Due to this reason antenna array is used to fill such gaps. The antenna array is mainly used to increase signal strength, to obtain High directivity, to reduce Minor lobes, to achieve a High Signal-to-noise ratio, and to reduce Power wastage, to obtain High gain and better performance.

1.3 Statement of Problem

In every wireless system, it is desirable to achieve a good beam scanning coverage .as a result phased array antennas with very costly phase shifters, switches and filters are used extensively which makes them unreachable for applications demanding large amount of them such as VANET. For VANET application each node (OBU vehicles) need a separate antenna mounted on the OBU of the vehicle .these results increased cost for each user. Apart from these in phased array antenna, the steering range of array antennas is limited by the number of phase shifters used by the array meaning the use of 4 phase shifters results only 4 different beam scanning angles.

Therefor in order to have more number of phase scanning angle .or in order to have wide coverage of beam scanning more number of phase shifters are needed which make the system complex and very expensive. But these problems can be solved by using FSA antennas where phase shifters, switches, filters and other facilities are not required .by changing the path length of the feeding line, the desired beam scanning range can be achieve

1.4 Objectives

1.4.1 General objective

- Design of planar Frequency Scanning Microstrip Array Antenna for Vehicular Ad Hoc Network at 23 GHZ.

1.4.2 Specific objectives

- To make mathematical modeling for single patch antenna and frequency scanning Microstrip array antenna.
- To Design a single Microstrip patch antenna at 23GHz.
- To design 2x1,4x1,6x1,8x1 frequency scanning Microstrip patch antenna.
- To make performance analysis between single, 2x1, 4x1 frequency scanning Microstrip patch antenna.

1.5 Significance of the study

One of the biggest challenges for the Designing of antennas for VANET is to enhance good beam steering capacity. Therefore the significance of this thesis work is to provide array antenna design that can be used for frequency selective environment with increased beam steering capacity so that the signals from or to the antenna can cover a wide range and cover larger coverage area without using phase shifters, filters or switches .therefor low cost, cheaper and simple antenna design is the main significance of this thesis work.

1.6 Scope and limitation of the study

Basically, in VANET performing a real life experiment at larger scale is very difficult and expensive because it requires technological resources to install antennas, to deploy and mount on board and road side units. Different logistic supplies such as large number of vehicles, labor (drivers) etc. Therefor the scope of this thesis work cannot be beyond software simulation hence the mathematically modeled and designed antenna will be simulated using Matlab and CST software. Coming to the limitation, the CST software is such an intense software that each significant points in the antenna is given focus every of its electrical and magnetic aspects are analyzed and calculated with predefined antenna properties assumed in the software. Due to the property of the FSA design chosen, increasing the number of the mesh cell (equivalent to pixel in image) is the mandatory. There for the more length of the antenna the higher the simulation time .because he number of cells in the Microstrip increases .which results increased simulation time .that may take four five days .which is very time consuming and difficult to work with .

1.7 Thesis organization

- The rest of this thesis work is organized in the following manner.
- Chapter 2 presents details al R Microstrip antennas such as their different type of feeding techniques ,applications ,advantage and dis advantages .also different beam steering techniques and some related works has presented .among the different applications of beam steering techniques ,VANET is reviewed.
- The chapter 3 deals with the techniques and procedures ,specifications and analytical modeling followed to design overall designing single,2x1,4x1 frequency scanning Microstrip antenna.
- In chapter 4 result for the designed antennas are presented. Meaning and reasons behind the result obtained is discussed and analyzed.
- Finally chapter 5 gives conclusion of this work and recommend what to be done in the future.

1.8 Main contribution

The main contributions of this work are:

- Design of single patch antenna at 23 GHz
- Design of frequency scanning Microstrip array antenna having scanning range of 90 degree at with increased frequency sensitivity

CHAPTER TWO

2 LITERATURE REVIEW

2.1 Basic of Microstrip Antenna

Microstrip patch antennas have been in use for decades due to their low cost, reduced weight, mechanical resilience, and simplicity of integration with other circuits at the micron level. Currently they’re one of the most common antenna type used widely. Because they are lightweight, they may be utilized in a variety of applications where surface volume is important. Fabrication in big quantities will be simple since they demand a reduced cost. They have several drawbacks, such as a narrow range band width and limited power handling, however some of these may be addressed by employing novel feeding techniques and patch configurations [14].

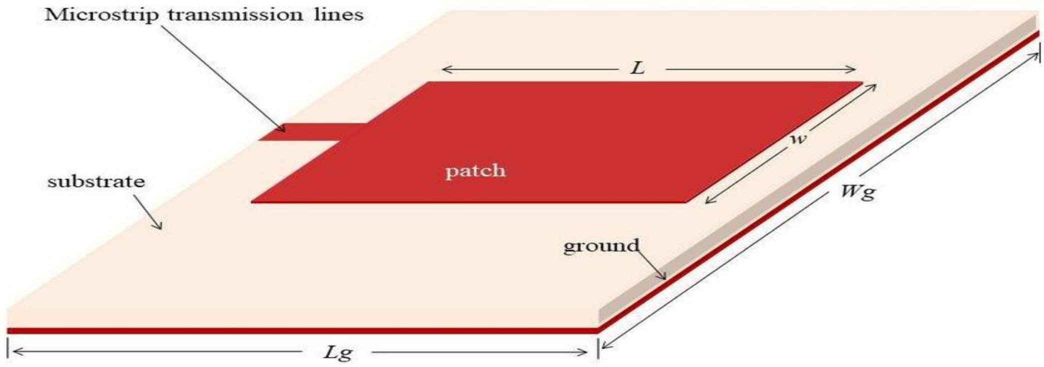


Figure 2.1 Microstrip patch antenna structure [14]

Radiating element (patch), substrate, and ground are the three regions. The former one is a very thin metallic strip with a very small thickness .and the substrate is a dielectric substance with a thickness of h, typically the value of height should be less than 0.003 εo should be greater than 0.05εo.most of the time .The value of εo =1 and 2.2 <εr >12. Thick substrates with a εr value towards the bottom of the range are the most ideal for optimal antenna performance because they give better efficiency, a broader bandwidth, and a loosely bound field for space radiation at the cost of larger element sizes. Microwave electronics need a tightly confined field, thin substrates with higher dielectric constants. Because microwave circuitry requires tightly linked fields to reduce unwanted radiation and coupling, lower element sizes are possible; however, due to higher losses, they are less efficient and have a lower bandwidth [15].

The patch used for radiating should be made of a material with low ohmic loss (the voltage drop across the cell induced by the internal resistance of the cell during current flow) and high conductivity (such as copper, gold). Copper is the most widely used metal due to the high price of gold. A regular rectangle, square, ellipse, circle, triangle, ring, or other forms can be used for the patch. More complex alterations to the fundamental shapes are commonly employed to meet special design needs.

The patch's shape is determined by a variety of elements such as polarization, bandwidth, gain, and so on. The shape and dimensions of the patch, the substrate thickness and dielectric constant, and the feed configuration all have a significant impact on the antenna's performance. The radiating patch can be designed with a variety of shapes such as: square, circular, triangular, semicircular, senatorial, and annular ring shapes; but rectangular and circular configurations are the most commonly used configuration because of ease of analysis and fabrication [16].

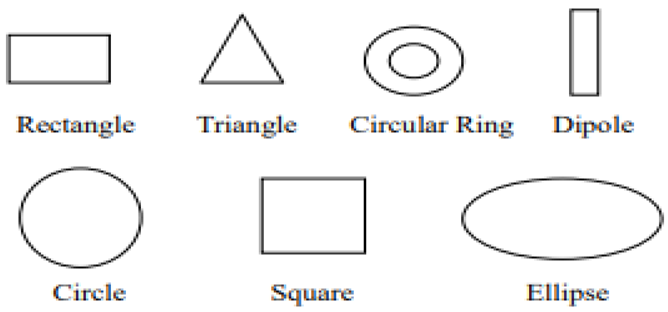


Figure 2.2 Variety shapes of patch antenna [16]

2.1.1 Feeding Methods for Patch Antennas

There are two broader categories of feeding techniques. These are contacting and non-contacting. Radio frequency power is given directly to the symbolizing patch using a connecting element such as a Microstrip line in the contacting approach. Electromagnetic area coupling will be used in the non-contacting as a means of transferring RF power. Microstrip line and coaxial probe are mentioned for contacting type. Aperture coupling and proximity coupling are the most widely used type of non-contacting techniques [15].

- **Microstrip line feeding techniques**

Microstrip line Feed conducting strip is attached directly to the edge of the Microstrip patch in this sort of feed technology. The conducting strip is narrower than the patch, and this type of feed arrangement has the benefit of allowing the feed to be etched on the same substrate as the patch, resulting in a planar structure [17].

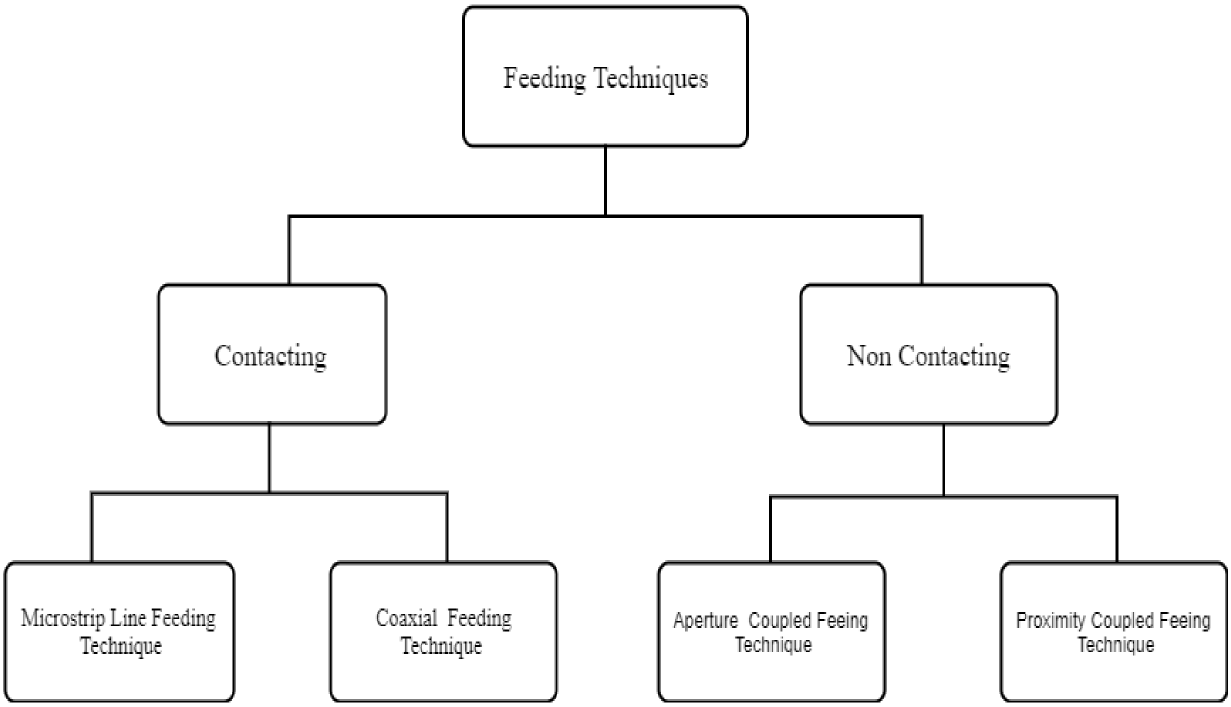
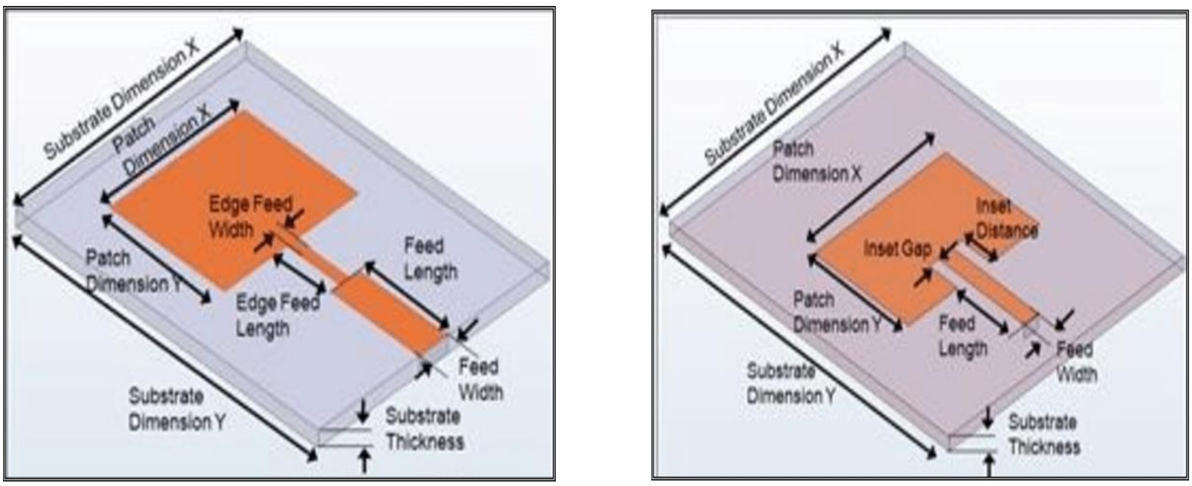


Figure 2.3 Classifications of feeding techniques

A Microstrip feed line is a conducting strip with a narrower width than the patch. They are simple to make and match by simply adjusting the feed position or the inset position. Microstrip patch antennas may be given by a choice of techniques. It may be of two types inset and (quarter wave transformer). Quarter wave transformer accomplishes impedance matching; by is linking the feed line to the patch through extra feed line which is quarter of the length Microstrip line.



(a) (b)

Figure 2.4 Microstrip line feeding (a) Quarter wave feeding technique (b) Inset feeding technique [17]

On the other hand in the Inset feeding method transmission line is in direct touch with one of the patch's edges .the matching is done by creating a cut in the radiating edge and extending the feed line. The feed line and radiating patch can both be etched on the same substrate, making design and implementation easier and more cost-effective and highly suited for array design. The purpose of the inset cut in the patch is to match the impedance of the feed line to the patch without the need for any additional matching element. This is achieved by creating a gap field between the patch and the transmission line.

- **Coaxial feed**

In this type of feeding the inner conductor is coupled to the patch, and the outside conductor is coupled to the ground. A coaxial probe is similarly straightforward to feed. It's simple to create and combine, and it emits very little unwanted radiation. However, the amount of bandwidth accessible is limited. Simulating it ,is also more difficult, especially when dealing with thick substrates [18].

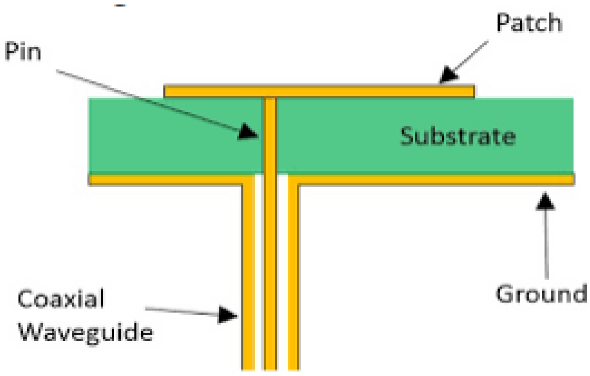


Figure 2.5 Coaxial Feed [18]

- **Aperture coupled feed**

There is no direct contact with the antenna in the case of coupled feeds. The capacitive nature is introduced by the distance between the feed and the antenna. Two substrates are joined together by a ground plane in the aperture coupling method. The energy of a Microstrip feed line is proportional to the patch that passes through it and it is located on the bottom side of the lower substrate.

- **Proximity coupled**

The electromagnetic coupling strategy is another name for this type of feed technology. The feed line positioned between the two dielectric substrates, with the radiating patch positioned above the top one [19].

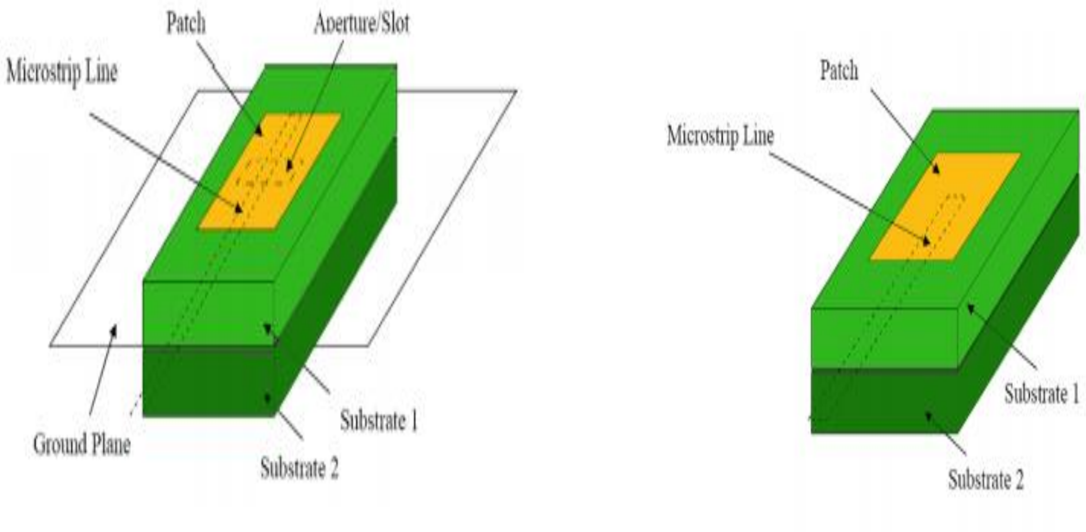


Figure 2.6 (a) proximity coupled feed (b) aperture coupled feed [19]

One has to consider his design interest in order to select among the feeding techniques. Some of the techniques are best to have good bandwidth range, some of them are easier to fabricate, some of them achieve lower cross polarization etc. this paper uses Microstrip line feeding with inset types.

Table 2-1 Summary of Feeding Techniques

s.no	Type	Advantage	Disadvantage
1	Coaxial	Easy to fabricate	Cross polarization
		Easy to model	Low bandwidth
		Easy to match	
2	Microstrip line	Easy fabrication	Low bandwidth
		simple impedance matching	High spurious radiation
		Simple to model	
3	Aperture coupled	Easy to model	Narrow bandwidth
		Moderate spurious radiation	Most difficult to fabricate
		Low cross polarization	
4	Proximity coupled	Low cross polarization	Difficult to fabricate
		Low spurious radiation	expensive
		High band width	

Microstrip has the following uses and limitations [20].

- **Advantages of Microstrip Antenna**
  - ✓ Light weight and low volume.
  - ✓ Low profile planar configuration which can be easily made conformal to host surface.
  - ✓ Low fabrication cost, hence can be manufactured in large quantities.
  - ✓ Supports both, linear as well as circular polarization.
  - ✓ Can be easily integrated with microwave integrated circuits (MICs).
  - ✓ Capable of dual and triple frequency operations.
  - ✓ Mechanically robust when mounted on rigid surfaces.
- **Disadvantages of Microstrip Antenna**
  - ✓ Narrow bandwidth
  - ✓ Low efficiency
  - ✓ Low Gain
  - ✓ Extraneous radiation from feeds and junctions
  - ✓ Poor end fire radiator except tapered slot antennas
  - ✓ Low power handling capacity.
  - ✓ Surface wave excitation

2.1.2 Beam Steering

Techniques used for changing the direction of the main lobe are called Beam steering. Changing antenna elements or adjusting the phase angle of the RF signal supplied to the antenna are the most known ways to accomplish this. There are different features used to determine the capacity of beam steering .among these; steering range is one of them which is the largest angle the beam can be directed away from the bore sight direction. The radiating element determines the steering range. The other factor is Steering resolution (S-Res) which is the maximum step increment possible while covering the steering range. It could be continuous, predefined, or fine.The former one, imply that it can accomplish any required steering angle. Predefined stand for large angles greater than 20◦ and fine indicate angle steps of 2◦ or less 0.38.a parameter that refers to how quickly the beam may be steered. The sensitivity of the approach is determined by the steering speed, which defines whether it is suitable for a dynamic or static environment [21].

As far as best beam steering is concerned, Complexity considers the ease with which a technique can be implemented. This has a direct impact on the cost of putting the technique in place. It will be given a high, moderate, or low rating. Not only this; application that will use the manufactured device will be determined by its size. Applications such as smartphones and tablets will be unable to accommodate, if it becomes too large. Therefore size is also another import factor to be considered. The other determining factor is cost .The cost of implementing a technique will influence the cost of the device from a sales standpoint.

2.1.3 Beam steering applications

The necessity for multi-purpose antennas in a single device has become critical due to the increasing proliferation of wireless communication systems. in order to conserve resources, increase space, and improve quality In terms of these multi-purpose antennas, steering with a beam .The rapid growth of modern wireless electronic technology necessitates the simultaneous existence of several functions in a single device in order to save resources and space, resulting in an increase as a result of the demand for multi-functional antennas. The most common procedures are beam steering, focusing, and vortex beam formation, which are all linked to wave front phase manipulation. Beam steering is extremely helpful in moving networks such as VANET

- **Vehicular adhoc network**

In the field of wireless communication an interconnection between different electronic devices; servers; and clients is termed as network it has different types depending on the type of application they are assigned for, the rage they can cover; or the mode where the connection is made from. Of the different types, an ad hoc network is a peer-to-peer wireless network mode in which wireless devices connect directly with each other without the use of a Wireless Access Point (WAP) device. For example, a Wi-Fi accesses point or a router. Typically, wireless networks rely on a base station or WAP device to achieve and direct data flow between wireless devices. But the network is spontaneously built in an adhoc setting, and it is broadly classed as WMN, WSN, MANET, and VANET, depending on the sort of application it is utilized for [22].

A wireless mesh network is a communication system made of radio nodes that are connected in a mesh topology. Mesh clients, mesh routers, and gateways are common components of wireless mesh networks. Where nodes don't just send and receive data, but also function as a relay for other nodes and each node cooperates in broadcasting data on the network.

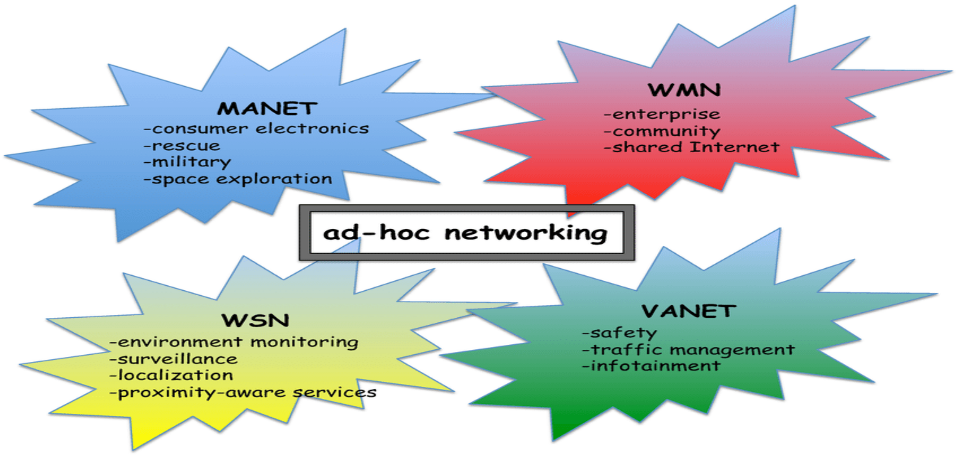


Figure 2.7 Types and applications of adhoc network [22].

Sensor-based devices are used in a wireless sensor network to regulate physical or environmental settings such as sound, pressure, and climatic changes, among other things. Wireless sensor networks are utilized in a variety of applications, including traffic management, vehicle identification, and greenhouse monitoring. A mobile ad hoc network is a collection of mobile nodes that are dynamically and arbitrarily arranged in such a way that their linkages can be converted on a regular basis. They are made up of a collection of mobile nodes that are connected wirelessly in a self-configuring, self-healing network without the need for a fixed infrastructure. Because the network architecture changes regularly, MANET nodes are free to move around. Each node acts as a router, forwarding traffic to different nodes in the network. VANET is a subset or derivation of MANET that employs cars as an anode.in other words, a VANET is a MANET in which vehicles serve as moving nodes. It offers services such as car safety, traffic control, and internet access [23].The rapid mobility of autos, the scarce or irregular scattering of vehicles, and the limited connection among nodes due to the limits imposed by the topology of highways and/or urban roads are also considered by VANETs, as a subset of mobile ad hoc networks. VANET aims to promote safe driving by improving traffic flow, resulting in a reduction in the frequency of car accidents. This can be accomplished by sending crucial information about current traffic problems to the driver or vehicle. However because each VANET node (i.e. vehicle) , must include a diverse range of sensors (e.g., LIDAR and proximity sensors), as well as computing and communication capabilities. Implementing a VANET is usually costly [24].

Its architecture consist of the most indispensable system components i.e. application unit (AU), On Board Unit (OBU) and Road Side Unit (RSU). The AU can be linked to the OBU over a wired or wireless connection and can exist in with the OBU in a single physical unit. The variation between the AU and the OBU is logical. The AU interconnects with the network only by the use of the OBU which brings task for all mobility and networking functions [25].

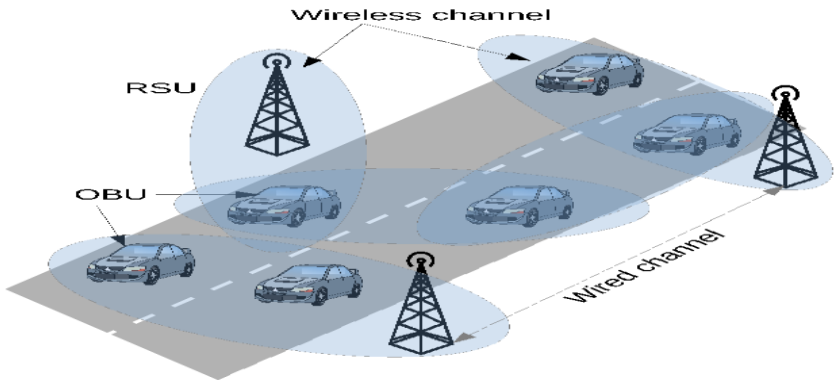


Figure 2.8 Major components of VANET [26].

Its architecture is made up of the most important system components, such as the application unit AU, the OBU, and the RSU .The AU and the OBU can be linked via a wired or wireless connection, and they can coexist in a single physical unit. The difference between the AU and the OBU is understandable. The only way for the AU to connect to the network is through the OBU, which brings task for all mobility and networking functions.

A hardware device put on the vehicle is known as an On-Board Unit. As shown in Figure 2-16, an OBU's primary job is to establish connections with other OBUs and RSUs. It usually has a transceiver, which is made up of a radio frequency antenna and a CPU. It also contains a user interface and read/write memory for storing and retrieving data .The Vehicle Control Unit works with the OBU to collect and distribute vehicle statistics. To be able to communicate with other devices such as:-laptops, Android phones, and PDAs. Bluetooth and USB are among the interfaces it employs. RSUs are similar to OBUs in that they have an antenna, processor, and read/write memory. Both wired and wireless interfaces are available on RSUs. The wireless interface connects to OBUs aboard cars, while the wired interface connects to other RSUs and the Internet. Using the data forwarding approach, an RSU can also extend the coverage area of OBUs. RSUs are strategically placed along roads, primarily near crossroads and gas stations. They are placed in high-vehicle-density areas including transit stops, interchanges, and parking lots [26].

Dedicated short-range communication allows vehicles to communicate directly with one another, either in a single hop or multiple hops. The communication could be (V2V, I2V, or V2I) or hybrid (V2V, I2V, or V2I).Vehicle-to-vehicle (V2V) communication refers to all communications between vehicles, whereas vehicle-to-infrastructure (V2I) communication refers to information sharing between cars and road-side-units [27]. Sometimes communication between two or more OBUs and RSUs or vice versa occurs; this is referred to as hybrid communication.

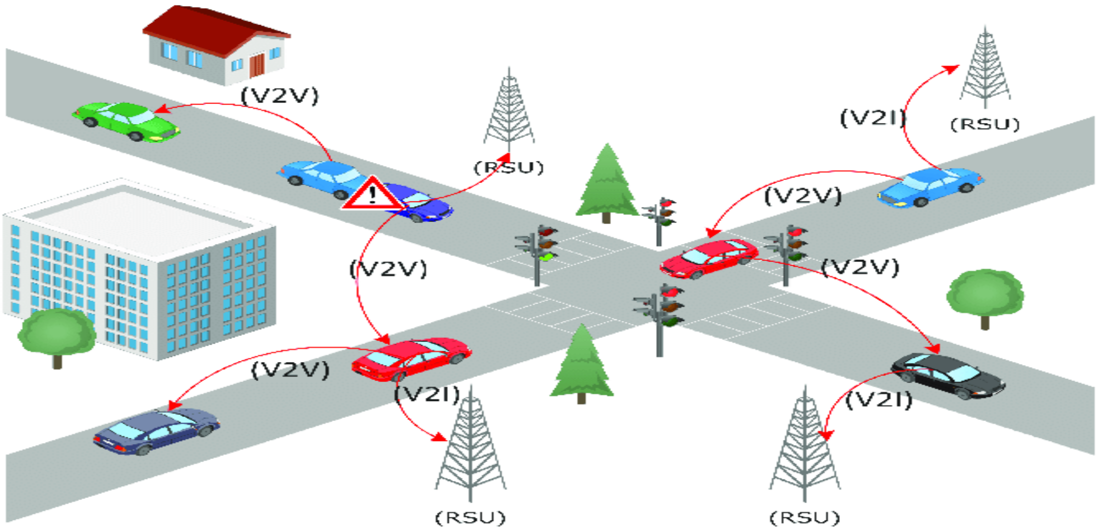


Figure 2.9 VANET communication architecture [27].

DSRC is a wireless communication technology tool that allows cars to interact with one another in ITS or other infrastructure networks such as V2V and V2I to improve and establish frequency standardization that allows VANETs to function. The FCC designated 5.850 to 5.925 GHz for DSRC applications in 1999. However, the Korea Communications Commission has implemented new spectrum policies based on dynamic spectrum access technology, such as the flexible access common spectrum (FACS) (KCC).The KCC has assigned 23 GHz spectrum to FACS bands, which are intended to be used mostly for vehicle communication. The route loss in short-range communication is decreased, making 23 GHz appropriate for VANET [28].

2.1.4 Beam steering techniques

Generally There are two approaches of beam steering, Mechanical and electrical scanning. The electrical steering approach is father divided in to two broad categories phased array antenna and frequency scanning array antenna.

2.1.5 Mechanical Steering

Mechanical rotation-based beam scanning is used here, such as using a parabolic reflector. These antennas, however, are very large and have a sluggish scanning speed, limiting their practical usage. This entails manually rotating the antenna to face the desired direction. Due to antenna size and weight, mechanical steering becomes ineligible and challenging [21]. Electric motors are frequently used in mechanical steering. Recently, MEMS devices have been employed to provide mechanical steering [29]. Offering faster scanning speeds compared to manually guided arrays as well as minimal system losses. Mechanical steering is extremely effective since it preserves the antenna's gain and provides flexibility in the antenna's steering range. That means additional devices are always needed to make rotation which make the system complicated, and slow speed. Due to the steering speed restrictions, it can only be used in static or extremely slow changing surroundings. Furthermore, rotating mechanisms are prone to mechanical failure owing to fatigue and wear of moving parts [30].The answers to these problems resulted in electrical beam steering.

2.1.6 Electronic Scanning

In this approach the electrical scanning, which works by electrically engineering the phase distributions to create angular deflection of the wave front is employed. Electronic scanning allows scanning at very fast rate [31].This approach is simple to implement and may be used with a variety of antenna configurations, including resonator cavities, reflect arrays dipole antennas, and patch arrays, The patch array antenna, in particular, offers a straightforward solution with a low profile, small size, cheap cost, and simplicity of integration with planar circuits .it is of two types phased array antenna and frequency scanning array antenna Electrical scanning efficiency is very crucial in VANET as it can provide increased beam scanning at faster rate as well as simplify of the systems and provide more flexibility. In fact, the best option for this is a frequency-scanning antenna. Search, tracking, traffic control, and collision avoidance radars, as well as smart base station antennas for WLAN and cellular connectivity, all require fast electronic beam scanning antennas [32]. Phased array or frequency scanning can be used for electronic scanning. Frequency scanning array antennas are a form of phased array antenna that is used for frequency scanning. The beam scanning approach employs a single main beam of an array and an associated feed network (through variable phase structure or time-delay lines) to position the beam in the desired direction.

2.1.7 Phased Array Antenna

It's an array antenna made up of many radiating elements, each having its own phase shifter. The phase of the signal transmitted by each radiating element is shifted to produce beams. It generates constructive and/or distributive interference. In order to direct the beam in the desired direction As a result, the goal of a phased array antenna is to steer the beam in the desired direction. This is mostly accomplished by equipping each element with phase shifters. Beam steering using phase shifter is another efficient technique for beam steering. The beam steering angle is depends upon the phase delay. In phased array antenna, the phase delay is achieved using phase shifter network using switch, mainly; The required steering angle can be realized using switch and the specific phase delay offered by the phase shift network [33].Any phased array antenna in general, apart from the array elements, consists of two functional blocks known as the feed network and the phase scanning circuitry as shown in the Figure 2-6 each of these blocks plays very important roles for the correct functionality of the array. A feed network distributes energy to the elements of the array by means of phase shifters according to a desired amplitude function. The phase circuitry in turn plays its role by implementing phase shifters with analog or digital phase control. Here a good choice for placement of phase shifters along the feed line play very important role [34].

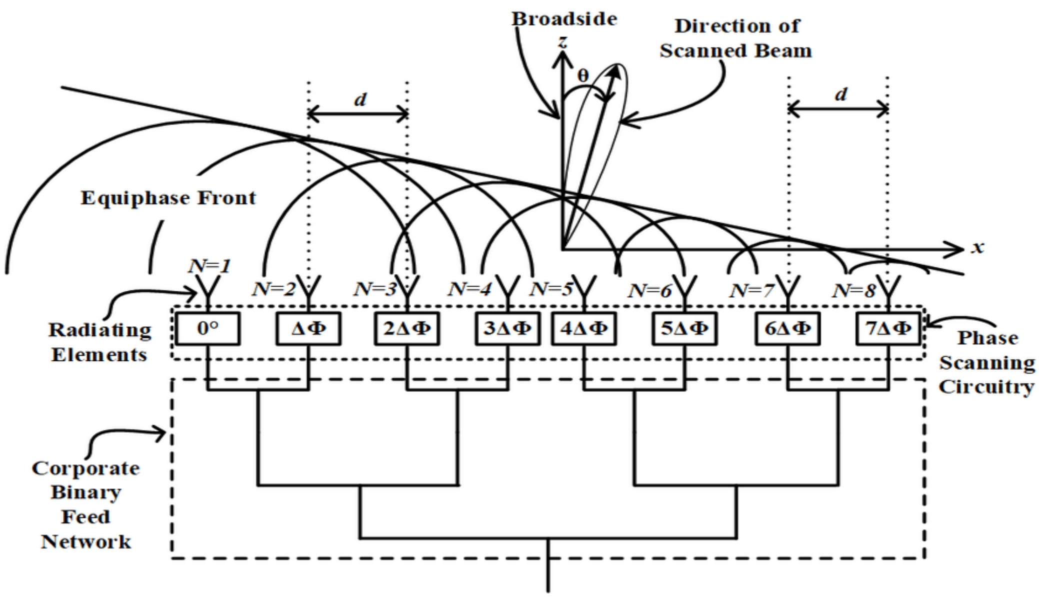


Figure 2.10 Phased array antenna feeding network [34]

The mathematical approach to the phased array antenna is that the each antenna elements are connected to each phase shifter. There for by changing the value of alpha (beam scanning angle) it is possible to steer the beam in intended direction.

Direction of major lob can be obtained by

$$\varphi = \beta d \cos\theta + \alpha \qquad (2.1)$$

Looking at the above equation beam steering can be achieved by changing the physical position the antenna (distance between patches (‘d’)) or, by changing initial phase of the beam Phased array antenna can be constructed. Phase shifters are needed in order to achieve change in the initial phase of each radiating element. This makes the system very complex and difficult to construct. High gain antenna, Suppressed side lobes , steering of beam Without physical movement Multi-function operation due to multi beam direction Reduction of fault signals components can achieved due to this features they are highly used in Radar tracking but they are complex expensive ,lower bandwidth .

2.1.8 Frequency Scanning Array Antenna Design Techniques

The row meaning of frequency scanning is searching a signal in given band or range of frequencies. As a result, the antenna in the Frequency scanning type is designed to search a specified frequency range by adjusting the scanning angle of the main beam. Formally speaking FSA is an array antenna where the direction of the beam is swept or scanned by changing the frequency of the each element in the array, meaning beam steering is done by shifting the frequency of the system .variation in the frequency of the system can be achieved in many ways, Mostly, by changing the path length of the each radiating element. Therefor by changing path length which in turn produces change in the frequency, beam steering can be achieved without physical movement or external phase shifter. From the fundamental relationship between frequency and wave length .it can be said that any change in the wave length of the system directly produce a change in the frequency of the system .in the same manner for the case of Microstrip patch antenna the guided wave length (λg) is changed resulting a change in the frequency of the system which in turn brings a change in the main lobe direction. The frequency scanning antennas can be classified into two types based on the antenna type and working analogy. Series feeding with open-ended structure or LWA, and full-corporate feeding with path difference phase shifter [35].

Basically leaky wave antenna stands for antenna family where traveling wave is used as a mechanism of radiation. These antennas consist of structures in which power is coupled from a guided mode to free space, in a continuous or discrete way. It can be considered that the guided mode "leaks" power to free space. In LWA's the angle of leakage is frequency dependent and hence the radiation pattern of the main beam direction. However it has one major drawback, it needed huge operating bandwidth to achieve large tuning angles [36].

In [37], Substrate Integrated Waveguide (SIW) Leaky-Wave Antenna With Transverse Slots is presented. In this work Leakage is obtained by introducing a periodic set of centered transverse slots on the top of the SIW, which interrupt the current flow on the top wall. The scanning results from frequency the shift are in the forward quadrant direction. Due to polarization it was made to radiate at end fire with the presence of wide ground plane .but in this work beam radiating exactly at the end fire was not found due to finite ground diffraction effects.

Periodic Microstrip Leaky Wave Antenna with Double-Sided Shorting Pins and Pairs of Slots is presented in [38] . a combination of periodic Microstrip leaky wave antenna made of rectangle Microstrip patch and shorting pins are presented .the Leaky wave antenna is kept uniform and the shorting pins are alternately loaded on its side. The pins are used to connect the antenna patch and the ground plane to form periodic shorting circuits. The designed MLWA antenna has achieved a 142° to 39° toward the end-fire.

In [39], Frequency-Fixed Beam-Scanning Leaky-Wave Antenna Using Electronically Controllable Corrugated Microstrip Line Corrugated Microstrip Line (CML) with surface impedance having three-sided modulation scheme has been studied. CML is used to control the leaky-wave scanning angle in real time at a constant frequency. The LWA comprises of corrugated Microstrip line (CML) loaded by Varactor diodes .In this work with frequency spacing from 5.5 GHz to 5.8 GHz, a scanning angle as high as 45º has been achieved.

Backward to Forward Scanning Periodic Leaky Wave Antenna with Wide Scanning Range is presented [40]. Here printed leaky wave antenna structure with circular polarization is studied.15 unit cells are cascaded in the direction of propagation just to provide continuous frequency scanning range in between 20 GHz to 29 GHz with a steering of 95º.

Periodic Leaky-Wave Antenna Based on Complementary Pair of Radiation Elements has been presented in [41]. A LWA loaded with two shunt radiation element together with host transmission line is considered in this work. The loading of the radiating element is done periodically. This complementary radiation loading results to open-stop band (OSB) suppression. There by facilitating a continuous leaky-wave beam scanning from backward, through broadside, to forward.

The second type is a relatively easiest way for achieving a frequency scanning with a straightforward operating concept. As a phase shifter, the frequency scanning antenna is fed by the path difference. Different length paths are used to meet the requirement of frequency Sensitive progressive phase shift for each radiation. The maximum radiation direction and the working frequency have a one-to-one correspondence. Because of their advantages of fast beam conversion, superior mobility, and ease of installation, frequency scanning antennas are commonly utilized in radar systems. Because the scanning is done solely by frequency change, the FSA antenna eliminates the need for expensive phase shifters, external switches, and a power combination network, which decreases the overall cost and weight of such systems. As a result, mobility and marketing become easier. Low cost, consistent operation and broad scanning beam angles are only a few of the benefits. There is no movement physically .is the most basic type

The maximum radiation direction and the working frequency have a one-to-one correspondence. Since the scanning is done only by frequency change, FSA antenna eliminates the need for costly phase shifters, external switches and power combination network used in the conventional phased array systems which reduce the overall cost and weight of such systems. This in turn opens a way for ease of portability and commercialization. Low cost, stable operation and large scanning beam angles. There is no moving physical movement .and simplest type of scanned array Due to this reasons beam scanning through frequency scanning array antenna is preferable. Many researches have been done, resulting variety of designing techniques so as to differentiate the path length between consecutive radiating elements. Some renowned works will be presented as follows

In [42], Frequency Scanning Microstrip Antennas was presented**,** this work can be thought as one of the most earliest and the pioneer in FSA antenna development.it come up with concept of using radiating Microstrip resonators as a part of FSA antenna. The resonators are cascaded and coupled. These cascaded- coupled resonators give additional phase shifter in addition to phase shift produced by the transmission line. This has brought significant increment in the steering range compared with the previous works .and has achieve a scanning angle -30° to +30° with a frequency variation of 300 MHZ.

Following the footsteps of the above work, in [43] ,Radiation and scanning characteristics of a frequency scanning Microstrip array antenna. Frequency scanning Microstrip array antenna combined in series and parallel arrangement having nineteen radiating elements with cascade –coupled resonators has been deigned. That means a total of 38 radiating patches have been used. The first 19 cell has been connected with series feeding .the other left 19 cells are also connected each with series feeding and the two seriously connected array are in turn connected in parallel. This design has achieved twice this scanning angle mentioned in [42].Following the above two works, other investigations were conducted in order to improve size, frequency sensitivity, and even to upgrade the FSA concept with a wider frequency range. A Low Loss Frequency Scanning Planar Array Using Hybrid Coupling has been presented in [44]. A hybrid coupling is used in the frequency scanning planar array to produce a large scanning range. The slow-wave structure is used as a conventional E-plane bent rectangular waveguide. Using this hybrid coupling feed, a scanning angle of (-48°, 45°) in one dimension and a gain of above 21.6 dBi has been achieved.

In [45], A Frequency-Controlled Active Phased Array an active phased array using frequency-controlled scanning is familiarized keeping constant radiating frequency through heterodyne-mixing method. The K-band transmitter array demonstrates up to 40 degrees beam-steering at 20GHZ.

2.2 Related works

Ka-band Frequency Scanning Antenna with Wide-Angle Span in [46] Proposes a meandering Microstrip construction with mitered corners that has scan of 52 to +42 GHz and a frequency change of 27.5 to 36.5 GHz, resulting in a 94 beam-steering range at the center frequency 32 GHz. The antenna is made up of 10 cells with a 6-cm length and a uniform ground plane.

In [47], Frequency Scanned Microstrip Antenna Array at waveband range with Low Profile in C-band used for radar applications has been studied. A 2*6 low-profile antenna array is created with a height of 0.0841 and is fed by a rectangular U-slot patch antenna proximity fed by a double D stub followed by a series feed-network comprising slow-wave line .A steering angle from 1 degree to 57 degree has been produced .for a frequency spacing of 1GHz.The feed-network uses one of the types of the meandering schemes that is serpentine where a single line is used as a fed.

In [48], Bandwidth Enhancement and Frequency Scanning Array Antenna Using Novel UWB Filter Integration Technique for OFDM UWB Radar Applications in Wireless Vital Signs Monitoring familiarized A fan beam array antenna with a CPW feed line with band pass filter is designed .the band pass filter and a fan beam array antenna are combined in by placing the filter in the CPW supplied line, but on the other part of the excitation lines. With 2.8 GHz to 6 GHz frequency range, a wide frequency scanning from the 50 to 125 degree (75 degree) range has shown.

A Wide Frequency Scanning Printed Bruce Array Antenna with Bowtie and Semi-Circular Elements is presented in [49]**.** A printed edge-fed equivalent of the wire Bruce array antenna is given. The suggested antenna's unit-cell is made up of bowtie and semi-circular elements that provide a wide bandwidth from below 22 GHz to over 38 GHz with open-stop band suppression. The open-stop band suppression allows for a large scanning range, from backward to broadside and forward end fire. To assess the antenna's efficient scanning performance, a side lobe threshold level of 10 dB is maintained. The antenna's peak realized gain is 15.30 dBi, and it can scan from m 64 to 76 degree.

In [50], SUB-MILLIMETER WAVE FREQUENCY SCANNING 8×1 ANTENNA ARRAY **is** introduced for imaging application .where the array structure is modeled by 8 waveguide with open endings, and combination of WR-3 rectangular waveguides and power divider created the phases shifting scheme. in this work apart from the array and the phase shifting structure the dielectric rods are used for larger beam steering angle .which results a steering range of 40◦ with frequency shift between 270 GHZ AND 330 GHZ.

This work presents 4X1 frequency scanning Microstrip array antenna design with RT Duroid /5880 substrate at the center frequency of 23 GHz. using inset feeding technique. The inset and other patches dimensions are optimized designed with the best dimensions. The array structure is constructed with multi port feeding scheme where each radiating element is fed with different port but the same signal at the same time. This is done nine times per each port. The phase shift in this work is achieved by length increment applied to each radiating element together with the frequency variation applied to each port at the same time but with nine rounds With frequency scanning spacing of 0.125 GHz between 22.5 and 23.5 GHz. 90 degree phase shift has been archived .

CHAPTER THREE

3 MATERIALS AND METHODS

3.1 Materials

Two typical softwares in antenna design are used for analytical modeling and designing the patch these are CST and matlab15a. The user of Matlab can potentially analyze statistics, broaden algorithms or create models and packages. In this paper Matlab is used for analytical modeling. Computer Simulation Technology is abbreviated as CST. Where Design, analysis and optimization of electromagnetic (EM) components and systems with high-performance can be done .It offers a good environment for high frequency (HF) devices like as antennas, filters, couplers, planar and multi-layer structures, in a quick and precise manner. Time Domain and Frequency Domain solvers are included in CST software, and CST MWS offers additional solver modules for specialized applications.in this paper CST software is used for designing, simulating and optimizing patch antenna using time domain solvers.

3.2 Methods

In order to achieve the desired objectives the following methods and steps are followed.

- **Step-1:-** Identify design specifications for single patch Microstrip antenna

Values of Parameters such as height, frequency, techniques such as feeding method and type of material used for patch, ground, and substrate are primarily selected in this stage.

- **Step-2:-** Analytical modeling

Using specifications from step-1, the patch will be modeled mathematically using Microstrip patch antenna design equations with the aid of Matlab software

- **Step-3:-** Design single patch Microstrip antenna

As per the design equations .the dimensions of the patch, ground, substrate, Microstrip line, and inset depth and gap will be designed using CST software.

- **Step-4:-** Find optimal points

Here, in order to get further improvement, some parameters are swept around the range obtained in step -3 keeping height, width of the patch ,width of the strip line ,thickness of copper for both for the ground and patch constant. This is because constant parameters have nothing to do with efficiency improvement or their change modification in the design specifications in the change in the operating frequency and input impedance.

- **Step-5:-**Analytical modeling for FSA antenna

As far as array design is concerned the distance between the radiating elements (patch) “d”, the number of radiating elements (patch) N and the length increment (since we are using FSA) Li (n_0) of each Microstrip line is modeled mathematically in this stage.

- **Step-6:-** Find optimal points for $\boldsymbol{n_0}$ and distance “d”

The best n_0 or length increment value which can comparatively achieve a good beam scanning angle and efficiency is selected.

- **Step-7:-** Design 2x1,4x1 ,6x1,8x1 frequency scanning Microstrip array antenna using “d” and ($\boldsymbol{n_0}$).
- **Step-8:-**Analyze and Compare the performance of single, 2x1, 4x1; 6x1; 8x1 patch antennas

3.3 Design Specifications and Procedures

In this sub-chapter, procedures for designing single Microstrip patch antenna at 23 GHz are discussed turn by turn.

3.3.1 Design Specifications for Single Patch Antenna

In order to meet once own objective; choice of designing specifications play a key role. The following specifications are chosen in order to attain the objective.

Table 3-1 Design Specifications for single patch antenna

Specifications	Type /values
Center Frequency	23 GHz
Input Impedance	50 ohm
Height of Substrate	0.254mm
Dielectric Constant	2.2
Dielectric Substrate	RT Duroid 5880

Radiating Element	Copper

- **23 GHz**

The operating frequency of a given patch antenna highly affect its size, characteristics and overall performance. 23 GHz is best known frequency for its miniaturized application and short distance applications. Especially for DSRC applications .it is becoming a new research area for its advantage in short distance communication application.

- **50 ohm**

In most antenna designs, 50 ohm impedance is used widely. This is just to make our system compatible with an existing system, where 50 ohm is used frequently. But originally the trend of using of 50 ohm begins from the design of coaxial cable which was having 30 ohms (optimal power handling) and 70 ohms (lowest loss), the expectation for air nonconductor coax is 53.5 ohms, with a mean of 48 ohms. As a result, the choice of 50 ohms for air nonconductor might be considered a compromise between power handling capabilities and signal loss per unit length.

- **RT/Duroid 5880 RT**

It is made of Poly characin Fluoro Ethylene composite. Which make it ideal for chemical resistance.it has loss tangent of 0.009 and dielectric constant of 2.2.which is very small compared to other substrate such as FR4, T.L.C etc. Dielectrics are used for improved electrical and mechanical stability [51].The choice of a dielectric material is critical because. It has a direct impact on gain, bandwidth, operating frequency shift, and radiation loss. In Microstrip patch antennas, the dielectric constant also controls the fringing field, which is the primary source of radiation. The lower the value of ε_r, the wider the fringes will be, resulting in better radiation as well as increased bandwidth and efficiency. Therefore the smaller the dielectric constant provided the larger radiation and bandwidth which is the main objective of this paper.inaddition to this unlike FR4, Duroid is ideal for higher frequency applications. In general due to its advantage on loss tangent and dielectric constant .RT/Duroid is chosen [52].

- **Copper**

The ground plane ,patch and transmission lines are supposed to be good conducting metal typically gold ,silver and copper .silver has higher conductivity but expensive .so as to have cost effective design ,copper is chosen .it is highly reactive ,hard and cheaper than the two .in fact its conductivity is not negligible.

- **Height**

The parametric requirements for different antenna may be different, some antennas need height of the substrate to be larger in case, wide bandwidth is critical, some may concentrate on the directivity, in this case the height or the thickness is preferable to be smaller for maximum radiations this is due to the fringing effect .since the main objective this paper to achieve the beam forming and steering, therefor height is chosen [53]. Apart from this for Microstrip line feeding type the thickness of substrate also depends on the guided wave length (λ_g). That means the substrate thickness should be small compared to guide wavelength of the antenna. This is because for higher frequencies and Microstrip type of antenna construction, where the signal and ground are separated by substrate thickness, typical thickness of even used in main researches may lead to "Surface waves" being excited and hence lead efficiency loss. There for the thickness should be smaller than guided wave length just to avoid surface waves being exited and improve efficiency.

3.3.2 Design procedures

The three essential parameters frequency, dielectric constant, and height for patch antenna should be determined first.

- Frequency of Operation **(**f_r**):** 23 GHz
- Dielectric Constant of the Substrate **(**ε_r**):** 2.2
- Height of dielectric substrate (h): 0.254

Specifying the above frequency, height, and dielectric constant, W_P ,L_P , L_g W_g calculated using the following design equations and steps [1].

Step -1:- determining the width and length of the patch for the specified frequency, height, dielectric substrate.

- Width of the patch is calculated as:-

$$W_P = \frac{c}{2f}\sqrt{\frac{2}{\varepsilon_r + 1}} \tag{3.1}$$

Where, w= width of the patch

C= velocity of light (3×10^{11}mm)

f = Resonant frequency

L= length of the patch

$\varepsilon_r =$ Dielectric constant of substrate

- Length of the patch is calculated as:-

$$L_P = L_{eff} - 2\Delta L \tag{3.2}$$

Where, ε_r =Dielectric constant of substrate

ΔL =The normalized extension in length

L_{eff} = Effective length

$$L_{eff} = \frac{c}{2f\sqrt{\varepsilon_{reff}}} \tag{3.3}$$

$$\Delta L = 0.412h\frac{(\varepsilon_{reff} + 0.3)\left(\frac{w}{h} + 0.264\right)}{(\varepsilon_{reff} - 0.258)\left(\frac{w}{h} + 0.8\right)} \tag{3.4}$$

Where, ε_{eff} = Effective dielectric constant, and the equation for it is given below.

$$\varepsilon_{eff} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2}\left[1 + 12\frac{h}{w}\right]^{\frac{-1}{2}} \tag{3.5}$$

Step 2:-Transmission line length is calculated considering 0 degree phase shift .then it will be equivalent to guided wave length

$$LT = \lambda_g \tag{3.6}$$

Where, $\lambda_g$is guided wavelength

$$\lambda g = \frac{\lambda}{\sqrt{\varepsilon_{eff}}} \tag{3.7}$$

Step 3:- Determining the substrate width and length

$$L_g = L + 6h_1 \tag{3.8}$$

$$W_g = W + 6h_1 \tag{3.9}$$

Where Lg and Wg are length and width of substrate and 'h_1' is given by

$$h_1 = \frac{0.0606\lambda}{\sqrt{\varepsilon_r}} \tag{3.10}$$

Step4:- Width of transmission line

$$\frac{Wf}{h} = \frac{8e^{A}}{e^{2A} - 2} \qquad \text{for } \frac{wf}{h} < 2 \tag{3.11}$$

$$\frac{Wf}{h} = \frac{2}{\pi}\left[B - 1 - \ln(2B - 1) + \frac{\mathcal{E}r - 1}{2\mathcal{E}r}\left\{\ln(B - 1) + 0.39 - \frac{0.61}{\mathcal{E}R}\right\}\right] \tag{3.12}$$

$$\text{for } \frac{wf}{h} > 2$$

$$A = \frac{Z0}{60}\sqrt{\frac{\mathcal{E}r + 1}{2}} + \frac{\mathcal{E}r - 1}{\mathcal{E}r + 1} \tag{3.13}$$

$$B = \frac{377\pi}{2Z0\sqrt{\mathcal{E}r}} \tag{3.14}$$

Step 4:- determine notch width and inset distance [1].

- Notch width (g)

$$f_r = \frac{v0}{\sqrt{2 \text{ x } \varepsilon_{eff}}} \text{x} \frac{4.6 \text{ x } 10^{-14}}{g} + \frac{f}{1.01} \tag{3.15}$$

Rearranging equation 3.11 will give equation used to calculate the gap width.

$$g = \frac{v0}{\sqrt{2x\varepsilon_{eff}}} \text{x} \frac{4.65 \text{ x } 10^{-12}}{f} \tag{3.16}$$

- Inset distance (depth)

$$z_0 = R_{in} \ cos^{\ 2} \left(\frac{\pi}{lp} \ d\right) \tag{3.17}$$

Where R_{in}= the resonance input resistance

Lp = length of patch

d = depth of inset

R_{in} is calculated using the following design equations

$$R_{in} = \frac{1}{2(G1 + G12)} \tag{3.18}$$

Where G1 and G12 are conductance of single slot and mutual conductance .they are calculated using the following equations.

$$G1 = \frac{1}{120\pi^2}\int_0^\pi \left[\frac{\sin\frac{ko\ \ wp}{2}\cos\theta}{\cos\theta}\right]^2 sin^3\theta\ \ d\theta \tag{3.19}$$

$$G12 = \frac{1}{120\pi^2}\int_0^\pi \left[\frac{\sin\frac{ko\ \ wp}{2}\cos\theta}{\cos\theta}\right]^2 j0\ \ (k0lp\sin\theta)sin^3\theta\ \ d \tag{3.20}$$

Practically rectangular Microstrip patch is composed of two radiating slots, each with a width of Wp and a height of h, separated by a distance of Lp. Each slot corresponds to a parallel equivalent to conductance susceptance and admittance.

Table 3-2 Designing Parameters for 23 GHz

s.no	Design parameters	values/mm
1	Length of the patch (Lp)	4.266mm
2	Width of the patch (Wp)-	5.1559mm
3	Length of transmission line (Lt)	9.4mm
4	Width of transmission line (Wp)	4.9615mm
5	Inset depth (d)	1.493mm
6	inset width (g)	1.34mm
7	Length of the ground	15mm
8	Width of the ground	15mm
9	Thickness of the patch	0.035mm
10	Thickness the ground	0.035mm
11	Guided wave length (λg)	9.4mm
12	Effective Dielectric constant (ε_{eff})	2.0756

13	Single element conductance (G1)	0.00158siemens
14	Mutual conductance (G12)	0.00049siemens
15	Resonant input impedance (R_{in})	242.2 ohm

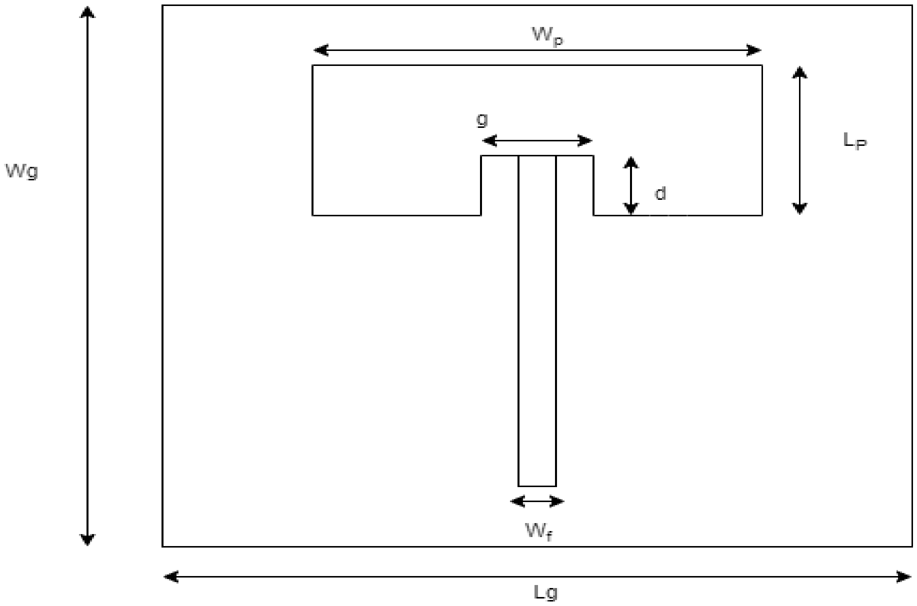
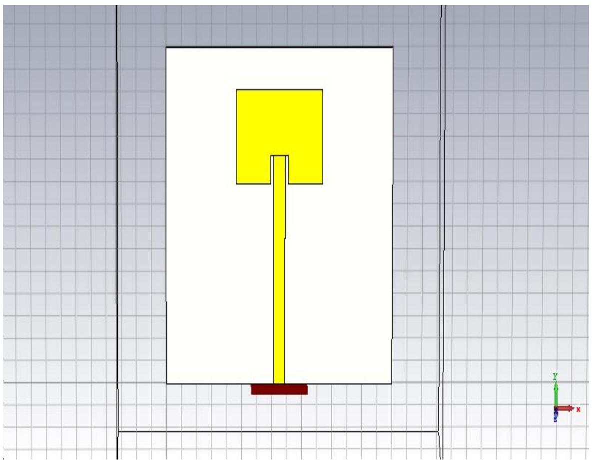
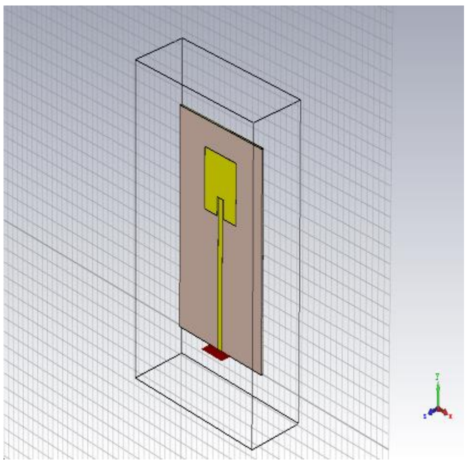


Figure 3.1 proposed design for single patch



(a)



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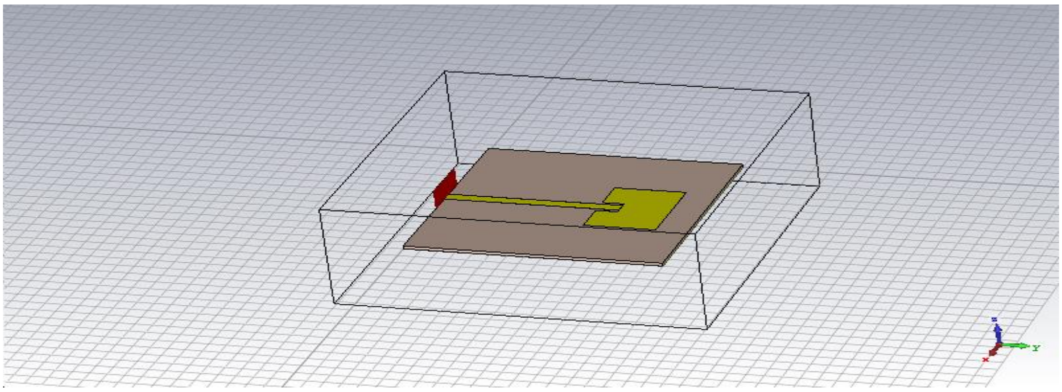


(c)

Figure 3.2 Single patch antenna design (a) Front, (b) side and (c) Top view

Array factor

The response of an array of isotropic elements is represented by the array factor, which allows us to treat the element and the array separately. Multiplying the element factor (the pattern created by a single element) by the array factor yields the total field pattern from an array. This is based on isotropic point sources. Isotropic point sources can be thought of as the ideal antenna, radiating power in all directions. A short derivation of the array factor (AF) is presented from equation to 3.21 -3.24.

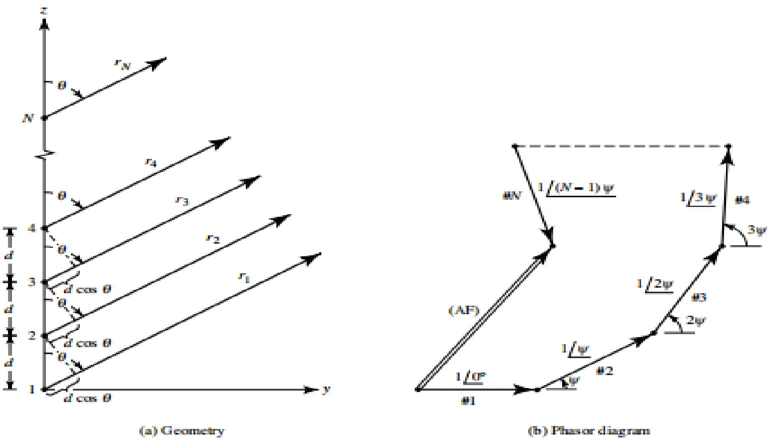


Figure 3.3 Far field geometry and phase diagram for Array factor arrangement [1]

$$\mathrm{AF}\left(\mathrm{e}^{\mathrm{j}\Psi} - 1\right) = \left(-1 + \mathrm{e}^{\mathrm{jN}\Psi}\right) \tag{3.21}$$

$$AF = \frac{e^{j\ N\ \psi} - 1}{e^{jN\ \psi} - 1} \tag{3.22}$$

(3.23)

$$AF = e^{j\ [(N-1)/2]\ \psi} \left[\frac{sin\ \left(\dfrac{N}{2}\ \psi \right)}{sin\ \left(\dfrac{1}{2}\ \psi \right)} \right]$$

If the reference point is at the same location as the array's physical center, equation 3.22 is reduced to likewise, where the highest radiation occurs at = 0

$$\text{AF}= \left| \frac{\sin\left(\frac{\text{N}\,\psi}{2} \right)}{\sin\left(\frac{\psi}{2}\right)} \right| \qquad (3.24)$$

3.3.3 Array Design Specifications

The foundation for array antenna design is proper single patch antenna design. Because the array is created from a collection of single patches, every effect in the single patch design will be reflected in the array antenna design. In array antenna construction, factors such as combination, impedance matching, inter antenna distance, and power feeding method makes a difference. The qualifications for array design may differ. It is dependent on the antenna's kind and purpose. The specs for frequency scanning array antenna design will be presented in this section.

3.3.4 Frequency scanning Microstrip patch antenna

Beam steering is accomplished by controlling the excitation of each radiating element individually through the use of electronically controlled phase shifters in phased array antenna. This can be done alternatively by using frequency scanning array antenna .where phases of all elements are simultaneously controlled just by incrementing the length of each radiating element and feeding variable frequency as shown below [54].

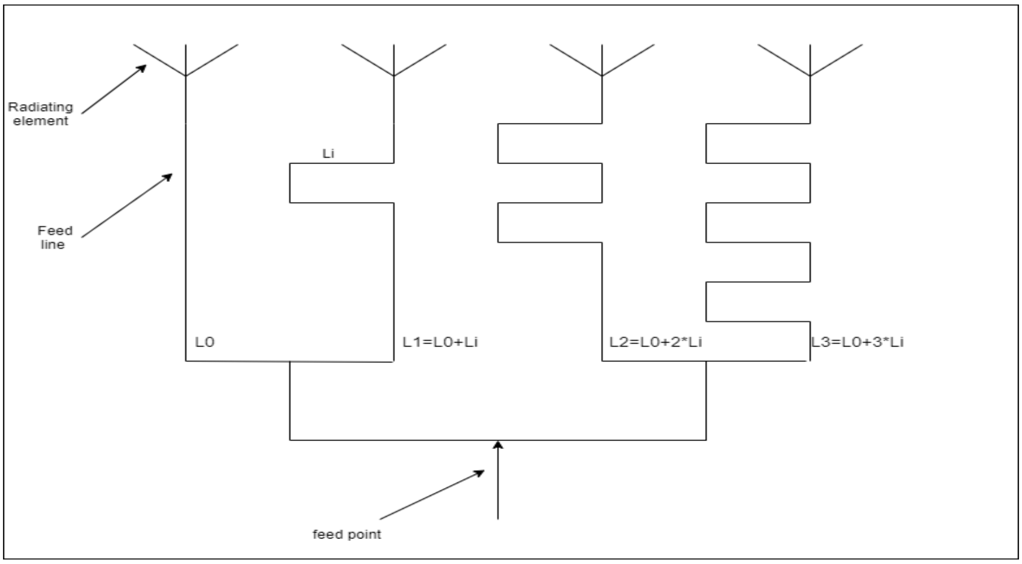


Figure 3.4 Frequency scanned antenna feeding arrangement

Figure 3.4 shows the path length between the common feed point and radiating element is longer by Li for the second element, by 2 x Li for the second element, 3xLi for the third element .therefore the path length of the I $_{th}$ element is given as

$$L_i = iL + L_0 \tag{3.25}$$

L_0represents the path length of the zero$_{th}$ element.

If a certain frequency f is propagating via a transmission line having a length of Li is characterized by phase constant β and phase velocity vp.as shown below.

$$\beta = \frac{2\pi f}{vp} \tag{3.26}$$

Relative to the zero$_{th}$ antenna phase, the incremental phase delay for the i$_{th}$ antenna element is calculated as:-

$$\varphi_{i(f)} = -\beta(L_i - L_0) \tag{3.27}$$

In order to choose the incremental length 'l', reference frequency and a specific positive integer n0 has to be chosen first .Using the relation shown below .Therefore the phase delay or total phase shift of the system becomes

$$\varphi_{i(f_0)} = -2\pi(\frac{L * f_0}{vp}) \tag{3.28}$$

In the same manner

$$\varphi_{2(f_0)} = -4n_0\pi \tag{3.29}$$

$$\varphi_{3(f_0)} = -6n_0\pi \tag{3.30}$$

That means at f_0 , all the elements will have equal phase which are multiples of 2 π and the array radiates in the broadside direction. If f is changed to $(f_0 + \Delta f)$ then the new phase shift of the first element relative to the zeroth element is given by

$$\varphi_{i(f_0+\Delta f)} = \frac{2\pi}{\mathrm{vp}}(f_0 - \Delta f)L \tag{3.31}$$

$$= -2\ n_0\pi - \delta \tag{3.32}$$

Therefore delta or phase shift between the radiating elements is given as

$$\delta = 2n_0\pi\ (\frac{\Delta f}{f_0}) \tag{3.33}$$

Similarly; $\varphi_{I\ (f_0+\Delta f)} = 2\varphi_1$, $\varphi_{i\ (f_0+\Delta f)} = 3\varphi_1$ and so on this it can be said that incremental phase shifts are directly proportional to the fractional deviations of frequency that means array having an element of N, controlling frequency deviation provides direct control of δ which in turn provide a direct control on the scanning angle θ_0.as shown below.

$$\cos\theta_0 = \frac{2n_0\pi}{k * d}\ (\frac{\Delta f}{f_0}) \tag{3.34}$$

As it can be seen from the above equation, the frequency spacing and n_0 values are directly proportional to the scanning angle (θ). But the distance between the patches (radiating element) is inversely related with scanning angle. I.e. the higher the incremental length the higher will be the steering range but the higher the distance between the radiating elements results a decrease in the steering range.

$$\cos\theta_0 = \frac{2n_0}{\lambda g}(\frac{\Delta f}{f_0}) \tag{3.35}$$

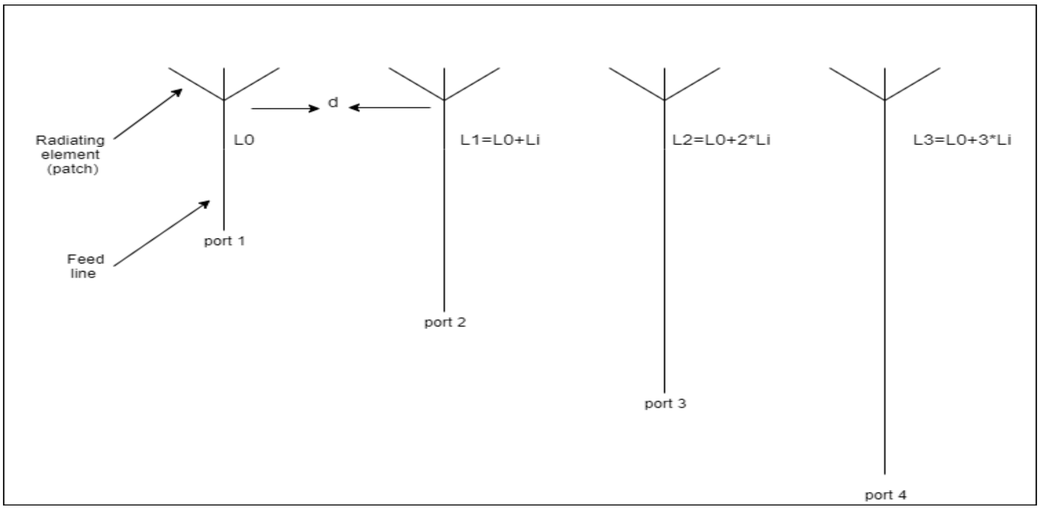


Figure 3.5 Feeding arrangement of proposed FSA antenna

Literally the phase velocity of a certain wave describes the rate at which the wave propagates in a given channel. That means the phase velocity of any signal describes the velocity in which the phase component of a certain frequency travels .it is described by the ration of wave length to time period as $\frac{\lambda}{T}$ where T = $\frac{1}{F}$ which $VP = \lambda * f$. In the same manner, in terms of it's the angular velocity (ω) which is the ration of angular change over a unit time to angular wave number (k). k denotes the proportionality between (ω) and the normal linear speed v.

$$\text{vp} = \frac{\omega}{k} \tag{3.36}$$

Where; $\omega = 2\pi f$ and $k = \frac{2\pi}{\lambda}$

But equation [3.24] in [54] was used for dipole antennas, where the VP (phase velocity) is taken as a ratio between wave length and time period. Mostly a value which is equivalent or some integer multiple of the speed of light is taken.

As far as Microstrip antenna is concerned the wave length is supposed to be guided wave length because the dielectric constant ε_{eff} of the Microstrip line affect its overall function.Therefor the relation between vp and wavelength is supposed to be slightly modified as:

$$\text{vp}_m = \frac{2\pi f}{\frac{2\pi}{\lambda}} \tag{3.37}$$

But λ replaced by λg therefor the new phase velocity will be.

$$VP_m = \frac{c}{\sqrt{\varepsilon_{\text{eff}}}} \tag{3.38}$$

n_0	(Li)	L_1	L_2	L3	L4	Scanning angle (degree)	Steering range (degree)

In the same manner equation (3.13) will be modified as:-

$$\beta = \frac{2\pi f}{VP_m} \tag{3.39}$$

$$\beta = \frac{2\pi f}{\frac{c}{\varepsilon_{\text{eff}}}} \tag{3.40}$$

$$\beta m = \frac{2\pi}{\lambda g} \tag{3.41}$$

In the same manner equation (3.24) will be modified to

$$\cos\theta_0 = \frac{2n_0\pi}{k * d} \ (\frac{\Delta f}{f_0}) \tag{3.42}$$

Where $n_0 = \frac{l * f_0}{VP_m}$

$$\cos\theta_0 = \frac{l * f_0}{VP_m} * \frac{2\pi}{k * d} \ (\frac{\Delta f}{f_0}). \tag{3.43}$$

$$\cos\theta_0 = \frac{2 * l * \lambda}{\text{vpm}} * (\frac{\Delta f}{\lambda g}) \tag{3.45}$$

If the distance between the two patches is assumed to be $\frac{\lambda g}{2}$ this will give

$$\cos\theta_0 = \frac{l}{\text{vpm}} * \frac{2\pi}{\frac{2\pi}{\lambda} * \frac{\lambda g}{2}} \ (\Delta f) \tag{3.44}$$

In this way, having a frequency spacing of 0.125 GHz between 22.5 to 23.5 GHz. for different Values of n_0, the following length increment and steering range has been found.

Table 3-3 Analytical modeling

5	46.8	9.4	56.2	102.9	149.7	[-4.15 , +4.15]	8.3037
10	93.5	9.4	102.9	196.5	290.0	[-8.30 , +8.30]	16.60
15	140.3	9.4	149.7	290.0	430.3	[-37.36 , + 37.3]	74.73
20	188.1	9.4	196.5	383.6	570.7	[-49.82,+ 49.82]	99.64
25	233.9	9.4	243.3	477.1	711.0	[-62.27,+62.27]	124.55
30	280.6	9.4	290.0	570.7	851.3	[-74.73,+74.73]	149.46
35	327.4	9.4	336.8	664.2	991.6	[-87.18,+87.18]	174.37
40	374.2	9.4	383.6	757.7	1131.9	[-99.64,+-99.64]	199.28
45	420.9	9.4	430.3	851.3	1272.2	[-112.10,+112.1]	224.20
50	467.7	9.4	477.1	944.8	1412.5	[-124.55,+124.5]	249.11
55	514.5	9.4	523.9	1038.4	1552.9	[-137.01,+137.0]	274.02
60	561.3	9.4	570.7	1131.9	1693.2	[-149.46,+149.4]	298.93

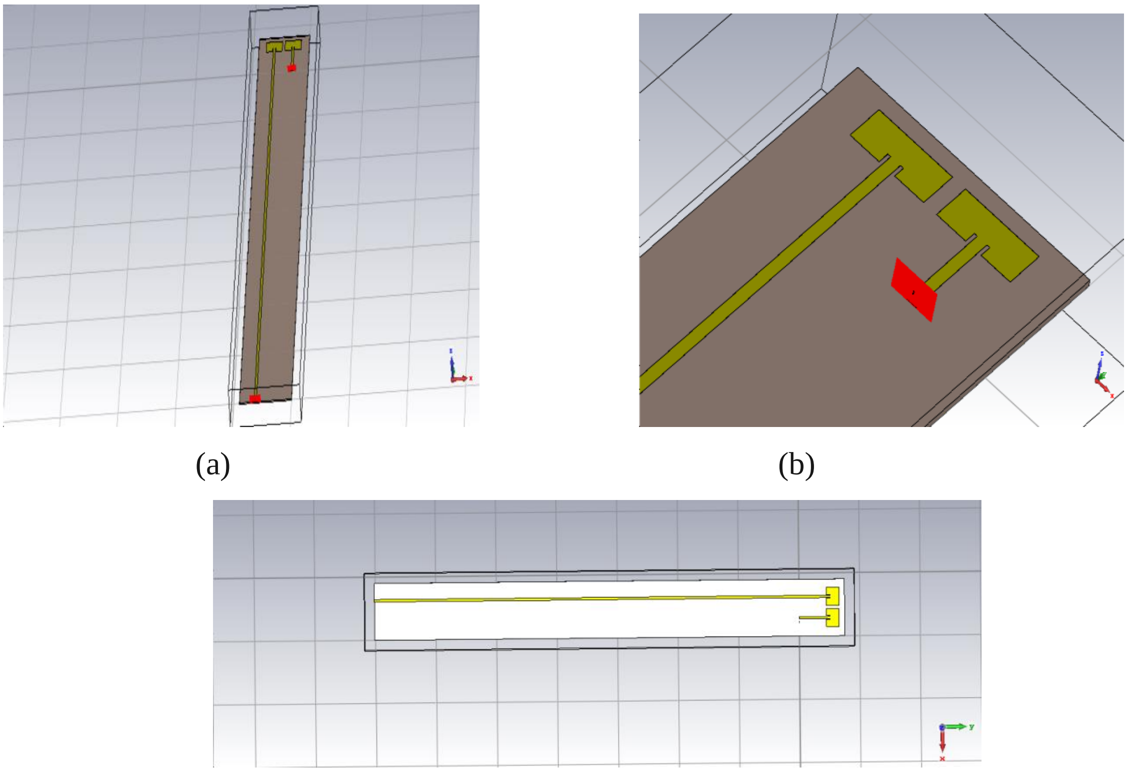
The calculated data in the Table 3-3 clearly demonstrates that the overall antenna length (size) increases as the value of n_0 increases .but increased length of patch antenna results a decrease in the radiation efficiency. Therefor n_0 value with smaller length increment and good beam scanning ability has to be selected .accordingly after a series of analysis n_0 at 20 with length increment of 188.1 has been selected.

Based on this, design specifications for 2x1, 4x1, 6x1, 8x1 are given in Table 3-4.the ground (substrate) length and width only differ as the number of patch increases.

Table 3-4 Calculated values for array design

Parameter (technique)	Values (type)	Values (type)	Values (types)	Values (types)
Number of patch	8	6	4	2

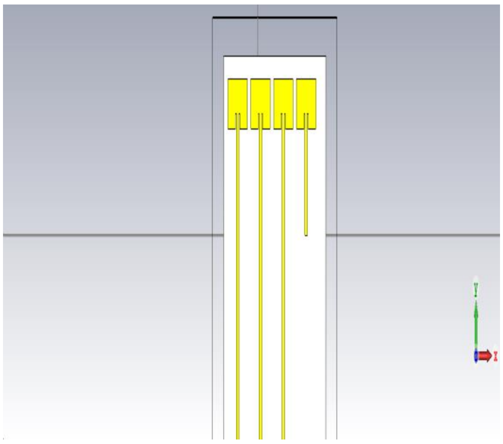
Feeding method	Inset	Inset	Inset	Inset
Input impedance	50 ohm	50 ohm	50 ohm	50 ohm
Radiating material	copper	copper	copper	copper
Patch length	4.1865mm	4.1865mm	4.1865	44.1865
Patch width	5.7mm	5.7mm	5.7mm	5.7mm
Ground length	1324.7mm	950.5mm	435.9mm	230.1mm
Ground width	60 mm	45mm	30mm	22mm
Patch distance (d)	1mm	1mm	1mm	1mm
Random number (n_0)	20	20	20	20
Length increment(Li)	188.1	188.1	188.1	188.1

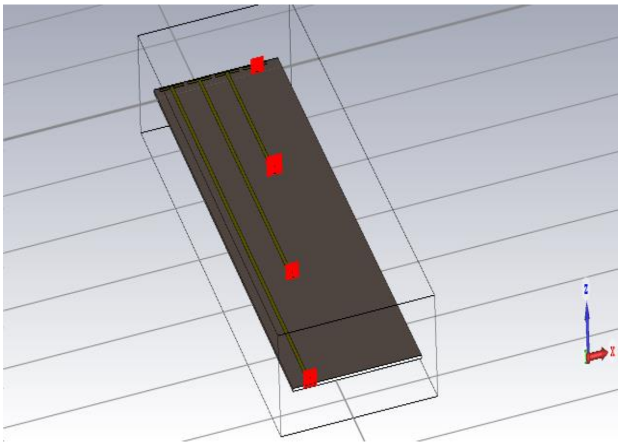


(a) (b)

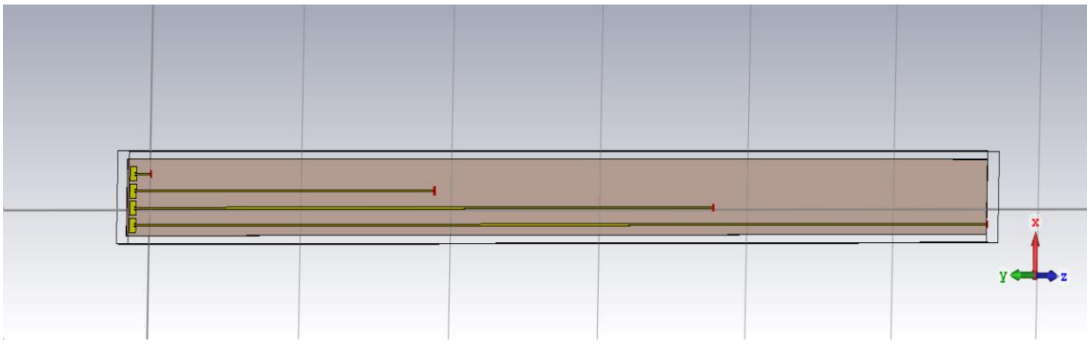
(c)

Figure 3.6 FSA 2x1 antenna design (a) perspective b) front and (c) top view



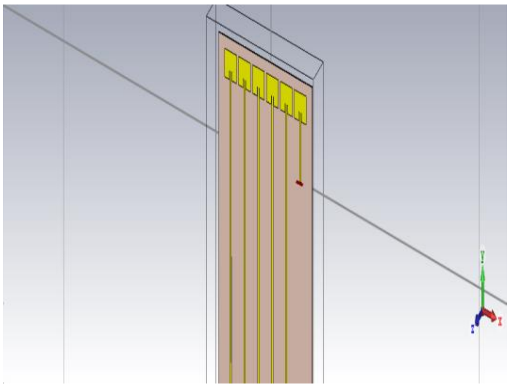


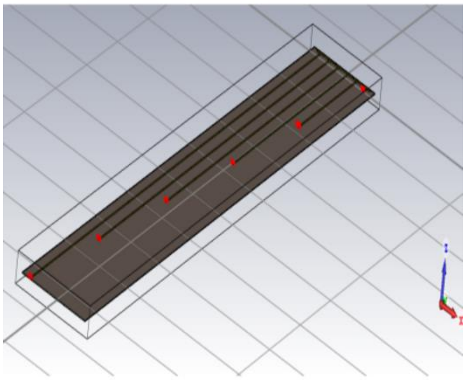
(a) (b)



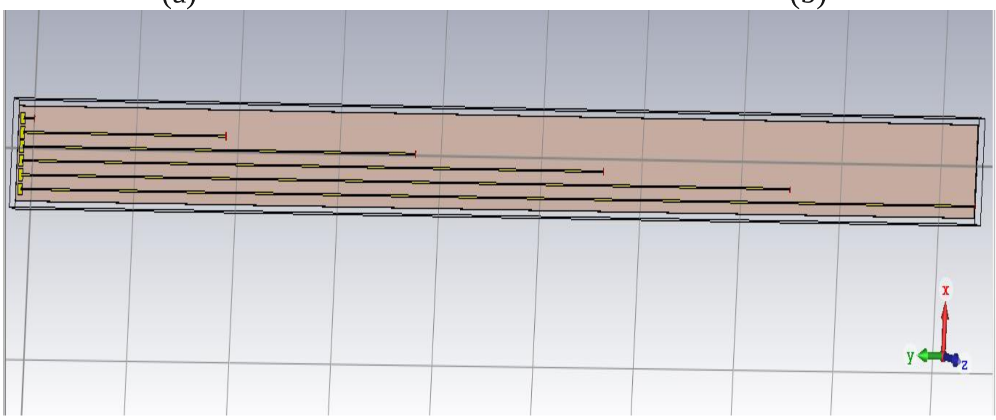
(c)

Figure 3.7 FSA 4x1 antenna design (a) Front b) perspective and (c) top view



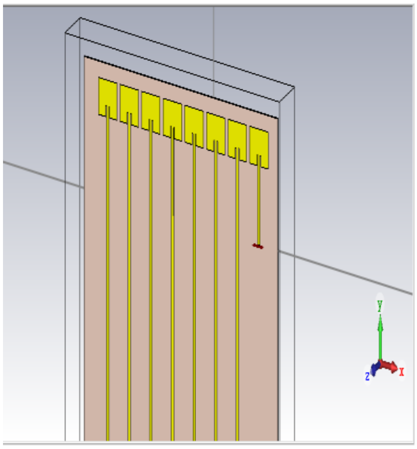


(a) (b)

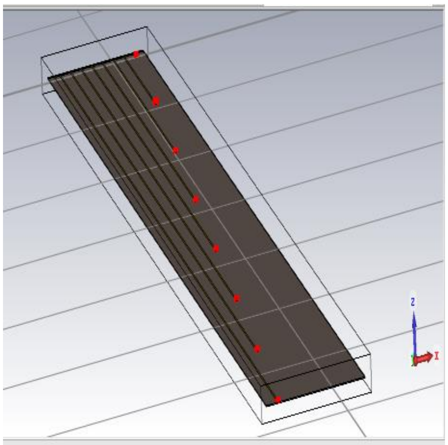


(c)

Figure 3.8 FSA 6x1 antenna design (a) Front b) perspective and (c) top view



(a)



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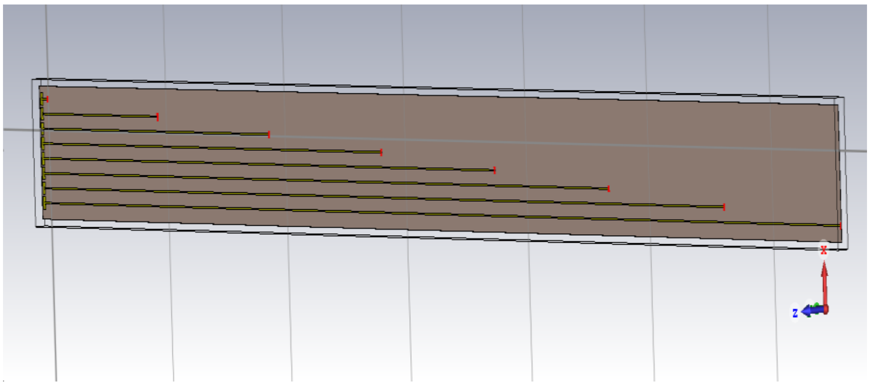


(c)

Figure 3.9 FSA 8x1 antenna design (a) Front b) perspective and (c) top view

CHAPTER FOUR

4 RESULT AND DISCUSSION

4.1 Result and analysis for single patch design

The parametric requirements for the design must be carefully chosen before commencing the real design. Some of the variables, however, are quite consistent. Due to their large impact on the output of the findings, parameters such as depth, length of the patch, and width of the inset are swept turn by turn to obtain the best return loss in the single patch design. This is the case because the return loss properly characterizes patch antenna. Similarly, when designing an array antenna, the n_0 and distance parameters are critical and should be carefully adjusted to provide the best beam steering range in terms of radiation efficiency. This will be detailed in the next subsection. The length of the inset or depth has been determined to be 1.493mm using the single patch antenna design calculation. Adding a few points before and after this figure will give you the best return loss value. The width of the inset is varied in the same way, with possible return loss values displayed in Figure 4.1 by adjusting the width and length of the inset in the range shown in Table 4.1 below.

Table 4-1 Calculated and range values of inset depth and width

	Inset length(d)	Inset width (wd)
Calculated value(mm)	1.493	1.34
Range(mm)	1 - 2	1 - 2

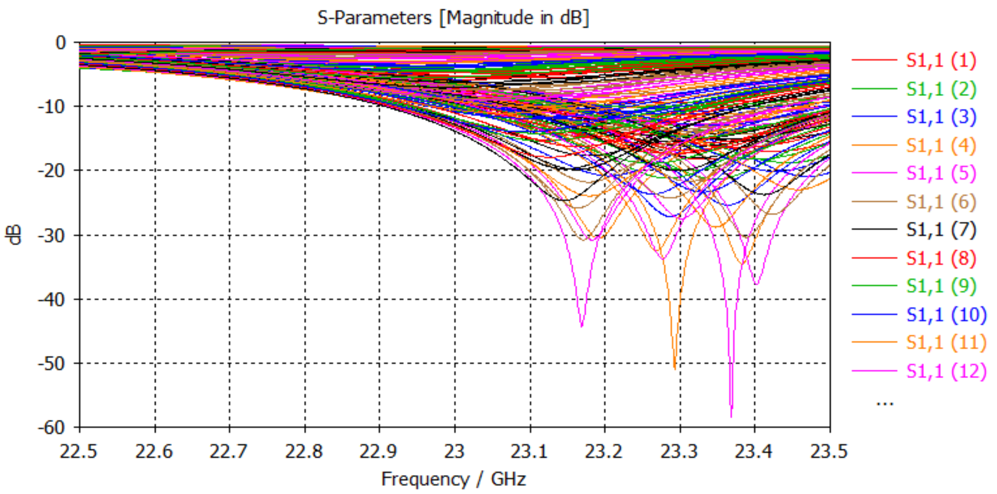


Figure 4.1 Reflection coefficient at different inset depth and width

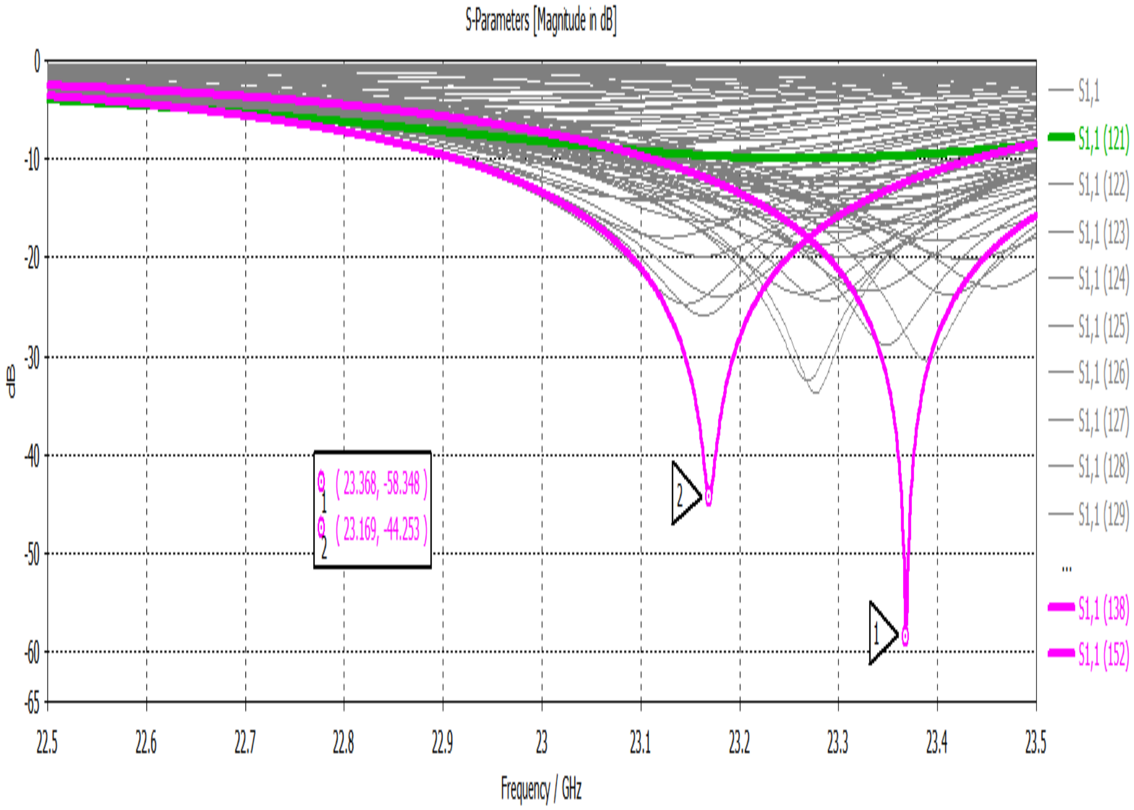


Figure 4.2 Best optimal points for reflection coefficient

Figure 4-2 shows that best return loss values of -58.348 and -44.253 are obtained, but not at the center of the center frequency, therefore the length of the patch in turn will deal with the frequency position. In other words, increasing the patch length will push the return loss line to the right, while lowering the patch length will pull the return loss line to the left. This is due to the relationship between the size of the patch (an antenna) and frequency, with a larger patch size antenna resulting in a lower frequency range and vice versa. Taking some points before the calculated value of patch length, as shown in Table (4.3), will result in return loss shown in the Figure 4.4

Table 4-2 Calculated and range values of patch length (LP)

	Inset length (depth)
Calculated value (mm)	4.266mm
Range(mm)	4mm - 4.266mm

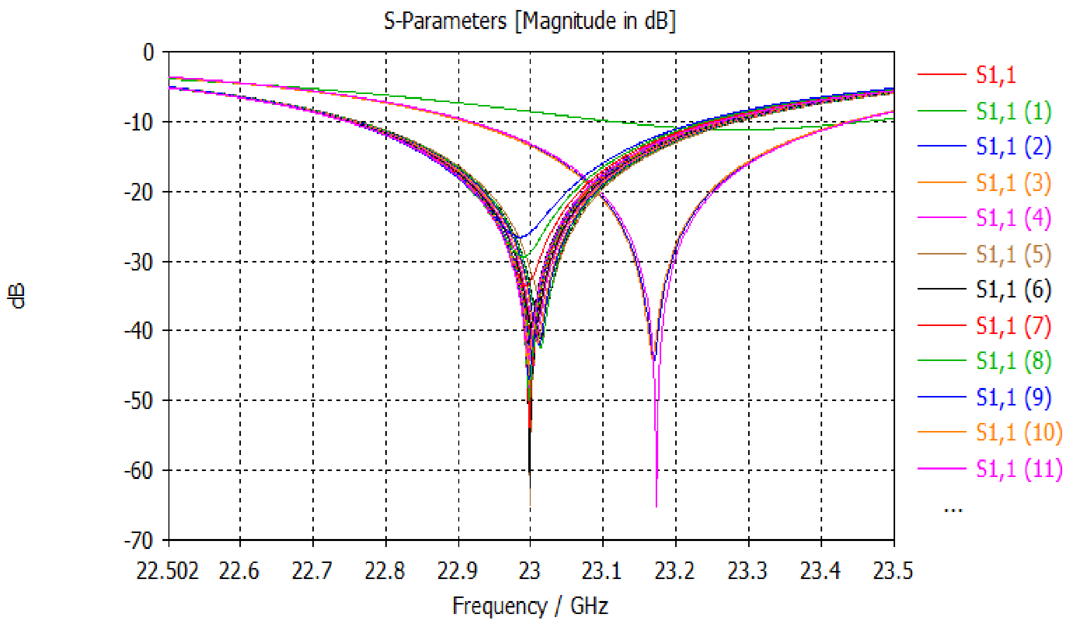


Figure 4.3 Reflection Coefficient at different patch length

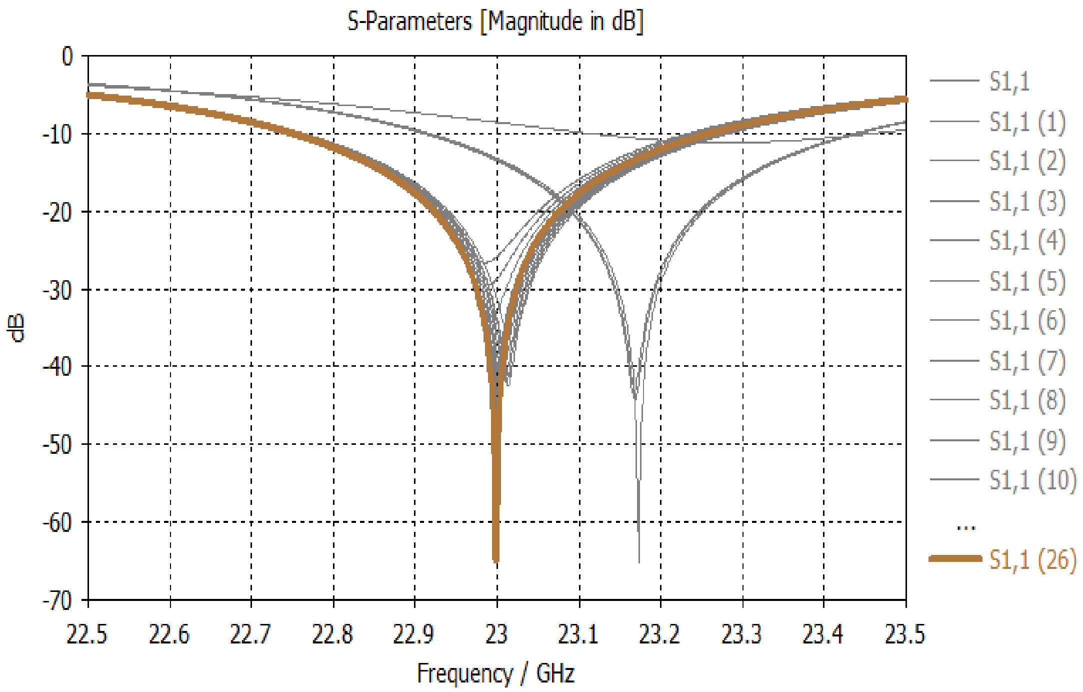


Figure 4.4 Optimal point for reflection coefficient at 23 GHz

Accordingly, after a series of parametric sweep, the optimal value for return loss at 23 GHZ is found to be -65.016208 dB taking Lp=4.18665, g=1.2,and d=1.263

- **S-parameter**

In fact, the most frequently mentioned antenna parameter is S11 or reflection coefficient (also known as gamma or return loss) it represents how much power is reflected from the antenna. When S11=0 dB, the antenna reflects all of the power and radiates nothing. The

S11 monitors how much of the device's input power is returned to the input port. There should be no reflected power, and the device should receive 100 percent of the power it needs. S11 below -10dB indicates that the device receives at least 90% of the input power and reflected power is less than 10%.there for practically a good antenna is supposed to have s11 parameter as small as possible. So that the radiating power will be Maximum Accordingly, -64.101037 is found for 23 GHz which is more than sufficient.

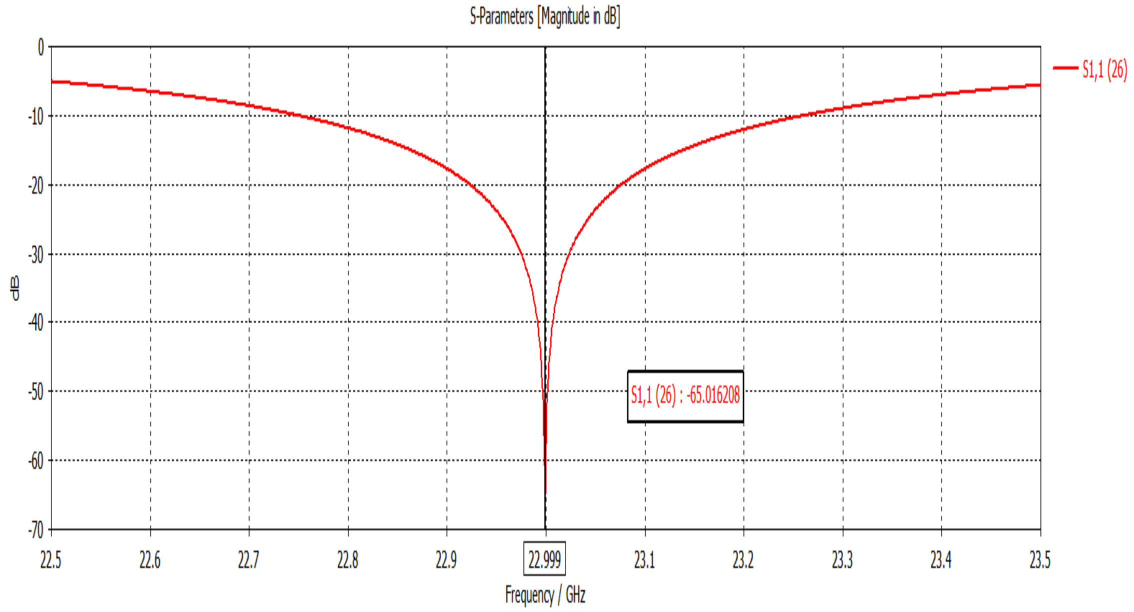


Figure 4.5 Reflection coefficient of single patch antenna

- **VSWR**

The voltage standing wave ratio (VSWR) is a measurement of how successfully radio-frequency power is transferred via transmission line from a power source to a load (for example, from a power amplifier through a transmission line, to an antenna). In a perfect system, 100 percent of the energy is transferred. This needs a precise match between the source impedance, the characteristic impedance of the transmission line, and all of its connectors, as well as the load's impedance. The AC voltage will be the same from beginning to end because the signal passes through without interference. Some power is reflected back toward the source in real systems due to mismatched impedance (like an echo). It's the ratio between the transmission line's highest and lowest voltages. The VSWR is 1.0 in a perfect system since the voltage does not change. But practically VSWR cannot be 1, because even in perfectly matched there is still fraction of losses due to mismatch.in the designed antenna VSWR of 1.0011 is achieved. Meaning matching very near to the ideal system is obtained.

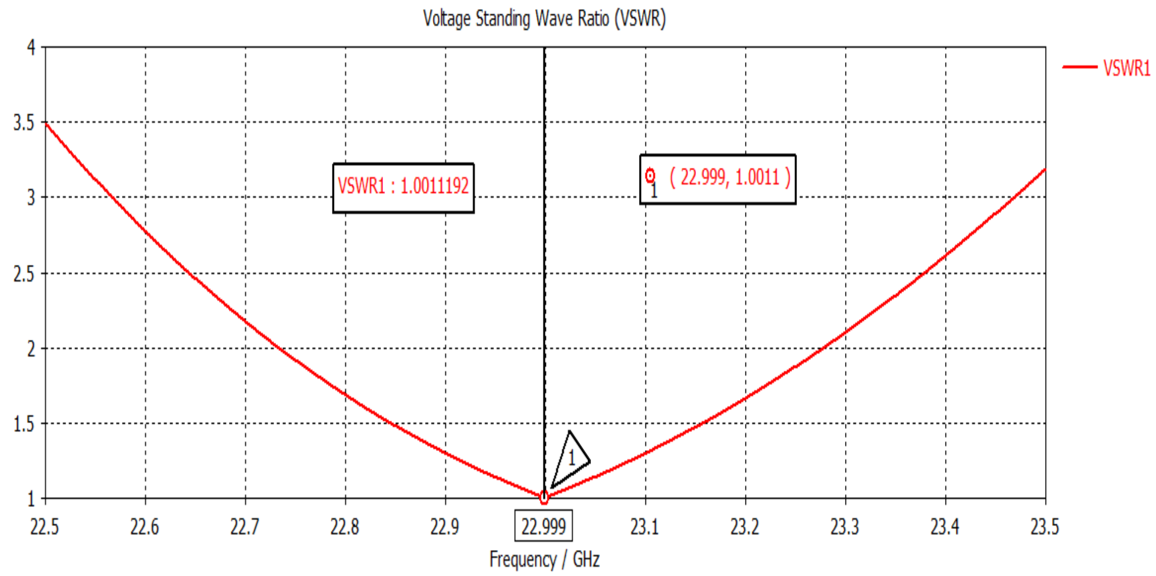


Figure 4.6 Voltage standing wave ration for single patch design

- **Band width**

Theoretically, the band width of an antenna is either calculated using equation 1.11 or 1.12 Bandwidth describes the range of frequencies over which the antenna can properly radiate or receive energy but for single patch antenna it can be easily found by subtracting the lower frequency from upper frequency at -10dB. As shown in the figure below 51.4% bandwidth is attained.

BW = upper frequency -lower frequency

$$\mathrm{BW}\ \% = \frac{\text{upper frequency} - \text{lower frequency}}{\text{total range of frequency}} * 100$$

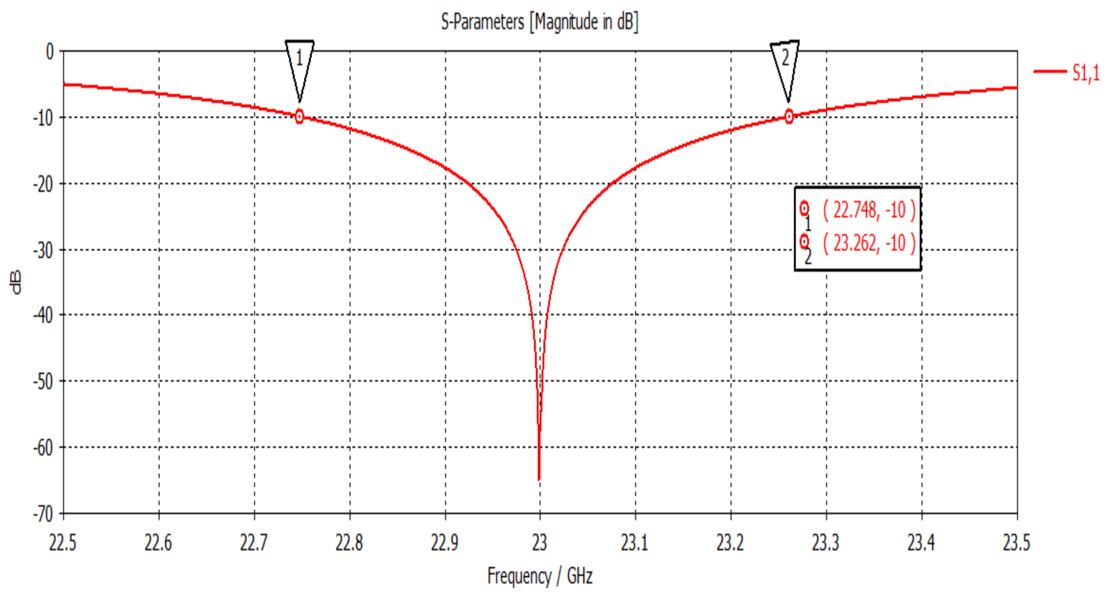
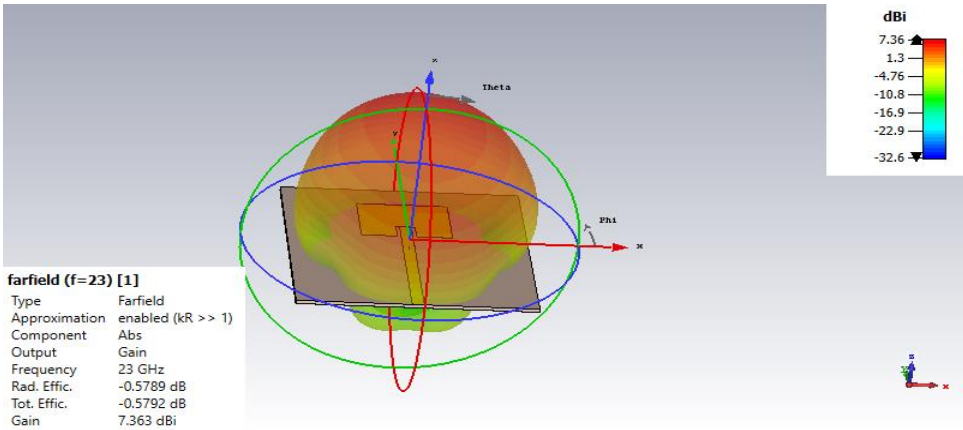


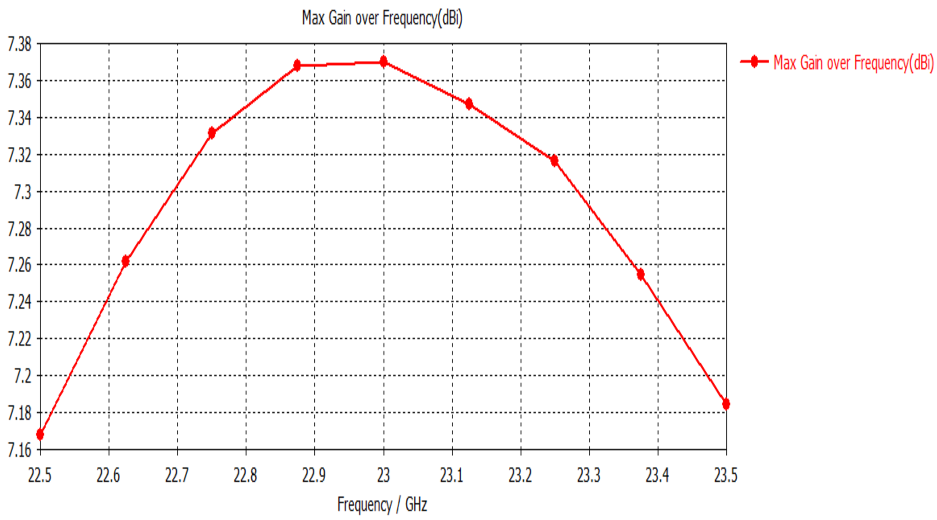
Figure 4.7 Bandwidth of single patch antenna

- **Gain**

The gain of an antenna describes how well the antenna converts input power into radio waves headed in a specified direction. In a receiving antenna, the gain describes how well the antenna converts radio waves arriving from a specified direction into electrical power.therefor the higher the gain of the antenna the higher performance of the antenna will be obtained .it has direct proportionality with the frequency .that means high frequency antennas are expected to have higher gain.so higher gain mean low input power .this is only valid for small sized antenna which mean higher frequency.therefor we can say that higher frequencies are expected to have higher gain .accordingly gain of 23 is found to be 7.36 dBi. In other word having a gain of 0dB means the input power is equivalent with output power.in the same manner having a gain of 7.36 dBi means the output power in 7.36 dBi more power full than the input power.



(a)



(b)

Figure 4.8 Fairfield results (a) 3D gain polar plot (b) Gain over frequencies

- **Directivity**

Directivity is the measure of the concentration of an antenna's radiation pattern in a particular direction. That means. The higher the Directivity, the more concentrated or focused is the beam radiated by antenna. It is a quantitative measure of an antenna's ability to concentrate radiated power per unit solid angle in a certain direction, and thus D is highly dependent on the three-dimensional pattern of an antenna. In the radiation pattern of an antenna, the main lobe is the main beam of the antenna where maximum and constant energy radiated by the antenna flows.in this work a Directivity of 7.942 dBi is attained.

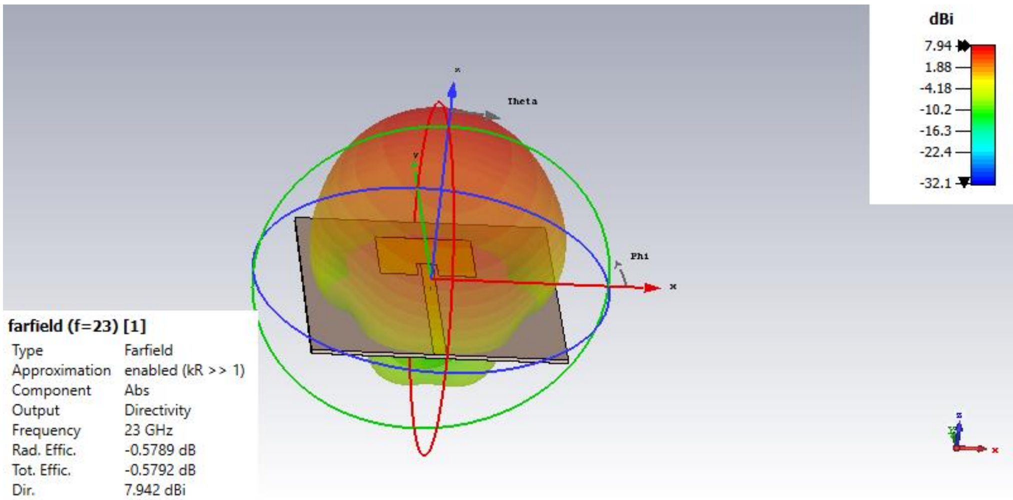


Figure 4.9 3D Polar plot for the gain single patch antenna

- **Beam width and Side lobe level**

Angular Beam width is the aperture angle from where most of the power is radiated. Practically it is the width of main lobe at 3dB. Main lobe of an antenna is the region around which the direction of maximum radiation occurs (usually the region that is within 3 dB of the peak of the main beam).The side lobes are smaller beams that are away from the main beam. These side lobes are usually radiation in undesired directions which can never be completely eliminated. But, recommended to have as smaller value as possible. Side-lobe level at the center frequency of 23 GHz has become -15.85 dBi as shown in the figure the side lobe levels increase with frequency this is because as the frequency increases the antenna is more disposed to noise and interference in and Angular beam width of 71.9 dB is acquired at the center frequency.

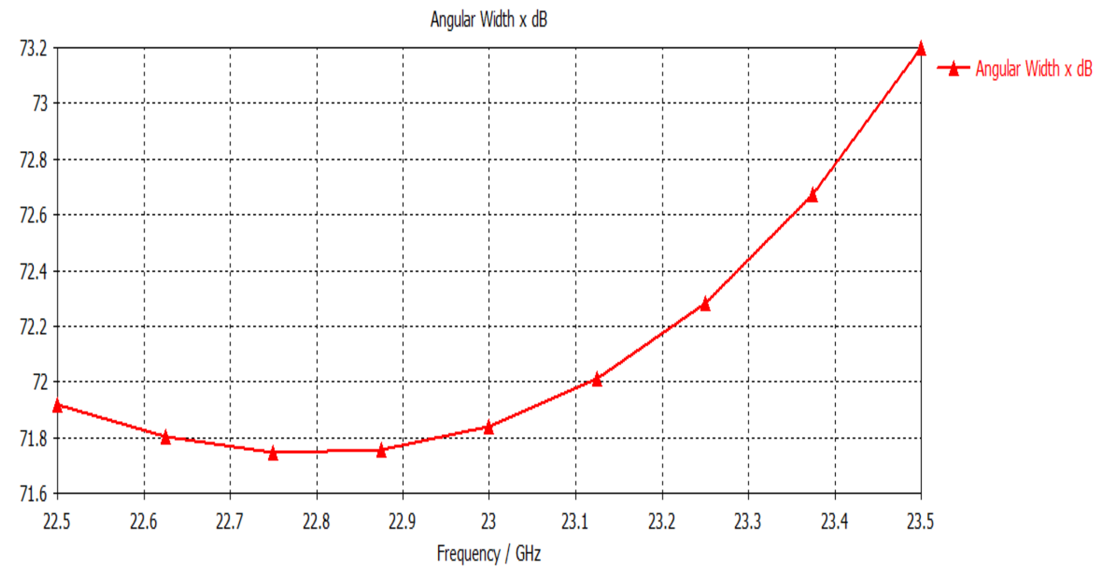


Figure 4.10 Beamwidth vs. Frequency at single patch design

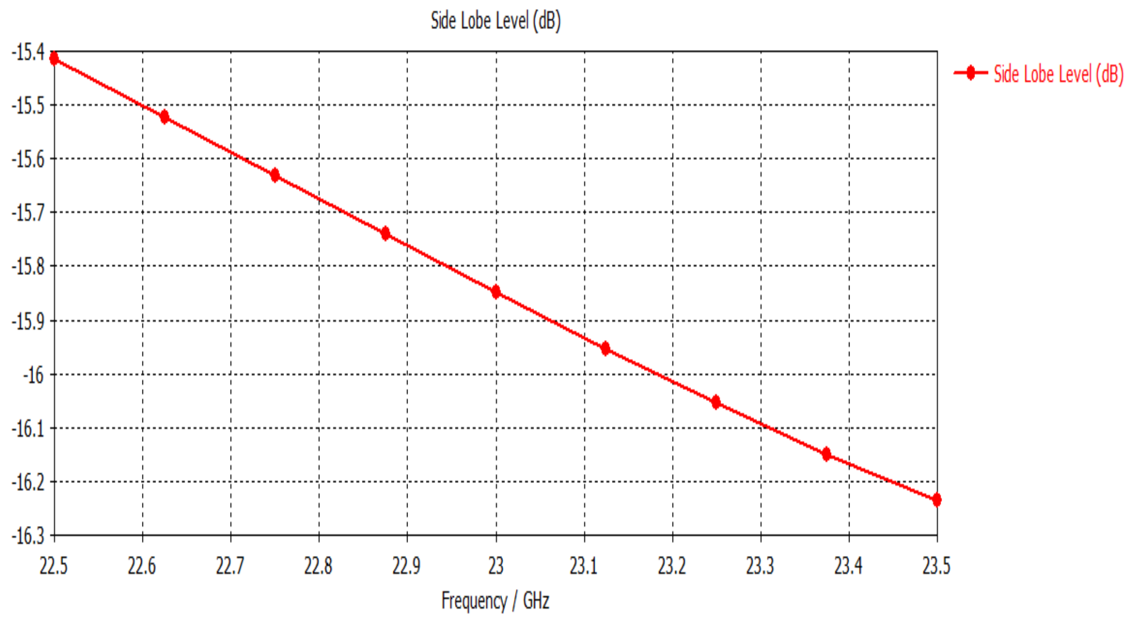


Figure 4.11 Side lobe level vs. Frequency for single patch design

Radiation and Total Efficiency

The ratio of power radiated (Prad) by the antenna to the power supplied (Ps) by the antenna is known as antenna efficiency. An ideal antenna has 100% antenna efficiency, which means it transmits all of the power it receives. In the real world, however, a good antenna radiates only 50 to 60% of the power it receives. At 23 GHz, a single patch antenna design with a radiation efficiency of 87 % and a total efficiency of 85 % is achieved. The ratio of the power emitted by the antenna to the power that enters the antenna is described by radiated efficiency. The total efficiency relates antenna's efficiency with mismatch loss. it takes into account both reflection loss and power energy dissipation in the antenna. The higher the mismatch the smaller will be the total efficiency.in this work a maximum total efficiency of from 58% to 85% is obtained, meaning 58% to 85% of input power available at the input is radiated.

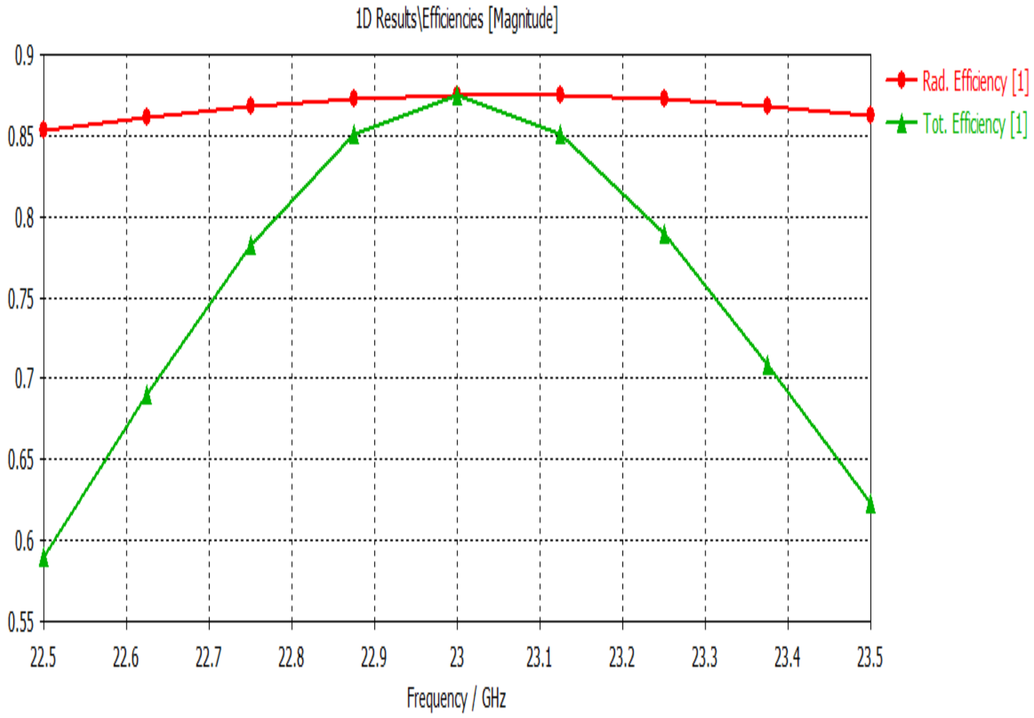


Figure 4.12 Efficiencies of single patch antenna design Radiation and Total efficiency

Table 4-3 Summary of results for single patch design

	Parameter	Value
1	Reflection coefficient	-64.10 dB
2	VSWR	1.0011
3	Gain	7.36 dBi
4	Directivity	7.942dBi
5	Beam width	71.9 GHz
6	Side lobe level	-15.85dBi
7	Total efficiency	85%
8	Radiation efficiency	87%

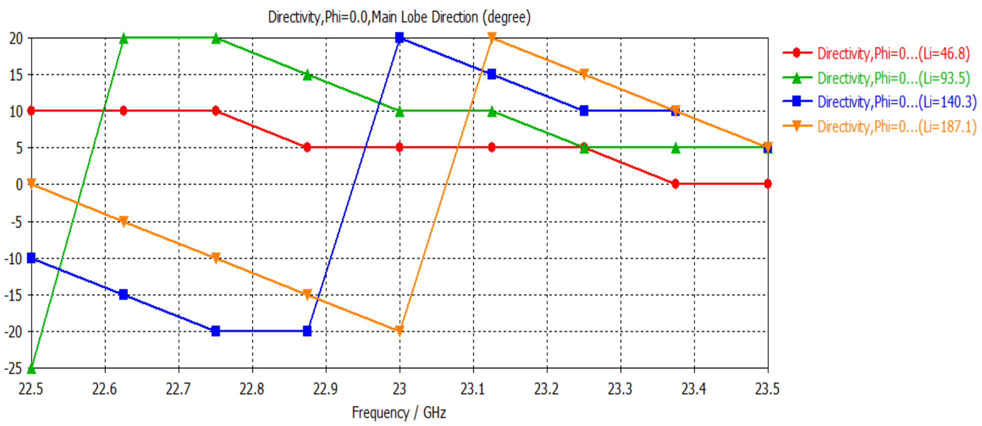
4.2 Results for Frequency Scanning Microstrip Array Antenna Design

The steering range (scanning angle) has a direct relationship with the random number n_0 according to the equation [3.24]. That means increasing the value of n_0 increases the scanning angle. This is due to the fact t n_0 has direct impact on the length of the feed line. As a result the higher the length of the feed line, the higher will be the n_0 value which results wide band scan.as shown in Table 3.3.But n_0 difference in the near distance (i.e. n_0 =1, n_0 =2, n_0 =3,. n_0 =4,. n_0 =5) has insignificant variation in the steering range .therefor n0 value with difference of 5 from 5 to 60 is considered.

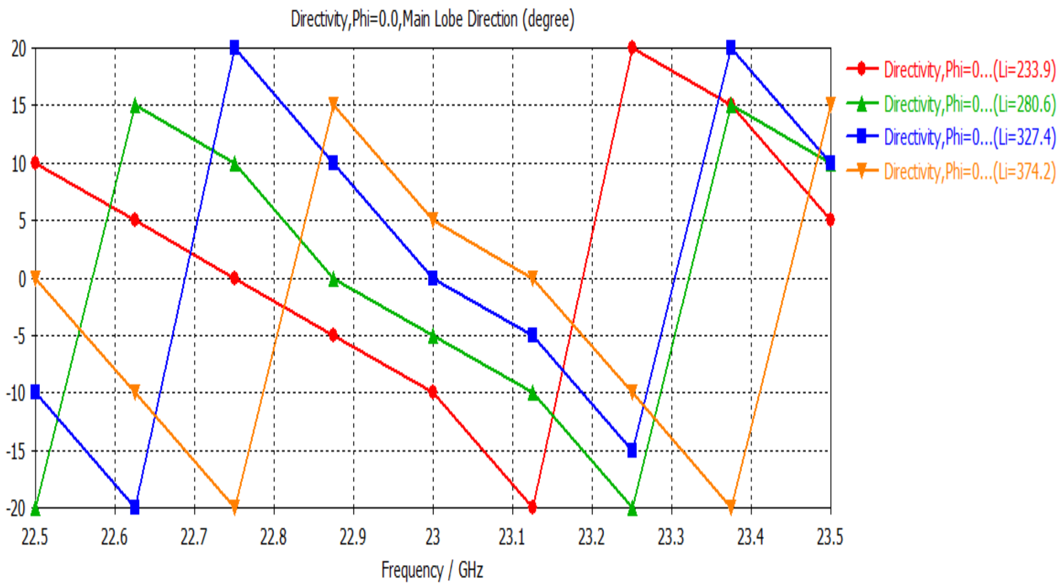
i.e. 5 ,10,15,20,25,30,35,40,45,50,55,60 values of n_0 are sampled .The procedure is done as follows

- Step-1:vary n_0 value keeping the distance (d) constant
- Step-2:vary the distance (d) between the patch, keeping the n_0 (length increment) constant
- Step-3:vary both distance (d) and n_0 (length increment) value simultaneously with selected values from step-1 and step-2
- Step-4 select optimal value of d and n_0 by comparing their efficiency and scanning angle
- Step-5 design 2x1,4x1,6x1,8x1 FSA patch antenna using optimal points of d and n_0 (length increment)

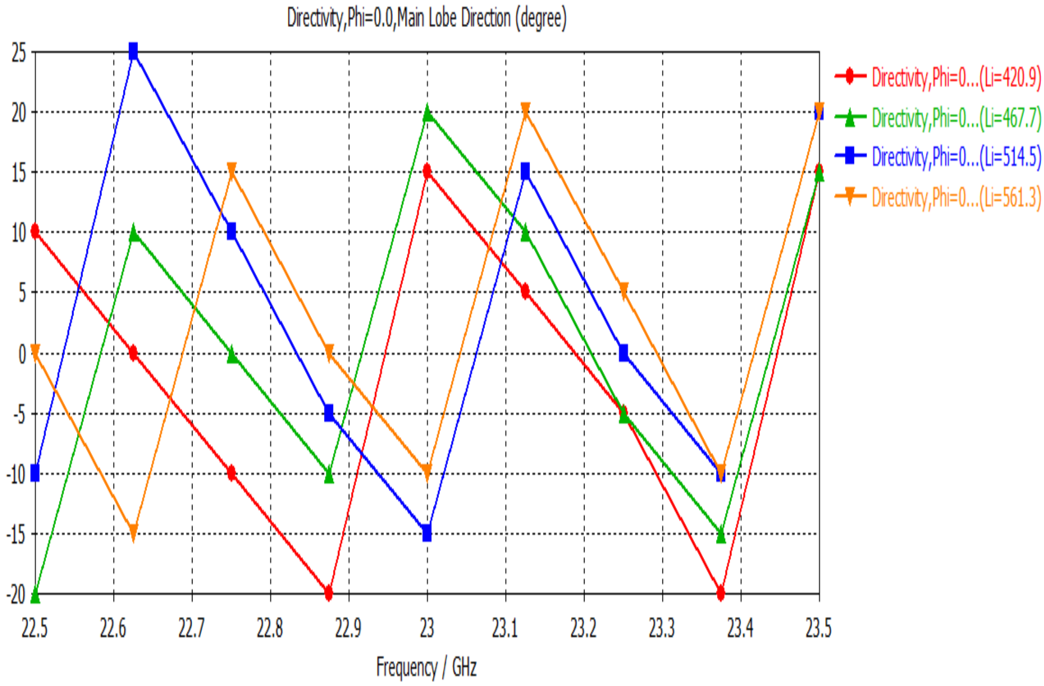
Varying n_0 value varies from 5 ,10,15,20,25,30,35,40,45,50,55,60, the length increment (Li) values will be 46.8,93.5,140.3,187.1,233.9,280.6,327.4,374.4,374.2,420.9,467.7,514.5, 516.3. Respectively hence, keeping distance d constant .the range of scanning angle radiation and total efficiency of the designed patch is shown in the Figure 4.14 /15



(a)



(b)



(c)

Figure 4.13 Scanning range (a) Li=46.8-1871 (b) Li=233.9-374.2 (c) Li= 420.9-561.3

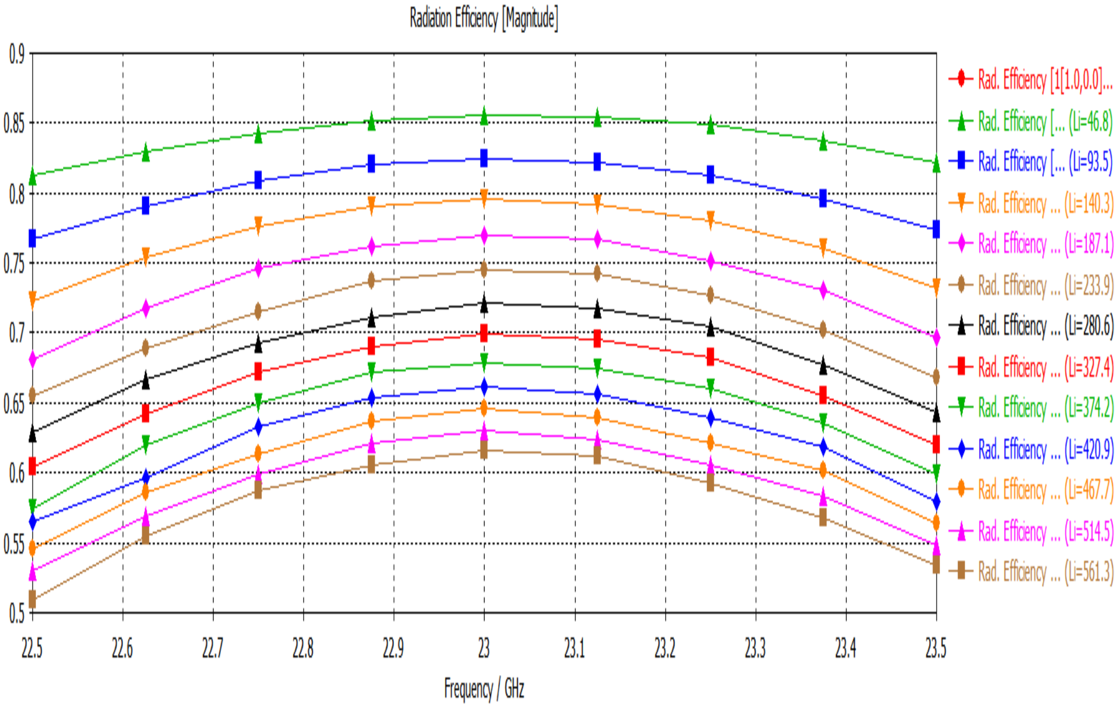
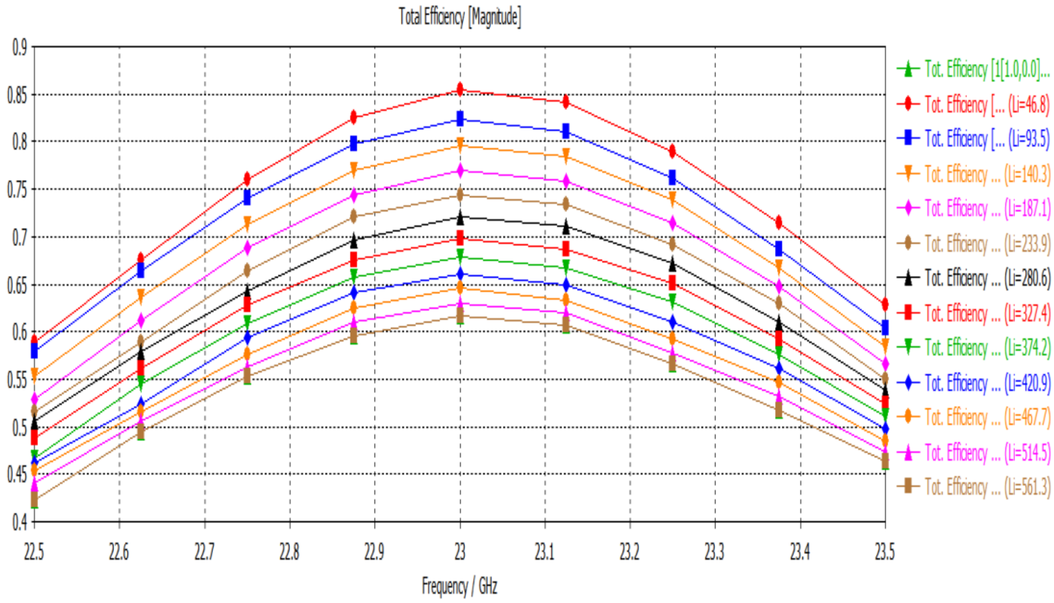


Figure 4.14 Radiation efficiency at Li=46.8-561.3



(b)

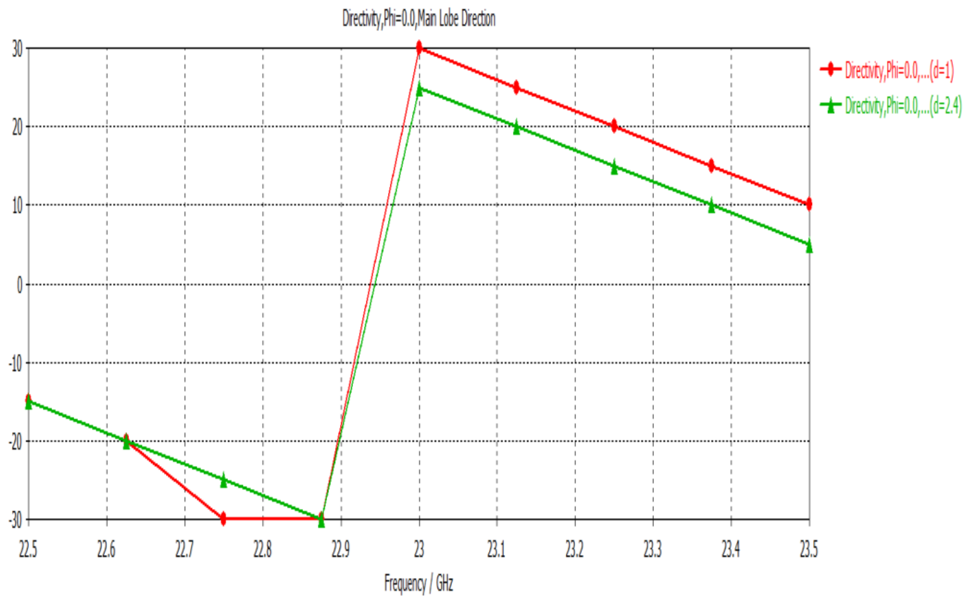
Figure 4.15 Total efficiency at different Li=46.8-561.3

From Figure 4.13 ,4.14 and4.15 it can be concluded that as the length increment increases ,both radiation as well as total efficiency decreases gradually , this is because of different types of losses arising from the type of material(both copper ,and Rogers Duroid) ,loss from the dielectric loss ,loss tangent .due to these losses not only the efficiency also the steering range have been affected. That it makes it very limited range compared to the mathematically modeled scanning range. The summary of Figure 4.12 presented Table 4.2.

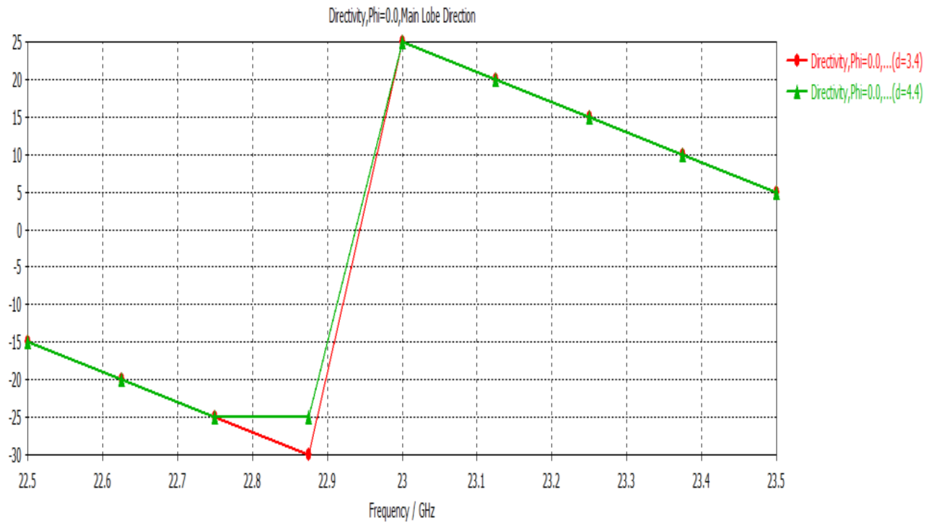
Table 4-4 Efficiency and steering angle range at different length increment

length increment	scanning angle range (degree)	Radiation efficiency (range)	Total efficiency Range
46.8	[0,+10]	81-86	59-86
93.5	[-20 ,+20]	76-81	58-81
140.3	[-20,+20]	73-79	55-79.5
187.1	[-20,+20]	69-76	54-76.5
233.9	[-20,+20]	66-74	52-74.5
280.6	[-20.+15]	63-72	51-72
327.4	[-20,+20]	60-70	49-70
374.4	[-20,+20]	57-67	46-63
420.9	[-20,+15]	56-66	40-61
467.7	[-15,+20]	55-64	45-64.5
514.5	[-15,+25]	54-63	44-62
516.3	[-10,+20]	51-61	43-61

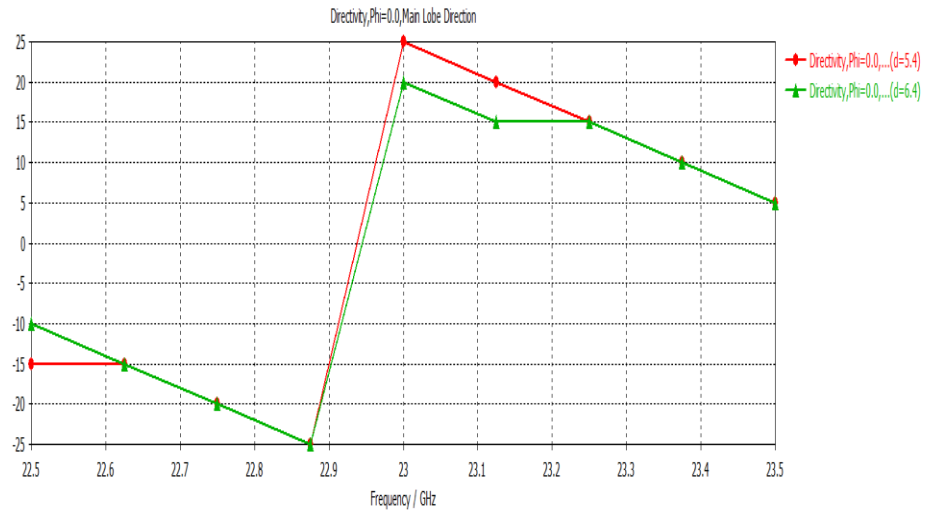
Alternatively the Figure 4.16 shows the exact reverse of the previous samples where length increment is kept constant as Li at 280.6 (this can be any value) and the distance between the patches is varied from 1 to 8.4.



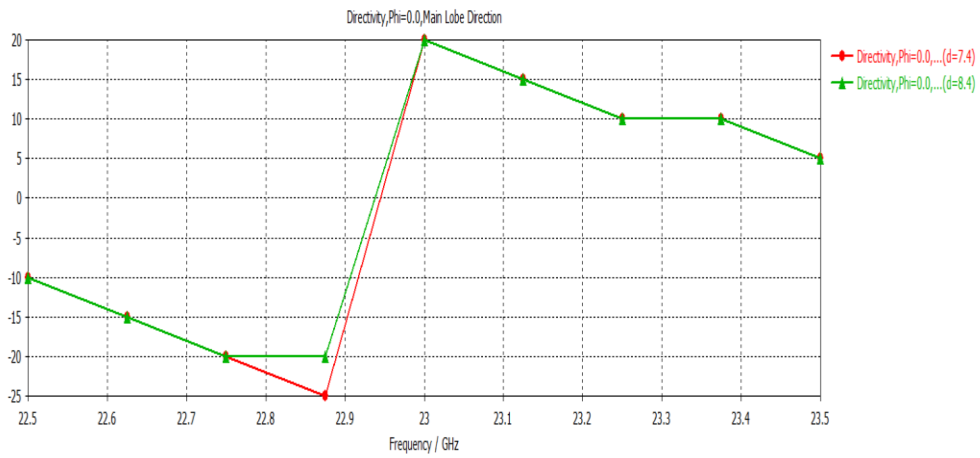
(a)



(c)



(b)



(d)

Figure 4.16 Directivity vs. frequency for (a) d=1, 2.4, (b) d=3.4, 4.4 (c) d=5.4, 6.4 (d) d =7.4, 8.4

It has been seen that at a constant length the variation distance between the patches has made difference around 5 degree range.in the Figure 4.16 (a) at d=1and 2.4 the steering range has become 60 and 55 degree in the same manner the for d=3.4 ,4.4,5.4,6.4,7.4,8.4 a steering range of 55,50,50,45,45,40 degree.so maximum range has been seen in the first three values of that mean d=1,2.4,3.4.but unlike phase angle the value d has no such a greater impact in the efficiency of the patch that is clearly shown in the Figure bellow .

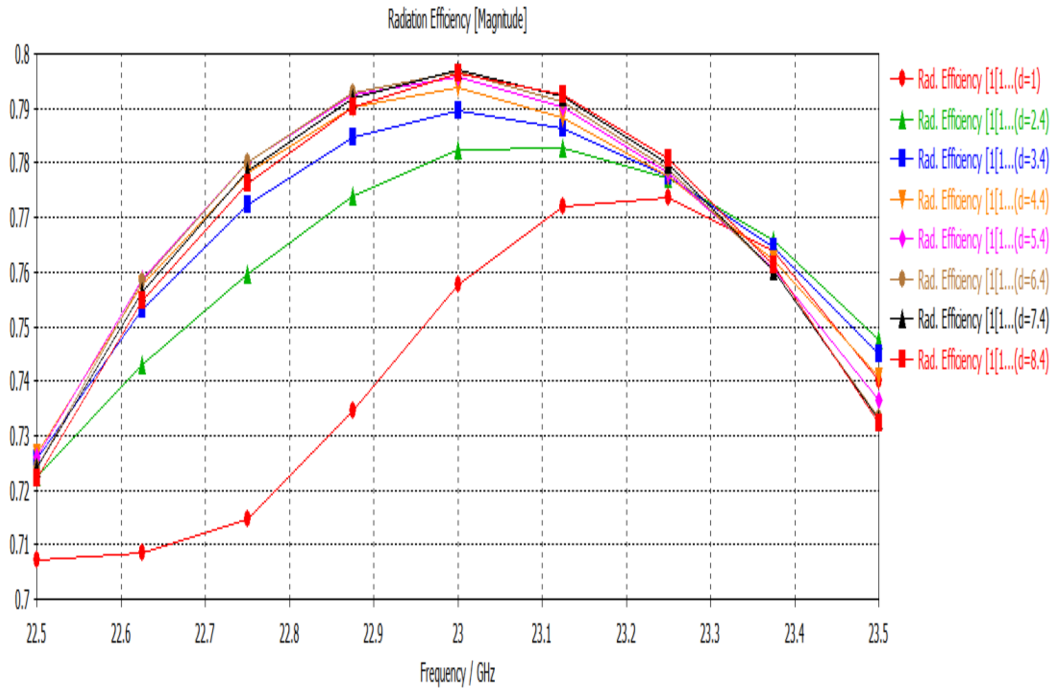
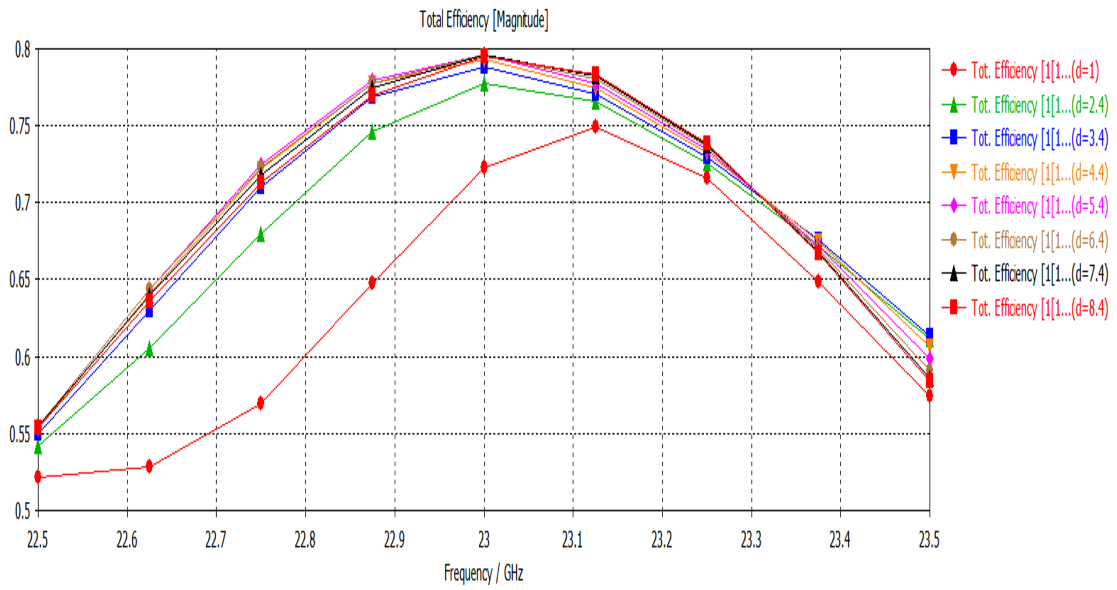


Figure 4.17 Radiation efficiency for d= [1-8.4]



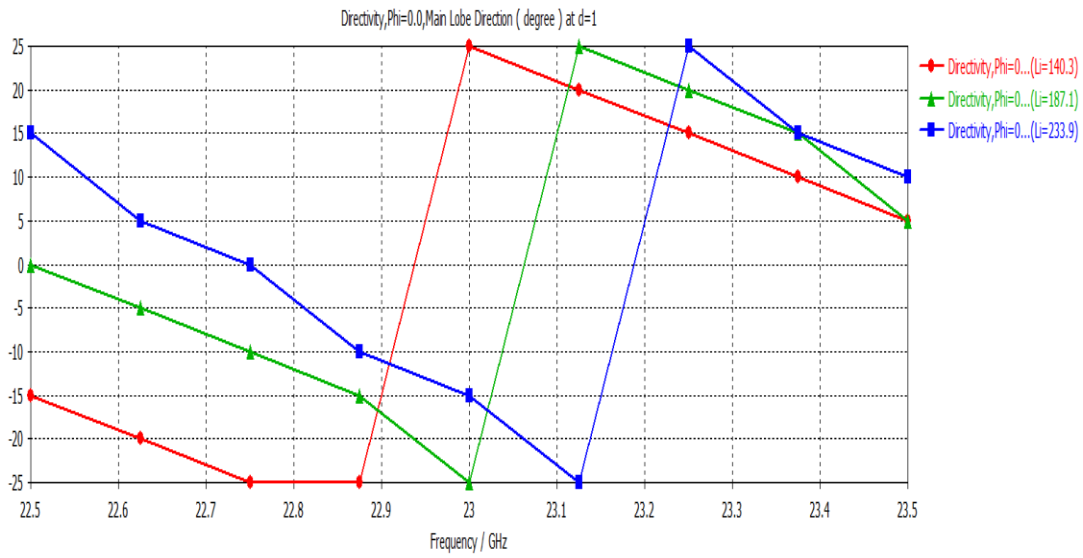
(b)

Figure 4.18 Total efficiency for d=[1-8.4]

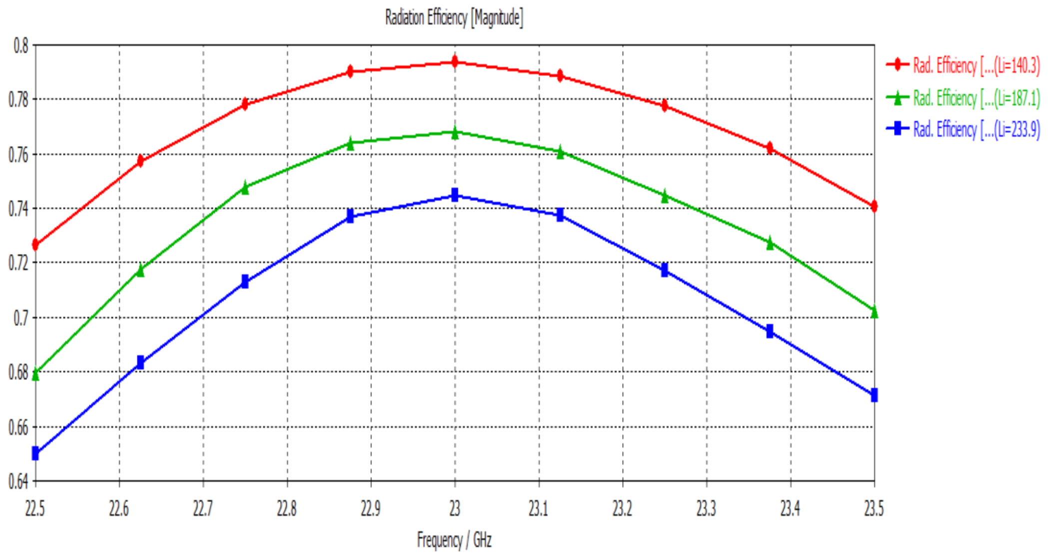
The above two steps clearly confirm that both length increment and distance between the patches have direct impact on the beam steering capacity as well as radiation and total efficiency of the system .since they have impact on the beam scanning angle and performance of the array it is not practical just to keep one parameter constant randomly and vary the other parameter. There for the next step will verify which combination of the two variables performs well. Hence selected length increment from step-1 (i.e.140.3, 187.1, 233.9) and selected distance between the patch from step-2 (1 to 3.4) has been tested simultaneously.

Table 4-5 Efficiency and steering angle range at different distance between patches

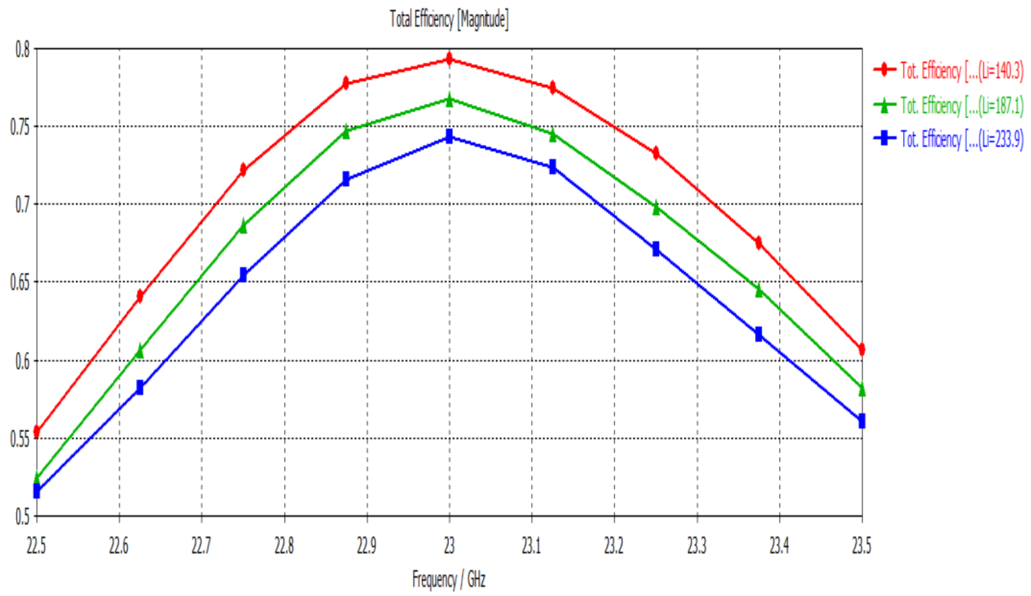
(distance)	Steering range (degree)	Radiation efficiency (range)	Total efficiency (range)
1	[-30,+30]	71-77	52-75
2.4	[-30 ,+25]	72.5-78	54.9-77
3.4	[-30,25]	72.5-79	55-79
4.4	[-25,+25]	72.75-79	55-80
5.4	[-25,+25]	72.8-79.5	55-80
6.4	[-25.+20]	72.5-79.5	55-80
7.4	[-25,+20]	72.5-79.9	55-80
8.4	[-20,+20]	72-79.9	55-80



(a)



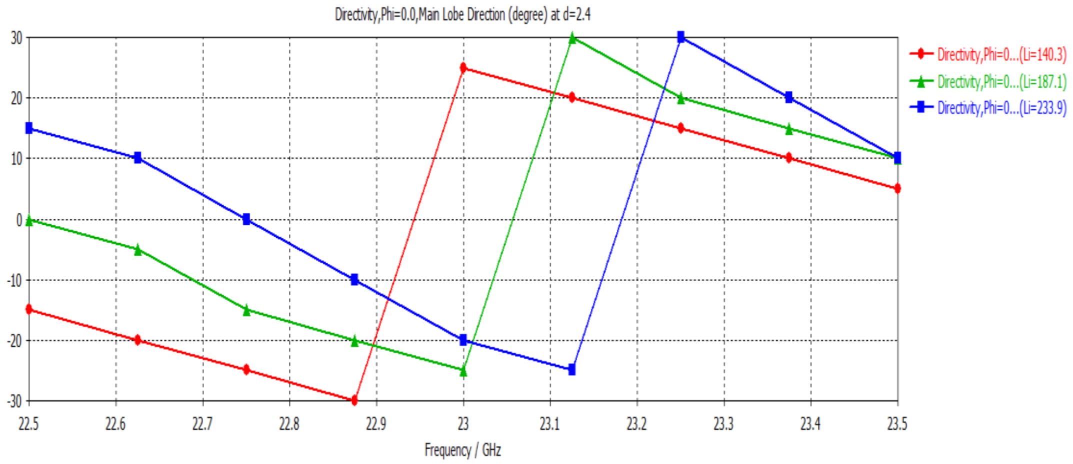
(b)



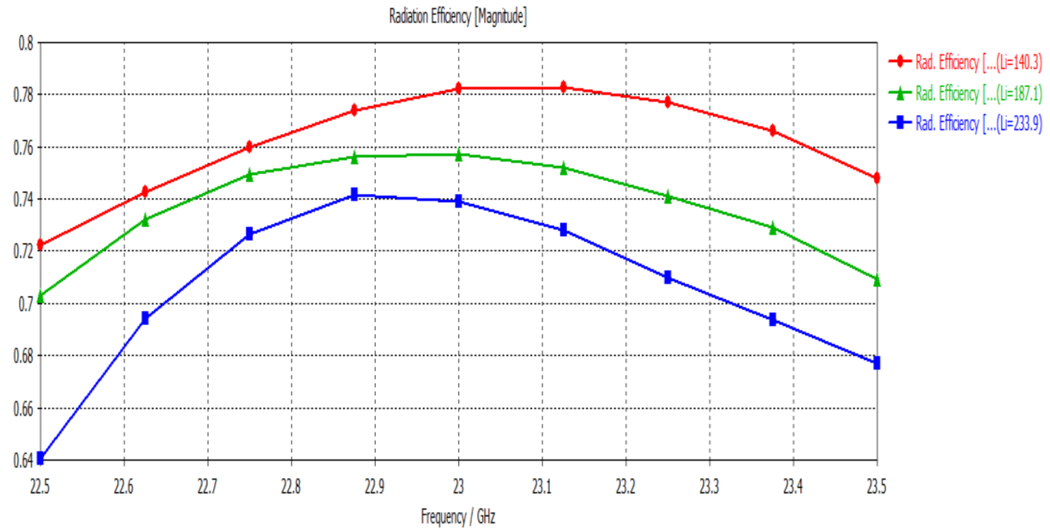
(c)

Figure 4.19 (a) Directivity vs. Frequency (b) Radiation efficiency (c) Total efficiency at d=1, Li=140.1, 187.1, 233.9

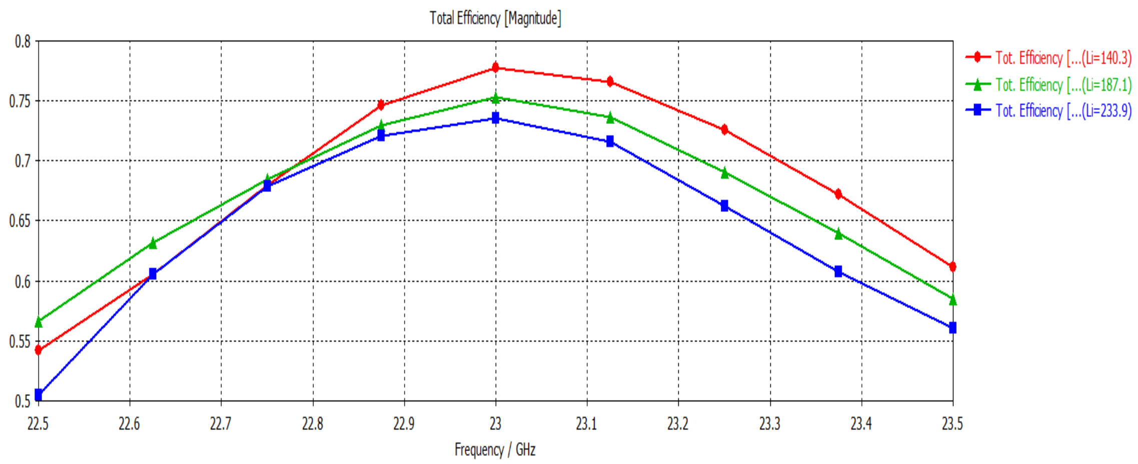
The beam scanning range is nearly identical for the three of them, but this is not the case in terms of efficiency. Total efficiency with length increment of 140.1, 187.1, and 233.9 radiation efficiencies and total efficiency of 79.8, 76.5, 74.3 and 79.8, 76.8, 74.3 at the center frequency is found respectively .but equal beam scanning range of 50 degree.



(a)



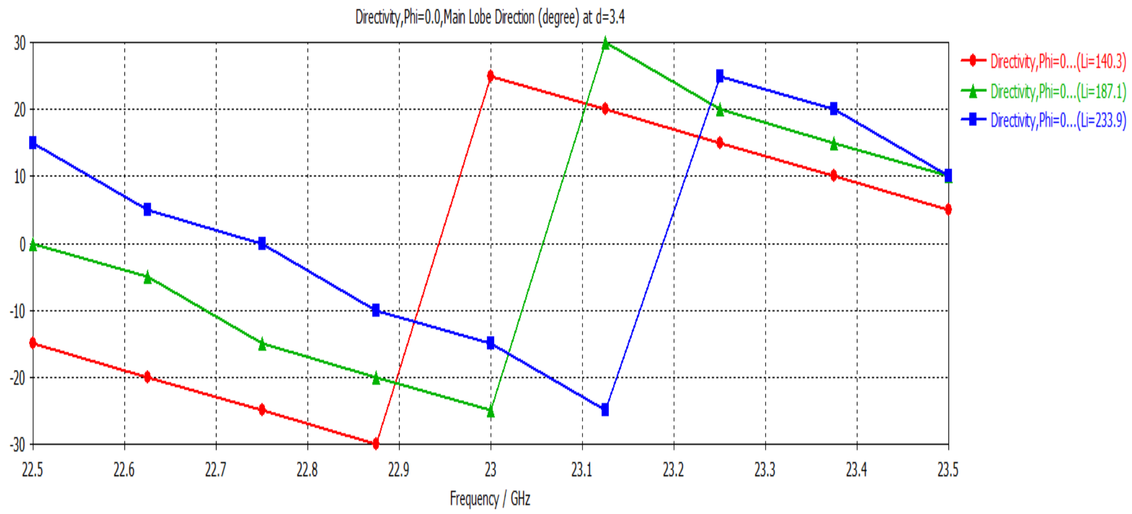
(b)



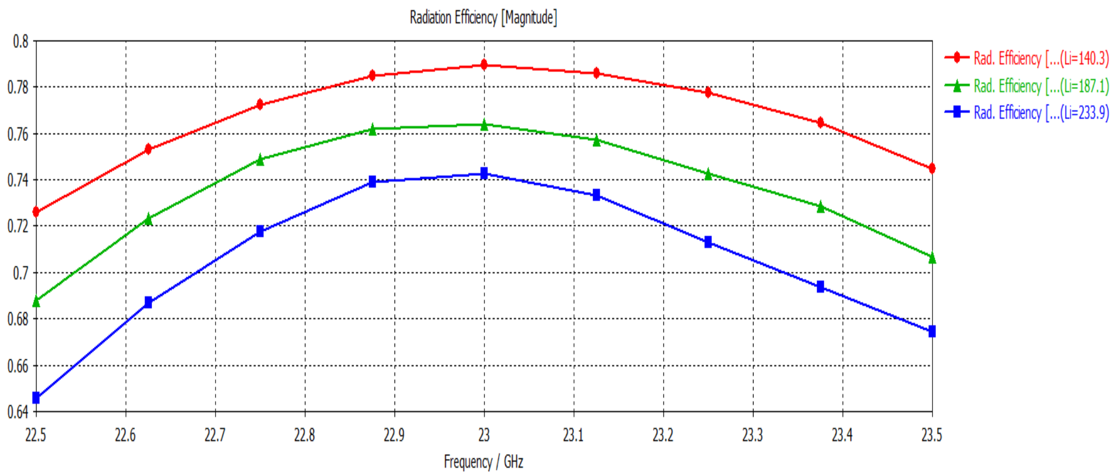
(c)

Figure 4.20 Directivity vs. frequency (b) radiation efficiency (c) total efficiency at d=2.4, Li=140.3, 187.1, 233.9

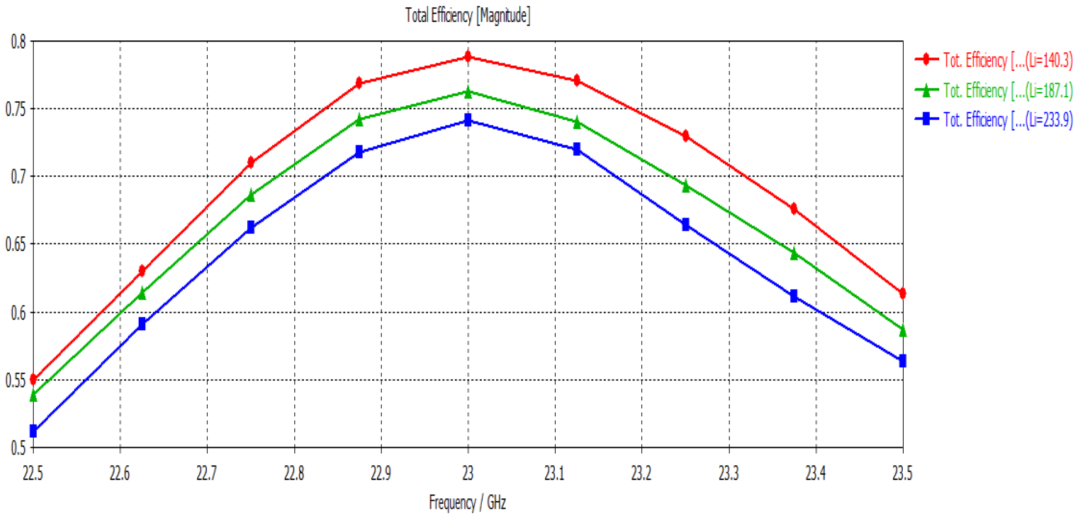
In the same manner beam scanning range for the Li values is nearly identical for the three of Li values it has been found to be 55 degree. Which is slightly greater than the first (d=1). Though, this is not the case in terms of efficiency. Total efficiency with length increment of 140.1, 187.1, and 233.9 radiation efficiencies and total efficiency of 78.1, 75.9, 74 and 77.5, 76.1, 74.3 at the center frequency is been found respectively .which shows approximately 2% decrease in efficiency. The same routine is followed for d=3.4.as shown in the figure 4.2 approximately the same result is obtained. That is maximum beam scan range is found to be 55 degree from -30 to 25 ,-25 to 30 and -25 to 25 for Li =140.1, 187.1, and 233.9 respectively. This indicates that further increment in length for d=3.4 will result a decrease in the steering range. In terms of efficiency, a radiation efficiency of 78.4%, 76.05%, 74.1 % and a total efficiency of 77%, 75.5%, 74% for is obtained at Li =140.1, 187.1, and 233.9 respectively.



(a)



(b)



(c)

Figure 4.21 Directivity vs. frequency (b) radiation efficiency (c) total efficiency at d=3.4, Li=140.3, 187.1, 233.9

Table 4-6 Summary of Li and d variation

	Steering Range	Radiation Efficiency	Total Efficiency
140.3 (d=1)	[-25,+25]	79.9 %	79.8%
187.1 (d=1)	[-25,+25]	76.8%	76.8%
233.9 (d =1)	[-25,+25]	74.31%	74.3%
140.3 (d=2.4)	[-30,+25]	78.1%	77.5%
187.1 (d=2.4)	[-25,+30]	75.9%	76.1%
233.9 (d =2.4)	[-25,+30]	74%	74.3%
140.3 (d=3.4)	[-30,+25]	78.4%	77%
187.1 (d=3.4)	[-25,+30]	76.05%	75.5%
233.9 (d =3.4)	[-25,+25]	74.1%	74%

The above Figurers from 4.17-4.19 noticeably summarize the sum effect of distance and length increment.so as to select the optimal point the following measures has been considered

- Good beam steering range
- Good total efficiency

- Good radiation efficiency
- Variable beam steering at different frequencies.

Accordingly length increment that means 140.3,187.1,233.9, with d=1 have been selected for further improvement .That is increasing the number of patch from 2x1 to 4x1 .now keeping the distance at d=1 increment length values of 140.3,187.1,233.9 will be compared by increasing the number of patches. And an antenna having the following characteristics will be selected:

- High beam steering range
- Good total efficiency (beyond 50 %)
- High radiation efficiency (beyond 50%)
- Variable beam scan at different frequencies
- More importantly continuous beam scanning patter

Before moving to the comparison Li value having 187.1 have been slightly modified so that it can exhibit continuous beam scan .therefore at Li=188.1 shows continues pattern from -45 to +45 degree approximately with 11-15 degree phase shift between consecutive frequencies As shown in the Figure 4.20 bellow.

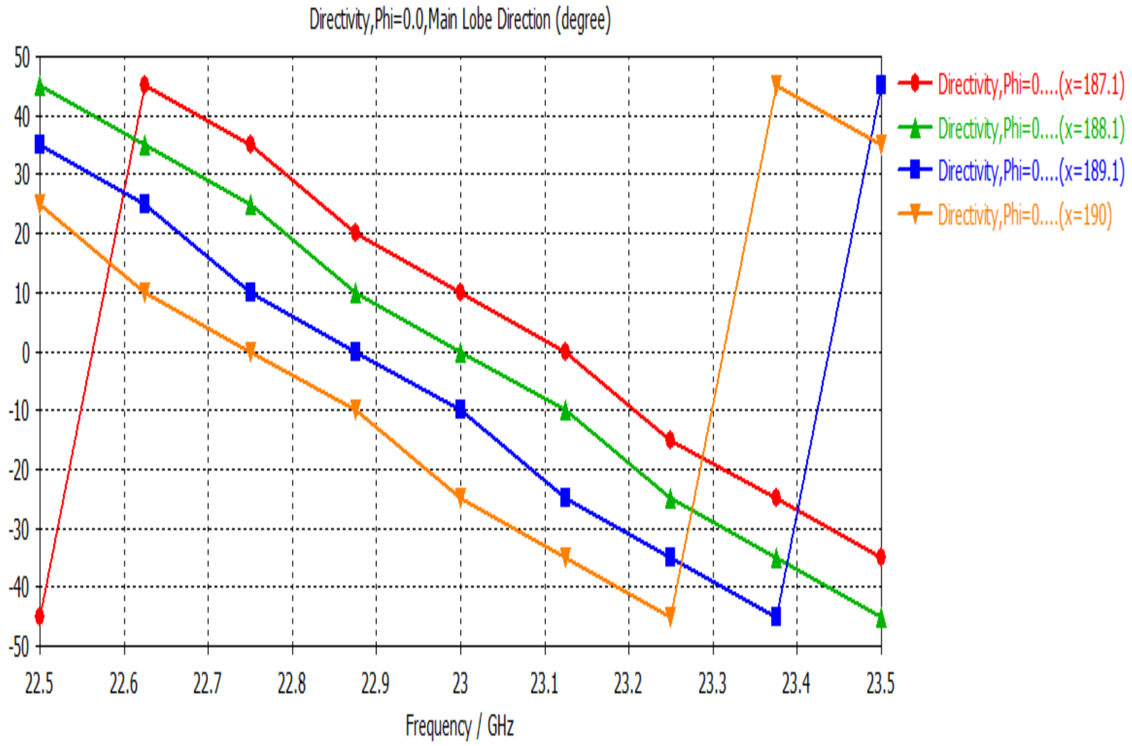
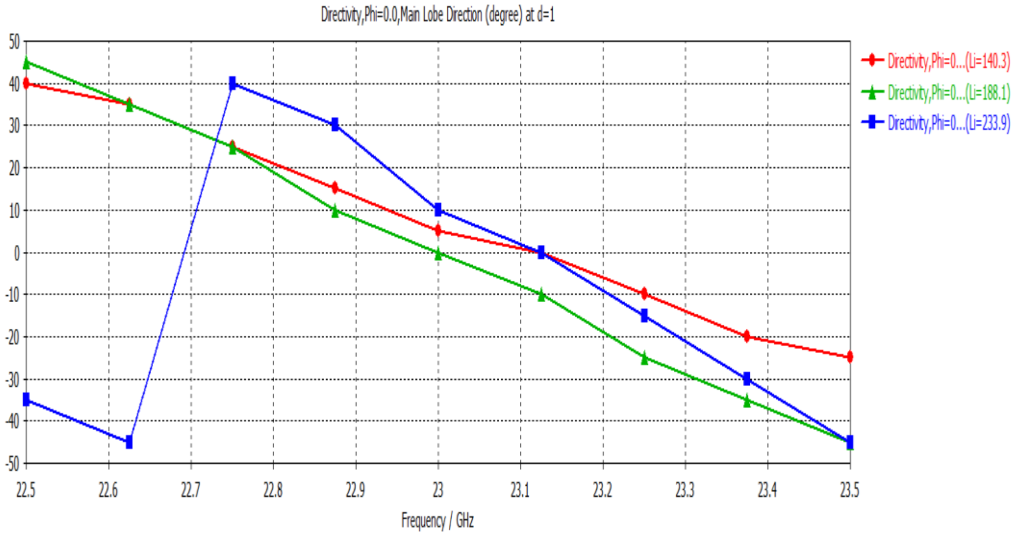
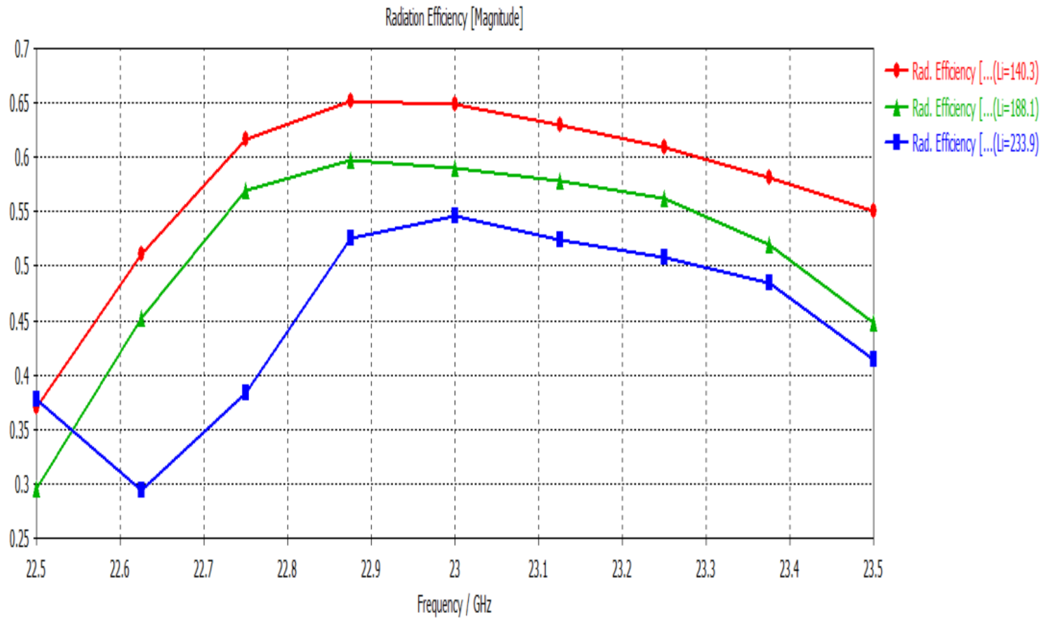


Figure 4.22 Optimization for Li=187.1

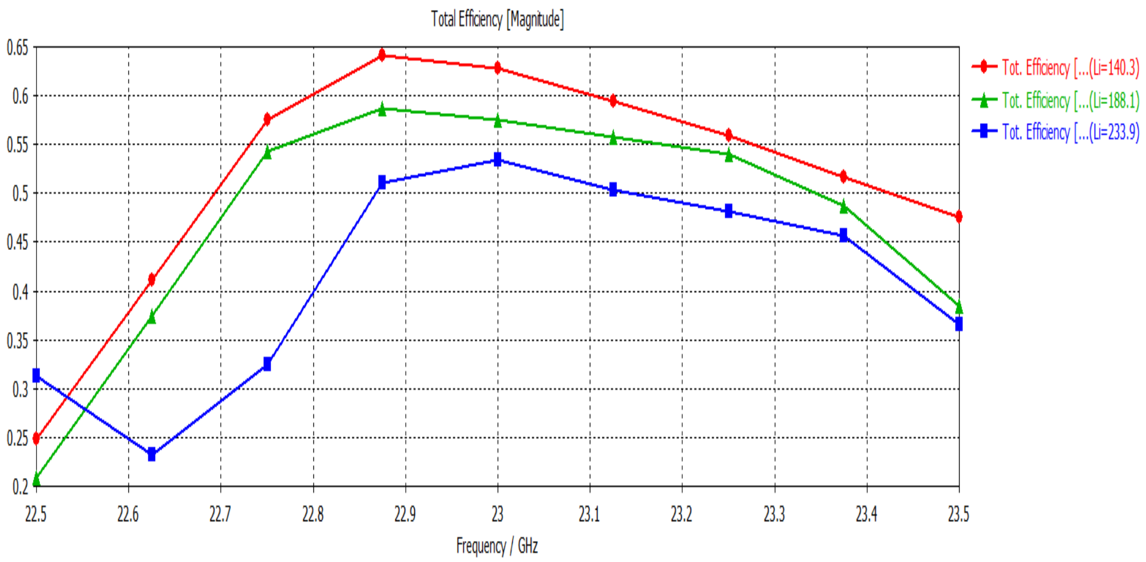
Based on Figure 4.22 (a), continuous scanning pattern is shown at Li=140.3and 188.1 whereas Li =233.9 starts scanning at -35 degree then moves to -45 degree then suddenly shifts to +40. This make the beam scanning pattern to be distorted and prone to fluctuation accordingly Li =188.1 is chosen as the best value. Summary of the above comparison will be seen in the Table 4.7 below.in the same fashion the even if. Li =140.3 has highest efficiency that the three. Its scanning range is the least of all. Since the objective this thesis work is to have design antenna with good scanning range priorities will be given to the one having wide beam scan.



(a)



(b)



(c)

Figure 4.23 Directivity vs. frequency (b) radiation efficiency (c) total efficiency at d=3.4, Li=140.3, 187.1, 233.9

Table 4-7 Summary of selected Li values

criterion	Value/character	Value/character	Value/character
Li (length increment)	140.3	188.1	233.9
Beam steering range	70 degree	90 degree	90 degree
Radiation efficiency	65%	60%	55%
Total efficiency	64%	58%	54%
Continues bean scan	yes	yes	no
Variable beam scan at frequencies	yes	yes	yes

Finally, after a series of parametric sweep, the two basic array design specifications are identified .that is

- Length increment =188.1
- Distance between the patches (edge to edge (d)) =1mm
- Distance between the patches (center to center)=1.402λg

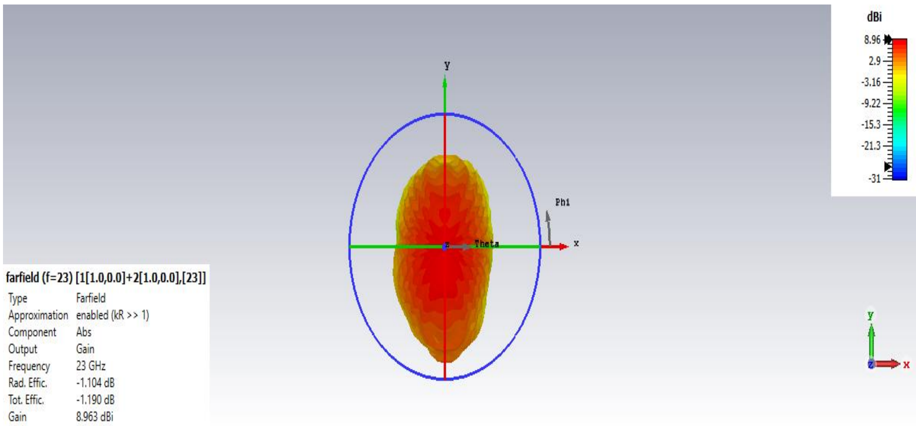
Accordingly using the these specifications 2x1, 4x1, 6x1 and 8x1 array antenna are designed and will be discussed a follow .

Results for FSMAA design

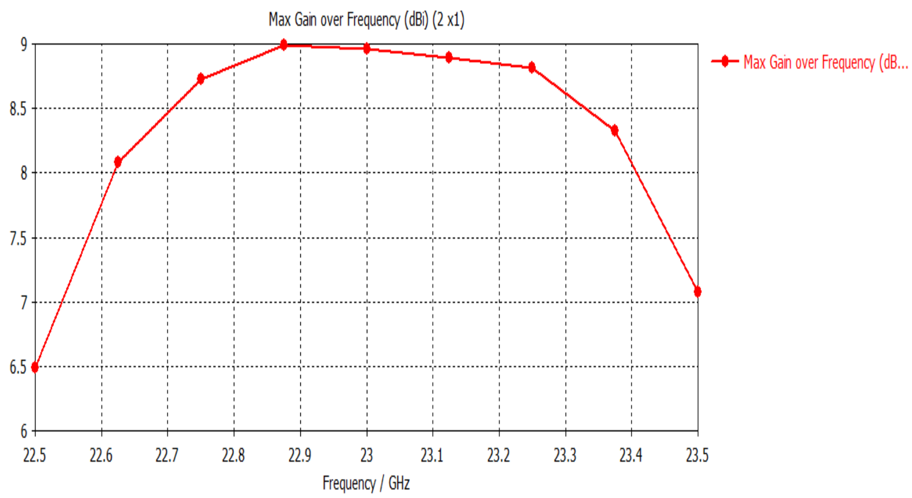
Based on the design specifications 2x1, 4x1 and 6x1, 8x1 FSA arrays are designed. The following antenna array parameters are obtained.

- **Gain over frequencies**

This figure demonstrates the value of gain obtained at different frequencies. The gain of antenna describes how well the antenna converts input power into radio waves headed in a specified direction. There for it is expected to have higher gain for higher frequencies. But practically this may not happen .this is because higher frequencies are always prone to noise and also increasing the number of radiating element increases the overall power consumption there it expected to have gain as the number of patches Is increasing therefore from the figure bellow the max gain for 2x1, 4x1, 6x1, 8x1 becomes 8.96 dBi, 10.32 dBi, 10.11dBi and 10.06 dBi. But the minimal gain range for 6x1 and 8x1 FSA is very small which is not feasible.

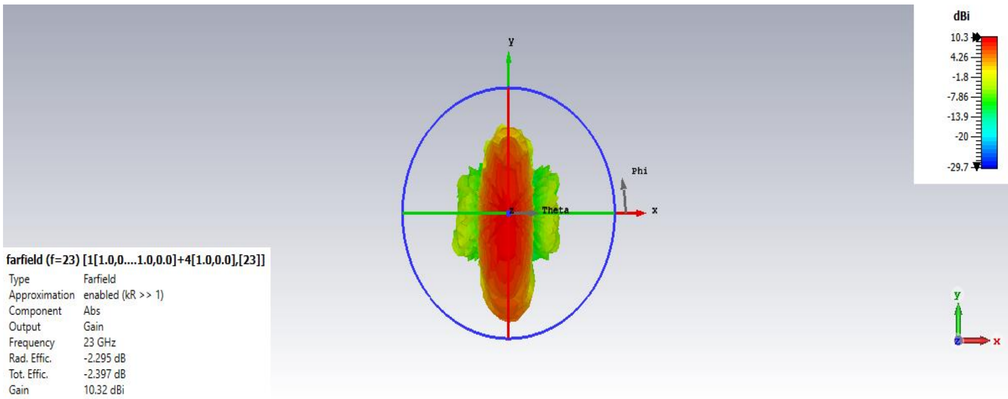


(a)

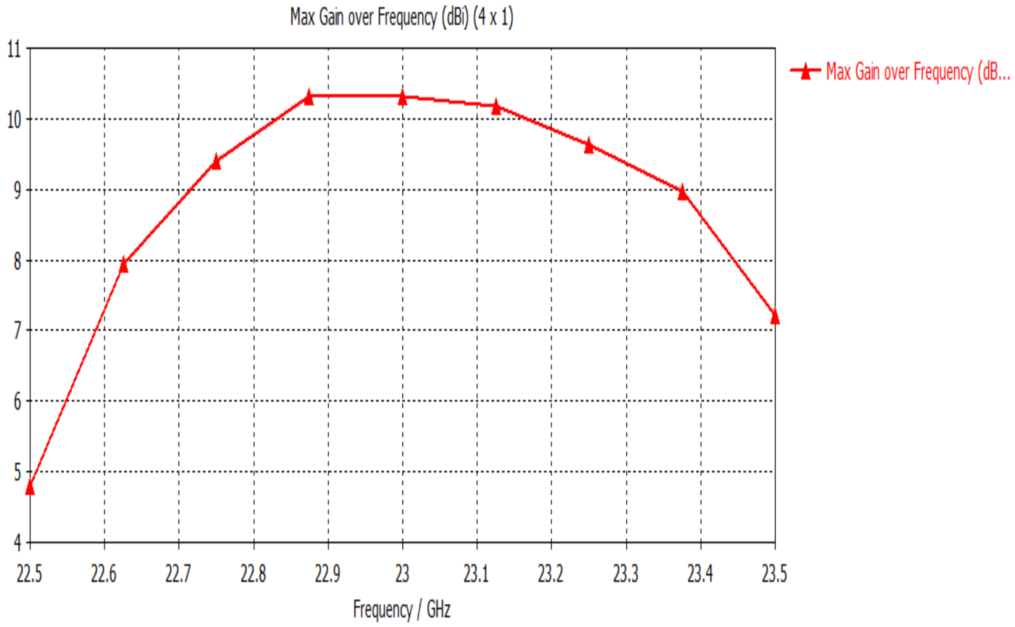


(b)

Figure 4.24 (a) 3D gain plot (b) Gain over Frequency for 2x1 FSA

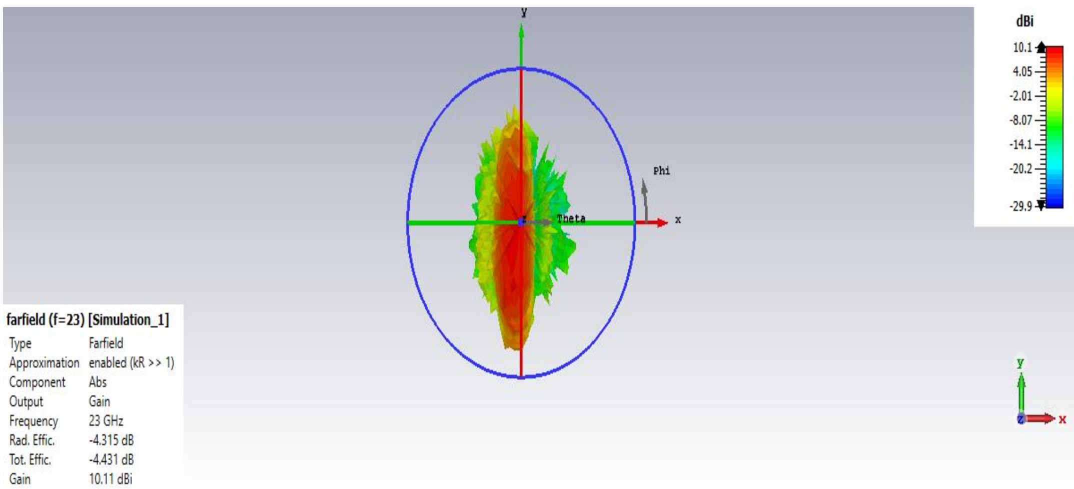


(a)

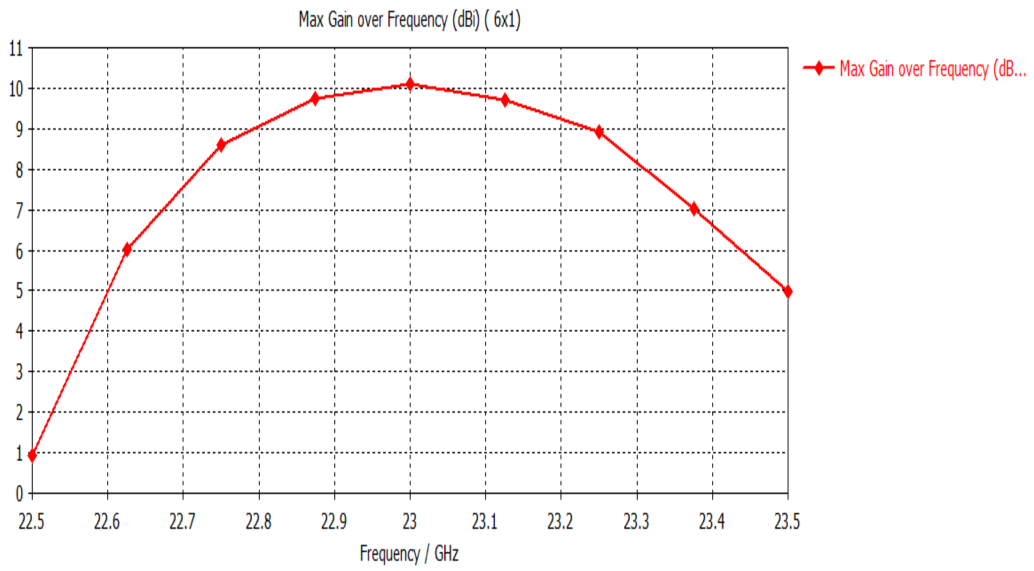


(b)

Figure 4.25 (a) 3D gain plot (b) Gain over Frequency for 4x1 FSA

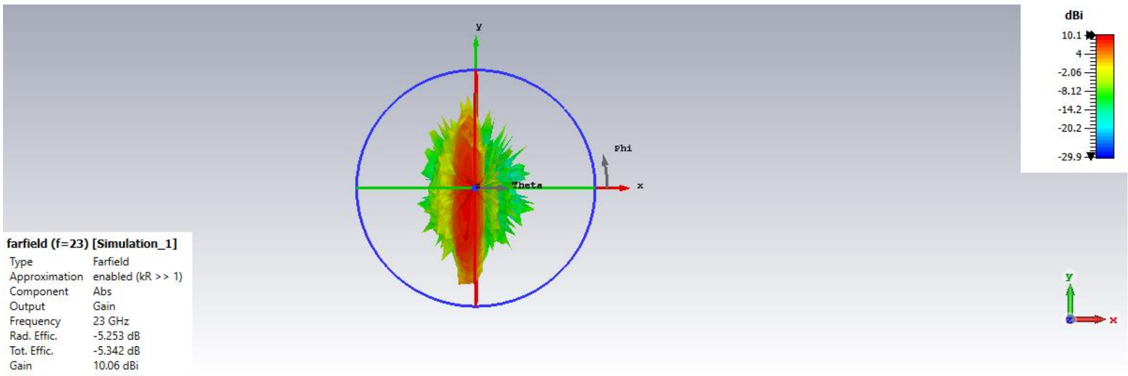


(a)

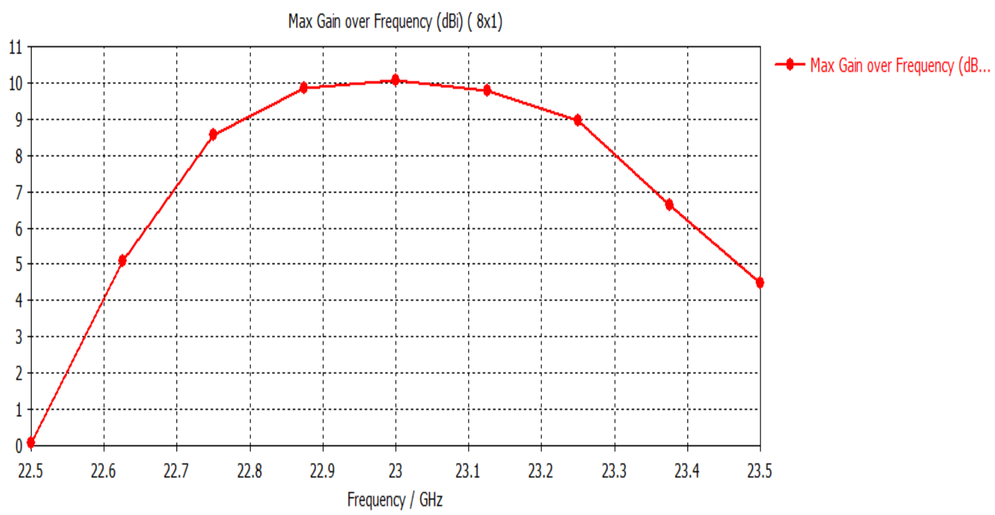


(b)

Figure 4.26 (a) 3D gain plot (b) Gain over Frequency for 6x1 FSA



(a)

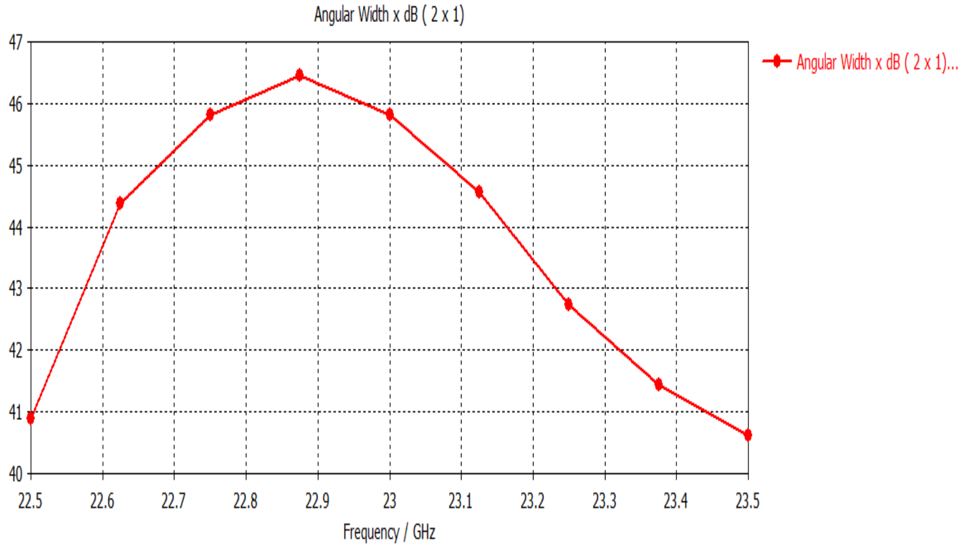


(b)

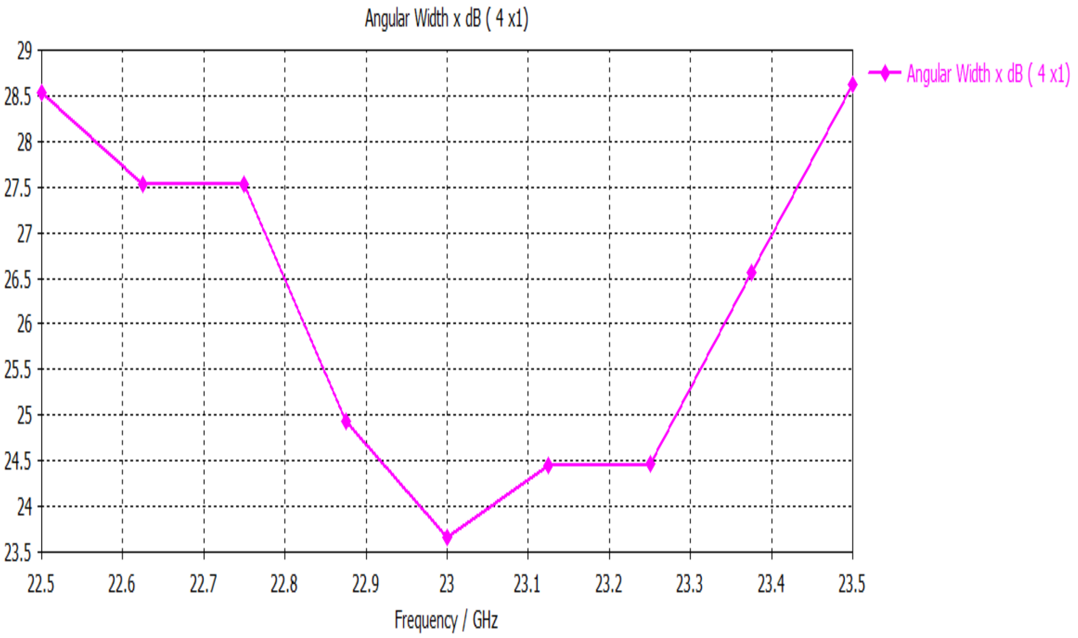
Figure 4.27 (a) 3D gain plot (b) Gain over Frequency for 8x1 FSA

- **Beam width**

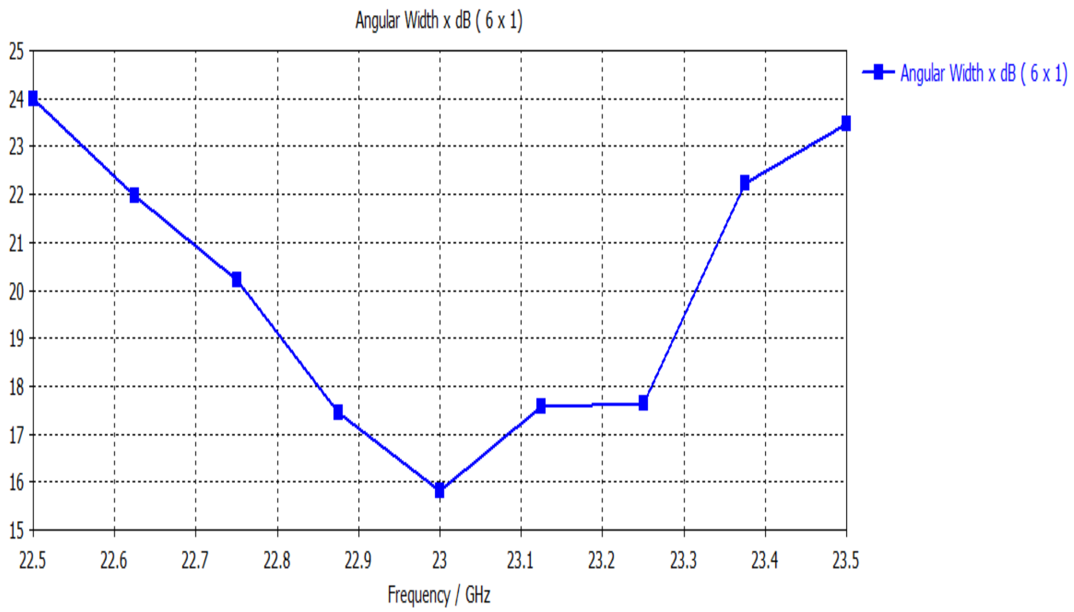
Angular Beam width is the aperture angle from where most of the power is radiated. Practically it is the width of main lobe at 3dB.Main lobe of an antenna is the region around which the direction of maximum radiation occurs (usually the region that is within 3 dB of the peak of the main beam).therefor the more the number of patches the smaller beam width will be. That as the number of patches or antenna increases the more power full and directive beam will be obtained. This phenomenon is called beam forming.



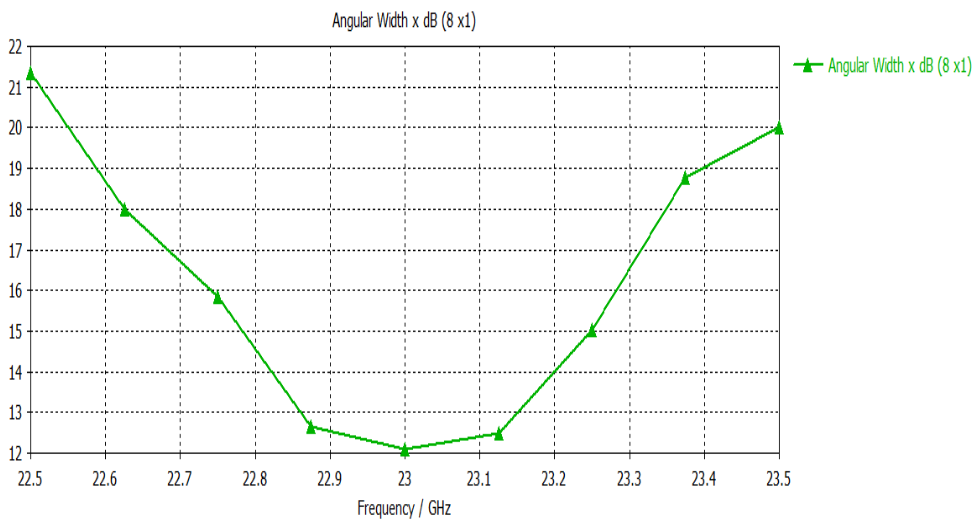
(a)



(b)



(c)



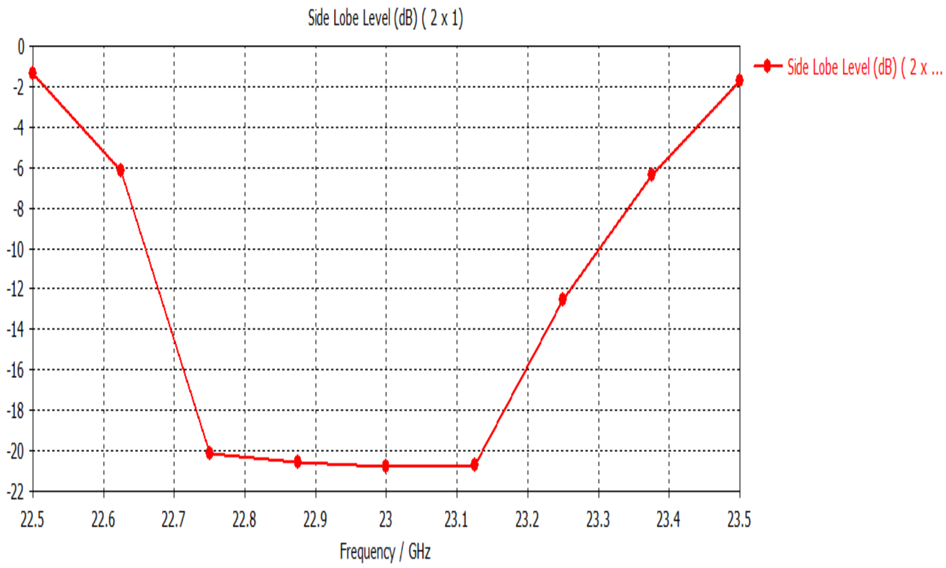
(d)

Figure 4.28 Angular beam width for (a) 2x1 (b) 4x1 (c) 6x1 (d) 8x1 FSA

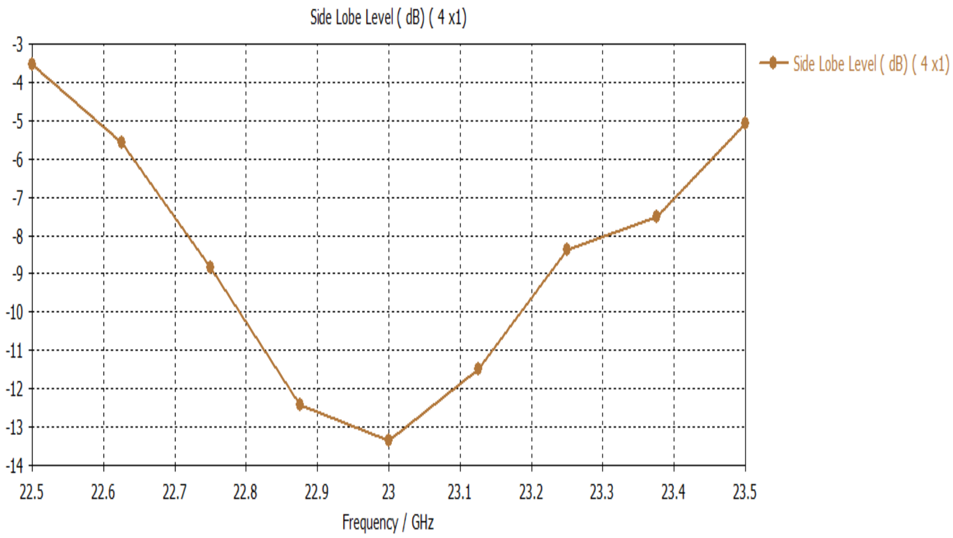
The beam width range is getting decreases as we move from figure (a) to (d).that is what is expected form this work, beam forming.

- **Side lobe level**

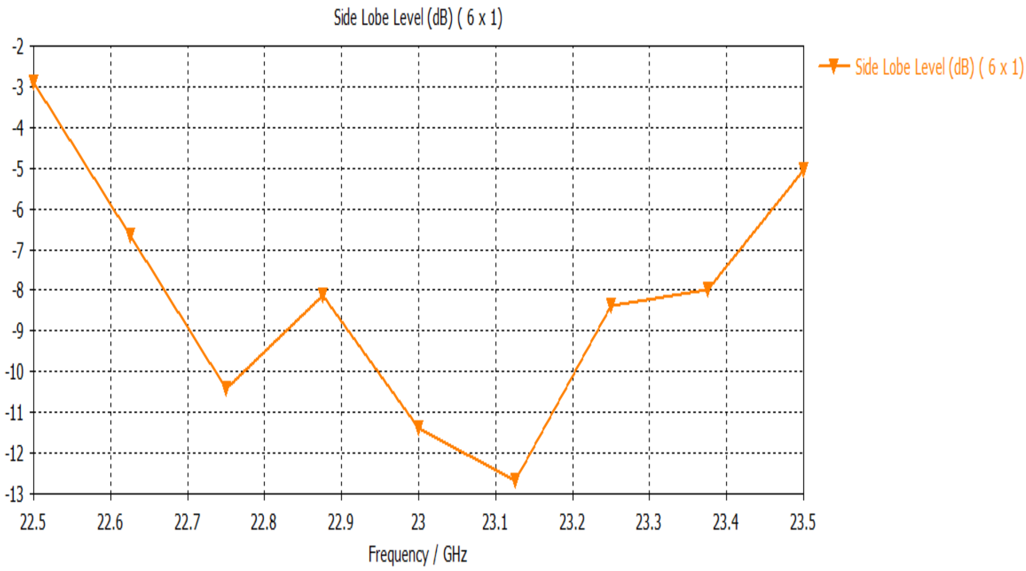
The level of side lobe indicates radiations in the undesired direction .as per the design the -21,-13.1,-10,-11 dB for 2,4,6,8 patches are obtained at the center frequency respectively. The side lobe level starts to increase as the number patches increases from -21 to -11 dBi .at the center frequency.


Side Lobe Level (dB) (2 x 1)
Side Lobe Level (dB) (2 x ...
0
-2
-4
-6
-8
-10
-12
-14
-16
-18
-20
-22
22.5
22.6
22.7
22.8
22.9
23
23.1
23.2
23.3
23.4
23.5
Frequency / GHz

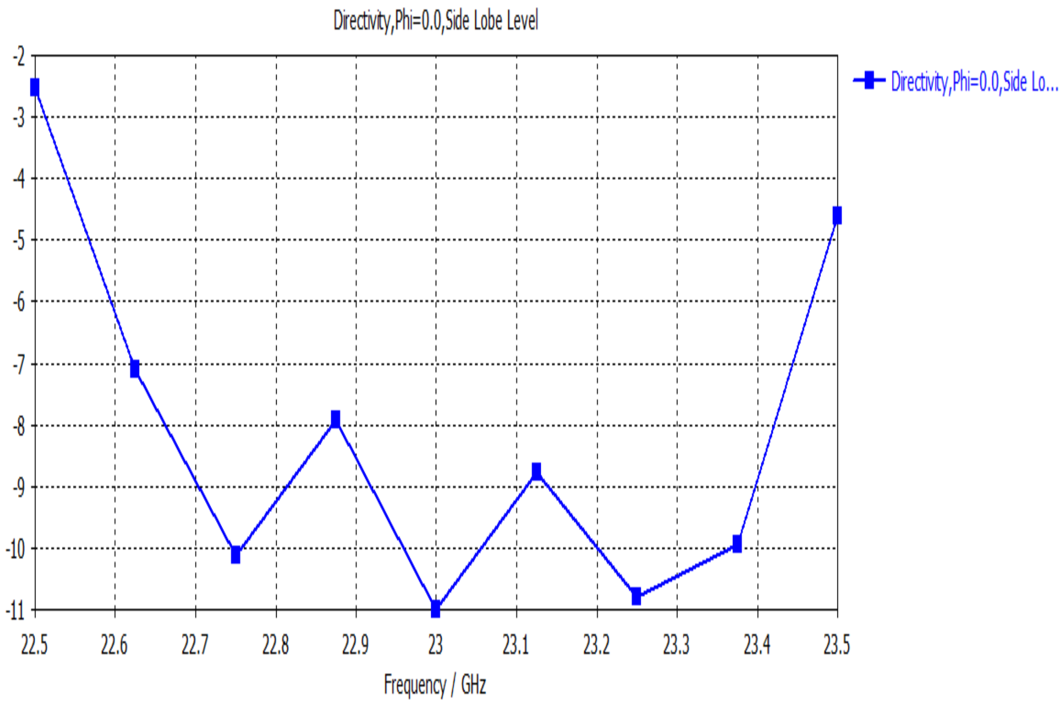
(a)


Side Lobe Level (dB) (4 x1)
Side Lobe Level (dB) (4 x1)
-3
-4
-5
-6
-7
-8
-9
-10
-11
-12
-13
-14
22.5
22.6
22.7
22.8
22.9
23
23.1
23.2
23.3
23.4
23.5
Frequency / GHz

(b)


Side Lobe Level (dB) (6 x 1)
Side Lobe Level (dB) (6 x 1)
-2
-3
-4
-5
-6
-7
-8
-9
-10
-11
-12
-13
22.5
22.6
22.7
22.8
22.9
23
23.1
23.2
23.3
23.4
23.5
Frequency / GHz

(c)

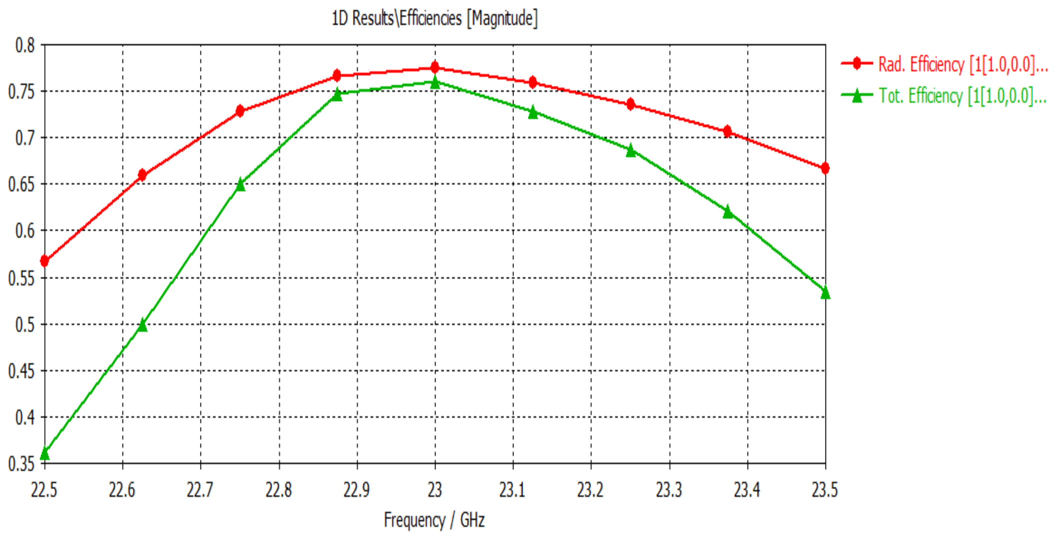


(d)

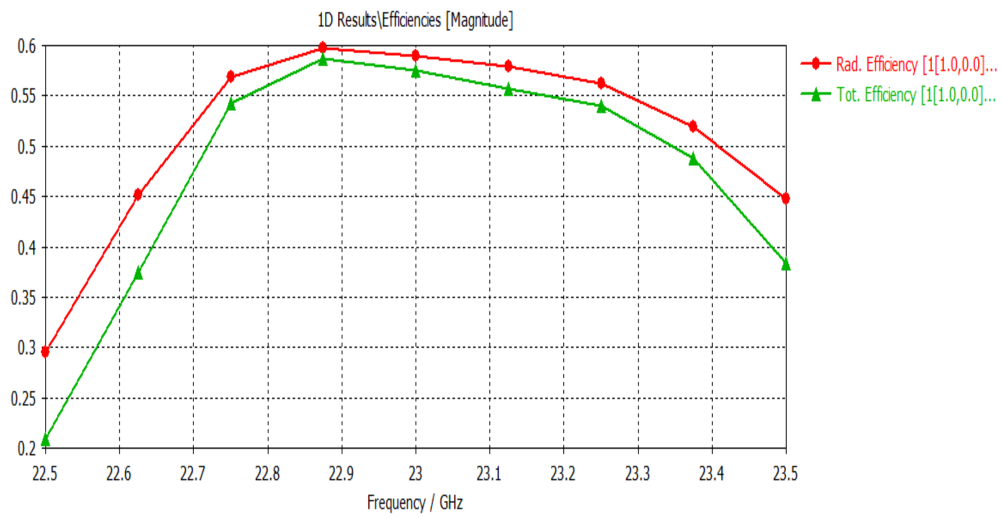
Figure 4.29 Side lobe levels for (a) 2x1, (b) 4x1, (c) 6x1, (d) 8x 1 arrays

- **Radiation and Total efficiencies**

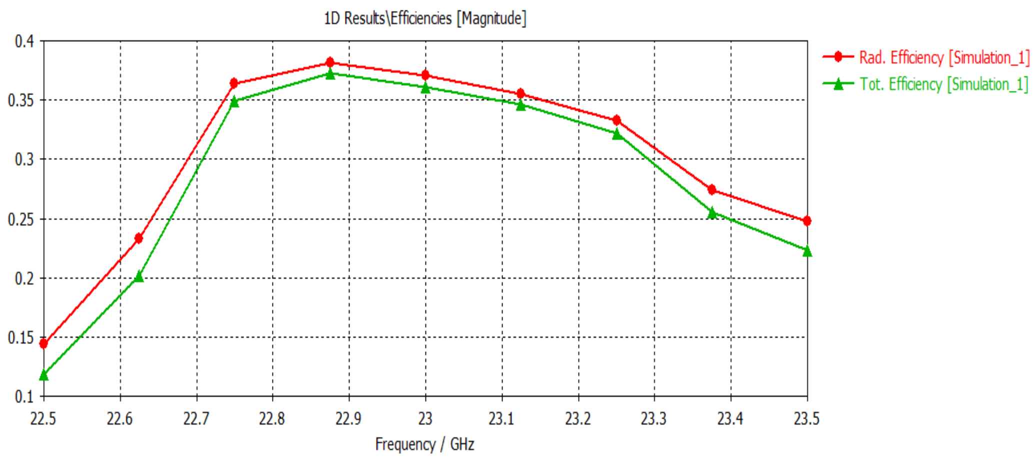
The total efficiency takes in to account antenna's efficiency with different loss. it takes into account both reflection loss and power energy dissipation in the antenna. The higher the mismatch the smaller will be the total efficiency.in the same manner the radiation efficiency In this work radiation efficiency of 76%,60$,37% and,31% and 75.5% ,55.8%.35% and 30.5 % attained for 2x1,4x1,6x1and,8x1 arrays respectively .



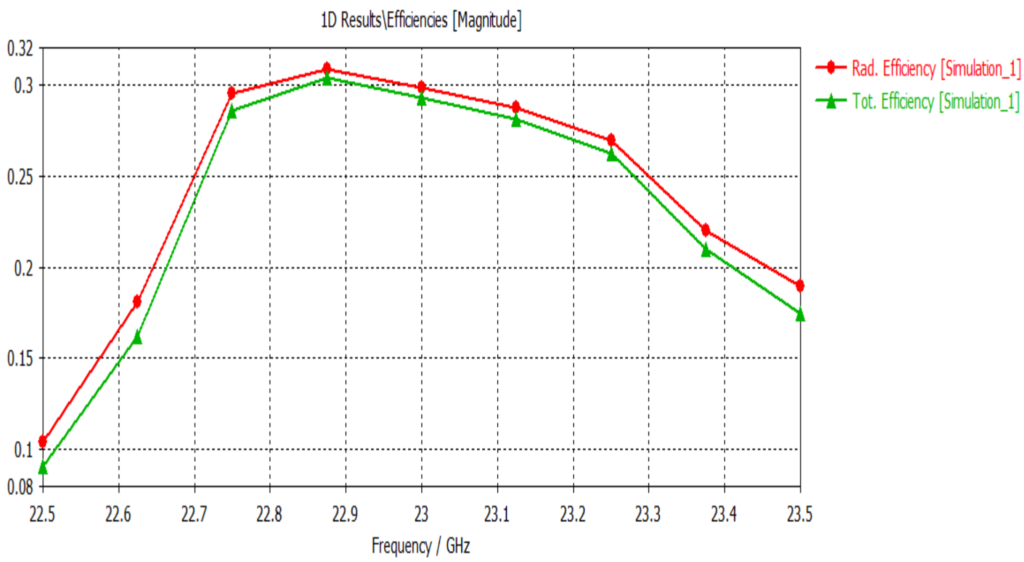
(a)



(b)



(c)



(d)

Figure 4.30 Radiation and Total efficiency for (a) 2x1, (b) 4x1 (c) 6x1 (d) 8x1

- **Beam steering**

It refers to the shifting of the angle of the main lobe direction .lots of parametric sweep has been done in order to have uniform ,wide beam scanning as result a beam scanning of 40 ,90,110,110 degree is obtained for 2x1, 4x1, 6x1,8x1.but uniform and incresed beam scanning is observed at 4x1 .as shown in the Figure 4.29

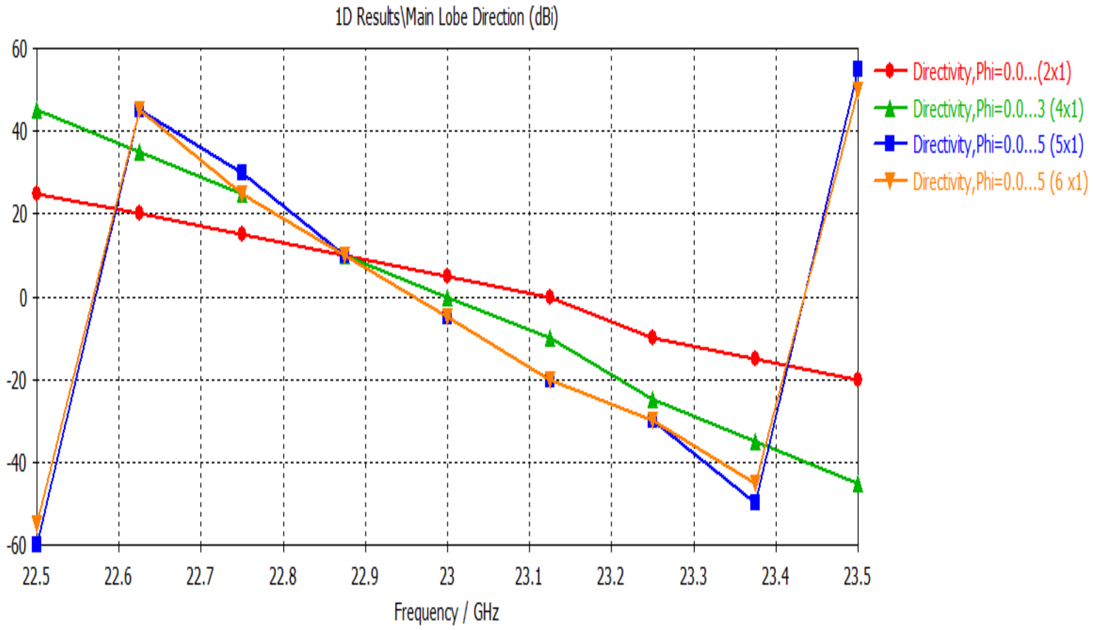


Figure 4.31 Beam Scanning range for 2x1, 4x1, 6x1, 8x1 arrays

Table 4-8 Comparison of 2X1, 4X1, 6X1, 8X1 FSSMA at the center frequency

	2x1	4x1	6x1	8x1
Gain (dBi)	8.96	10.32	10.11	10.06
Beam width (dB)	45.9	23.55	16	12
Side lobe level (dB)	-21	-23.1	-10	-11
Radiation efficiency(max)	76	60	37	31
Total efficiency (max)	75.5	55.8	35	30.5
Beam scanning Range (degree)	40	90	110	115

From the four types of array designs 4x1 patch antennas relatively has good performance in terms of Beam scanning range. In fact its gain, side lobe level, beam width are good enough compared with the highest and lowest margin.

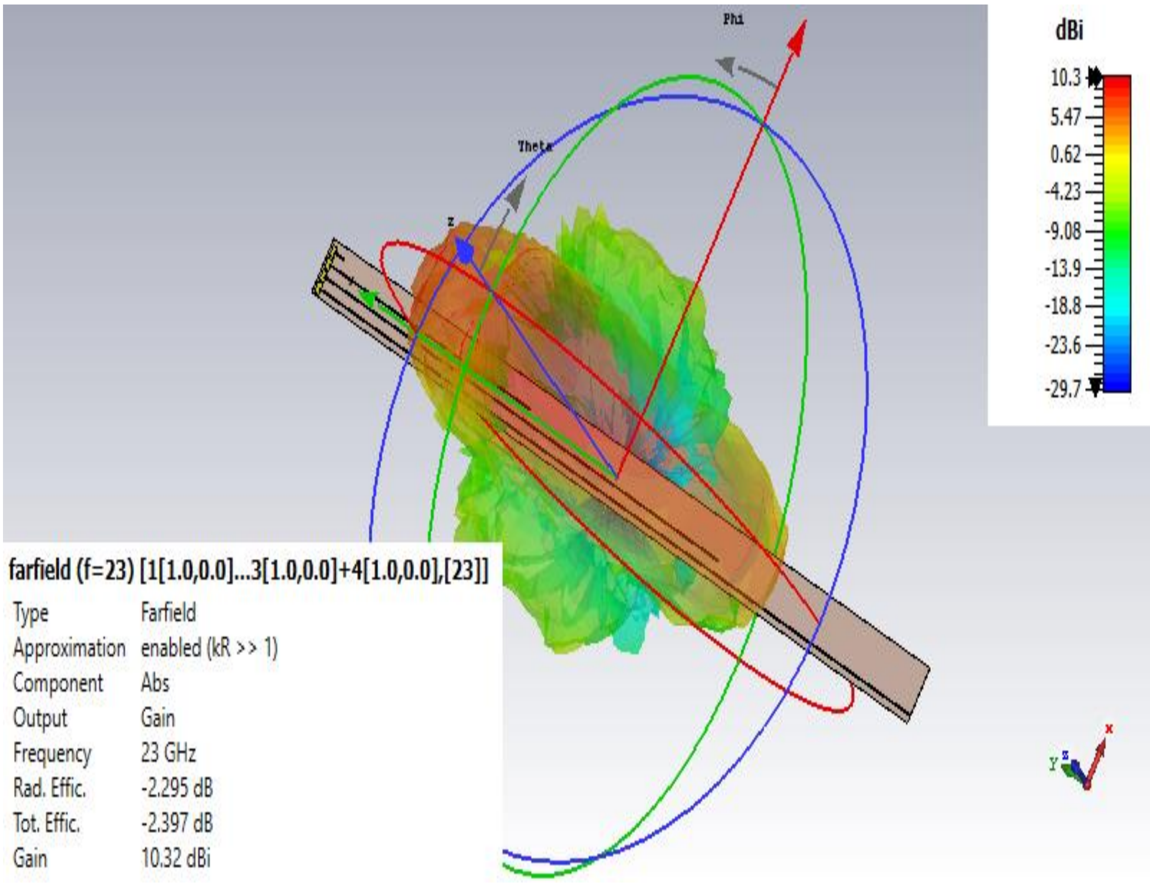
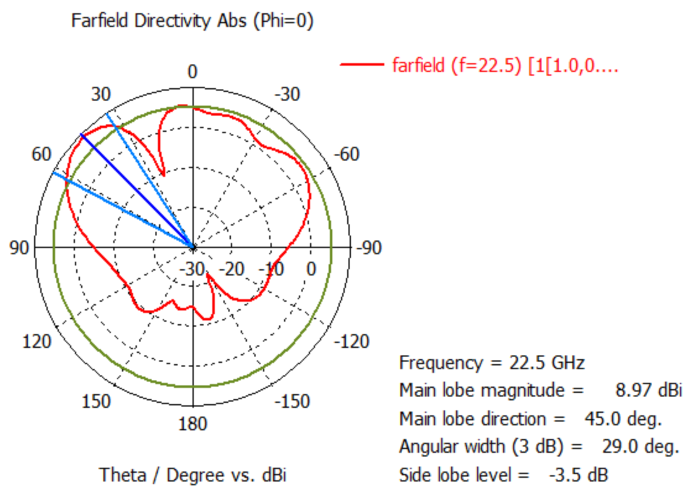
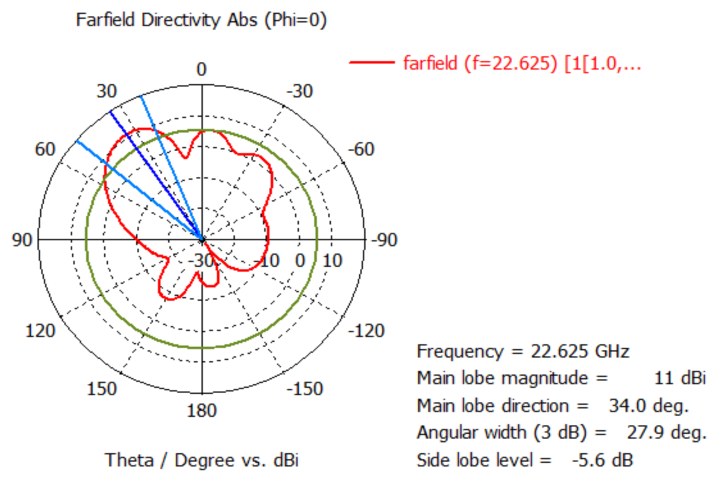


Figure 4.32 3D Polar plot for 4X1 frequency scanning array antenna

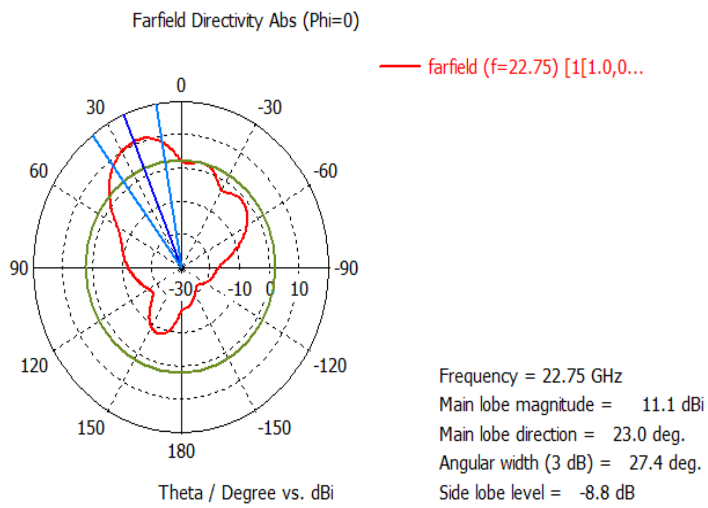


(a)



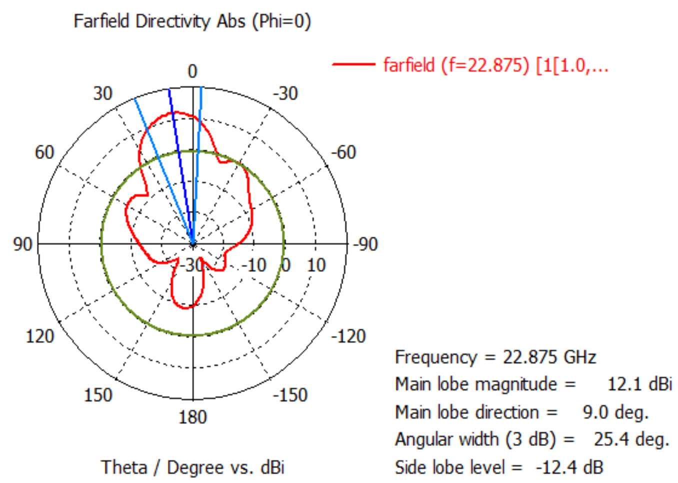
Farfield Directivity Abs (Phi=0)
farfield (f=22.625) [1[1.0,...
Theta / Degree vs. dBi
Frequency = 22.625 GHz
Main lobe magnitude = 11 dBi
Main lobe direction = 34.0 deg.
Angular width (3 dB) = 27.9 deg.
Side lobe level = -5.6 dB

(b)



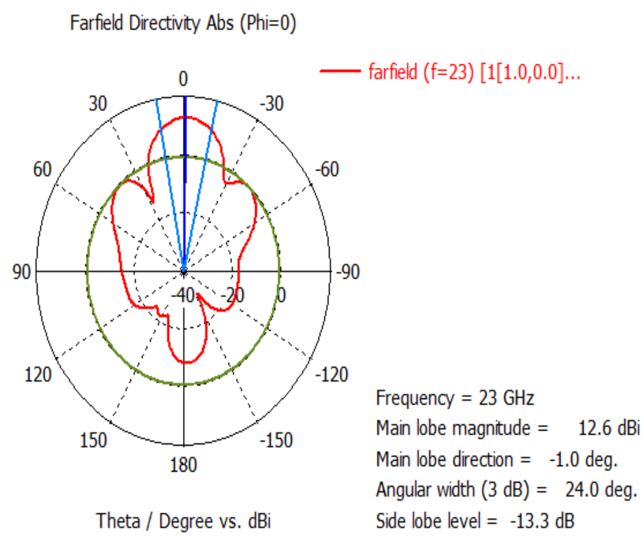
Farfield Directivity Abs (Phi=0)
farfield (f=22.75) [1[1.0,0...
Theta / Degree vs. dBi
Frequency = 22.75 GHz
Main lobe magnitude = 11.1 dBi
Main lobe direction = 23.0 deg.
Angular width (3 dB) = 27.4 deg.
Side lobe level = -8.8 dB

(c)

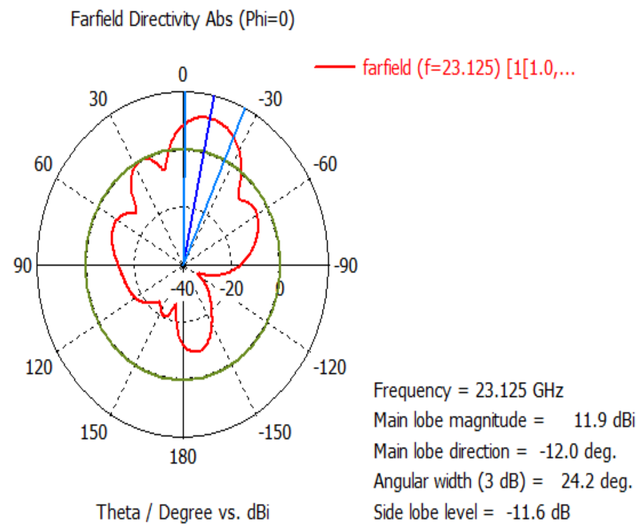


Farfield Directivity Abs (Phi=0)
farfield (f=22.875) [1[1.0,...
Theta / Degree vs. dBi
Frequency = 22.875 GHz
Main lobe magnitude = 12.1 dBi
Main lobe direction = 9.0 deg.
Angular width (3 dB) = 25.4 deg.
Side lobe level = -12.4 dB

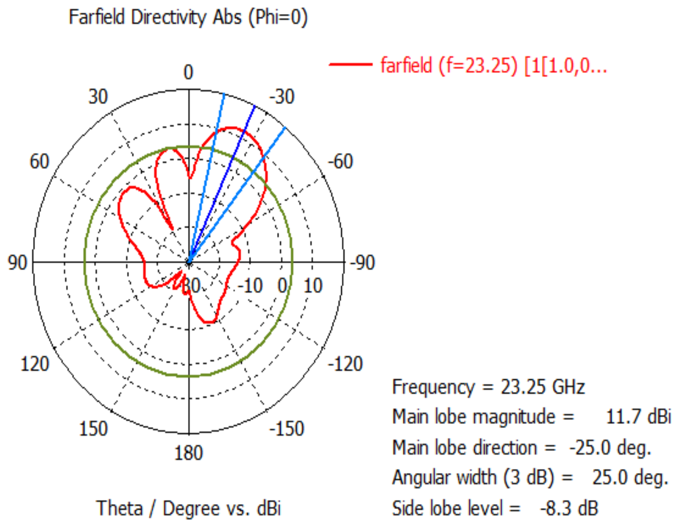
(d)


Farfield Directivity Abs (Phi=0)
farfield (f=23) [1[1.0,0.0]...
0
30
-30
60
-60
90
-90
-40
-20
0
120
-120
150
-150
180
Theta / Degree vs. dBi
Frequency = 23 GHz
Main lobe magnitude = 12.6 dBi
Main lobe direction = -1.0 deg.
Angular width (3 dB) = 24.0 deg.
Side lobe level = -13.3 dB

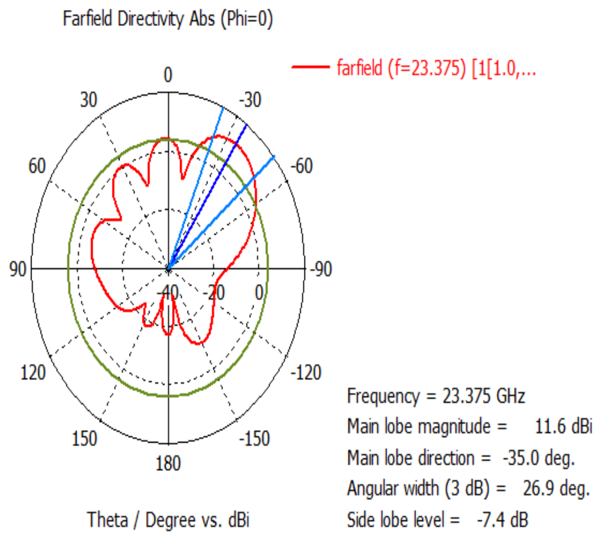
(e)


Farfield Directivity Abs (Phi=0)
farfield (f=23.125) [1[1.0,...
0
30
-30
60
-60
90
-90
-40
-20
0
120
-120
150
-150
180
Theta / Degree vs. dBi
Frequency = 23.125 GHz
Main lobe magnitude = 11.9 dBi
Main lobe direction = -12.0 deg.
Angular width (3 dB) = 24.2 deg.
Side lobe level = -11.6 dB

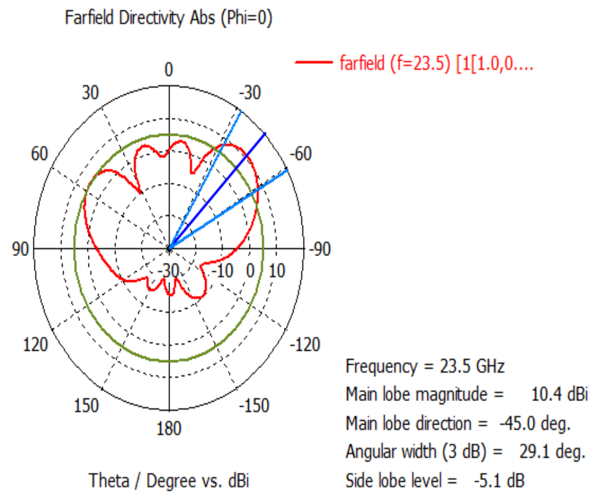
(f)


Farfield Directivity Abs (Phi=0)
farfield (f=23.25) [1[1.0,0...
0
30
-30
60
-60
90
-90
-10
0
10
120
-120
150
-150
180
Theta / Degree vs. dBi
Frequency = 23.25 GHz
Main lobe magnitude = 11.7 dBi
Main lobe direction = -25.0 deg.
Angular width (3 dB) = 25.0 deg.
Side lobe level = -8.3 dB

(g)



(h)



(j)

Figure 4.33 Main lobe direction at (a)22.5GHz (b) 22.625GHz (c) 2.2750 GHz (d) 22.875GHz (e)23 GHz (f)23.125 GHz (g)23.25GHz (h)23.375 GHz (i)23.5 GHz

The above figure illustrates that the beam steers from -45 degree to +45 degree covering nearly endfire direction at the center frequency. At 22.5GHz the main lobe is located at -45 degree when the frequency shifts to 22.625GHz the main lobe consecutively steers to 34 degree in the manner. When the frequency shifts to 22.750 GHz sequentially the main lobe shifts to 23 degree. When frequency shifts to 22.875GHz the beam in turn shifts to 9degree.in the same way a shift in frequency from 22.875GHz to 23 GHz results a shift in main lobe from 9degree to -1degree .adding 0.125 GHz to the exiting frequency and feeding at each port will again shift the main lobe direction to -12 degree .

following the same routine will locate the main lobe at -25,-35 and -45 degree for 23.25GHz, 23.37 GHz, 23.5 GHz respectively.in this manner a total of 90 degree scanning angle is obtained .

Table 4-9 Comparison of this work with related frequency scanning antennas

Parameter/ref	Scanning range (°)	Bandwidth (GHz	Rate (°/GHz)
[46]	[-52.42]	27.5 to 36.5	10.4
[47]	[1,57]	1GHZ	57
[48]	[50 to 125]	2.8 to 6	23,437
[49]	[64,76]	[22-38]	0.75
[50]	40°	270- 330	0.18
This work	[-45 ,+45]	22.5-23.5	90

5 CONCLUSION AND FUTURE WORK

5.1 CONCLUSION

Single patch Microstrip patch antenna has been designed and simulated at 23 GHz. With optimized points. Basic antenna parameters such as return loss, VSWR, gain, bandwidth, side lobe levels, and total and radiation efficiencies have been successfully evaluated. Using this single patch antenna 2x1, 4x1, 6x1, 8x1 patch have been designed .optimal points for the number of patches, incremental length (Li), distance between patches have been selected .and according to this 4x1 patch antenna with (Li) value of 187.1 and distance of 1mm have been designed successfully and a beam steering range of 90 degree has obtained. Also other parameters for the array design such as gain, directivity, side lobe level, beam width have evaluated. The design was simulated to meet the best possible result by varying frequency with constant length increment and feeding variable frequencies for each radiating element Accordingly beam steering and beam forming has been done successfully.

5.2 FUTURE WORK

Since this work only presents the array design for linear polarization scheme further works can be done for other types of polarization such as circular polarization. Also length reduction mechanism such as using bending structure or adding meander-lining is recommended

REFERENCES

[1] R. Bansal (2008), "Antenna theory; analysis and design," JOHN WILEY & SONS, INC. PUBLICATION, vol. 72, no. 7.

[2] V. Kaushik and J. Panchal (2017), "Dielectric Resonator Antenna and its Design Parameters-A Review," *Int. Res. J. Adv. Eng. Sci.*, vol. 2, no. 4, pp. 128–133.

[3] N. Sharma and V. Sharma (2017), "A Journey of Antenna from Dipole to Fractal: A Review," *J. Eng. Technol.*, vol. 6, no. 2, pp. 317–351.

[4] J. Hirokawa and M. Zhang, *[tecknologies] Waveguide Slot Array Antenna*. 2016.

[5] A. Verma, "Antenna and Its Application," no. January 2015, 2020.

[6] S. Vashist, M. K. Soni, and P. K. Singhal (2014) ,"A Review on the Development of Rotman Lens Antenna," *Chinese J. Eng.*, vol. 2014, pp. 1–9, ,

[7] A. Q. Khan, M. Riaz, and A. Bilal (2016) ,"Various Types of Antenna with Respect to their Applications : A Review," *Int. J. Multidiscip. Sci. Eng.*, vol. 7, no. 3, pp. 1–8.

[8] J. Eichler, P. Hazdra, M. Capek, and M. Mazanek (2012), "Modal resonant frequencies and radiation quality factors of Microstrip antennas," *Int. J. Antennas Propag.*, vol. 2012.

[9] G. Buttazzoni, A. Cuttin, and R. Vescovo (2018), "Design procedures for rectangular patch antennas," *IET Conf. Publ.*, vol. 2018, no. CP741.

[10] G. Buttazzoni, M. Comisso, A. Cuttin, M. Fragiacomo, R. Vescovo, and R. Vincenti Gatti (2017), "Reconfigurable phased antenna array for extending cubesat operations to Ka-band: Design and feasibility," *Acta Astronaut.*, vol. 137, no. February, pp. 114–121.

[11] P. F. Li, S. W. Qu, S. Yang, and Z. P. Nie (2017), "Microstrip array antenna with 2-D steerable focus in near-field region," *IEEE Trans. Antennas Propag.*, vol. 65, no. 9, pp ,110-130.

[12] G. Buttazzoni and R. Vescovo (2013),"Deterministic and stochastic approach to the synthesis of conformal arrays for SAR applications," *Proc. 2013 Int. Conf. Electromagn. Adv. Appl. ICEAA 2013*, pp. 520–523.

[13] X. Yang, W. Geyi, and H. Sun (2017), "Optimum Design of Wireless Power Transmission System Using Microstrip Patch Antenna Arrays," *IEEE Antennas Wirel. Propag. Lett.*, vol. 16, no. c, pp. 1824–1827.

[14] S. N. S. Mahmud, M. A. Jusoh, S. E. Jasim, A. H. Zamani, and M. H. Abdullah (2018), "Design, simulation and analysis a microstrip antenna using PU-EFB

substrate," *IOP Conf. Ser. Mater. Sci. Eng.*, vol. 342, no. 1.

[15] A.Arora, A. Khemchandani, Y. Rawat, S. Singhai, and G. Chaitanya (2015), "Comparative study of different feeding techniques for rectangular microstrip patch antenna," *Int. J. Innov. Res. Electr. Electron. Instrum. Control Eng.*, vol. 3, no. 5, pp. 32–35.

[16] S. K. Sidhu and J. Singh Sivia (2015),"Comparison of Different Types of Microstrip Patch Antennas," *Int. J. Comput. Appl.*, no. Icaet, pp. 975–8887.

[17] N. Kumar and N. Sharma (2019), "The Various Feeding Techniques of Microstrip Patch Antenna Using HFSS," *Int. J. Electron. Commun. Eng.*, vol. 6, no. 6, pp.23–29.

[18] J. Kaur and R. Khanna (2013), "Co-axial Fed Rectangular Microstrip Patch Antenna for 5.2 GHz WLAN Application," *Univers. J. Electr. Electron. Eng.*, vol. 1, no. 3, pp. 94–98.

[19] M. Rahman (2016), " Small Size Coupling Feed And Inductive Shorting Antenna For Wide Bandwidth, Increased Gain And Efficiency With Low Specific Absorption Rate (Sar) Operation," no. January 2017.

[20] "Survey on Microstrip Antenna," no. 2, pp. 189–193, 2017.

[21] I. Uchendu and J. Kelly (2016) ,"Survey of beam steering techniques available for millimeter wave applications," *Prog. Electromagn. Res. B*, vol. 68, no. 1, pp. 35–54.

[22] T. Doctoral (2011), "Entrega de Datos Escalable en Redes M ´ oviles Ad-hoc Multi-salto – Aplicaci ´ on a Protocolos de Descubrimiento de Pasarelas," no. April 2011.

[23] M. R. A. Kale (2013),"an Overview of Manet Ad Hoc Network," vol. 6, no. 2, pp. 223–227.

[24] M. S. Sheikh and J. Liang (2019), "A comprehensive survey on VANET security services in traffic management system," *Wirel. Commun. Mob. Comput.*, vol. 2019.

[25] R.Barskar and M. Chawla (2015) ,"Vehicular Ad hoc Networks and its Applications in Diversified Fields," *Int. J. Comput. Appl.*, vol. 123, no. 10, pp. 7–11.

[26] M. Saini, A. Alelaiwi, and A. El Saddik (2015),"How close are we to realizing a pragmatic VANET solution? A meta-survey," *ACM Comput. Surv.*, vol. 48, no. 2.

[27] S. S. Shah, A. W. Malik, A. U. Rahman, S. Iqbal, and S. U. Khan (2019) ,"Time Barrier-Based Emergency Message Dissemination in Vehicular Ad-hoc Networks," *IEEE Access*, vol. 7, no. February, pp. 16494–16503.

[28] L. Wang *et al. (* 2019*)* , "Vehicular Channel in Urban Environments at 23 GHz for Flexible Access Common Spectrum Application," *Int. J. Antennas Propag.*,vol. 2019.

[29] N. Haridas *et al. (*2008*)*, "Reconfigurable MEMS antennas," *Proc. 2008 NASA/ESA Conf. Adapt. Hardw. Syst. AHS 2008*, no. July, pp. 147–154.

[30] D. Rodrigo, L. Jofre, and B. A. Cetiner (2012), "Circular beam-steering reconfigurable antenna with liquid metal parasitics," *IEEE Trans. Antennas Propag.*, vol. 60, no. 4, pp. 1796–1802.

[31] N. Ud Din, A. Afzaal, J. Tahir, and N. Hafeez (2011), "Electronic beam scanning for radar applications," *8th Int. Conf. High-Capacity Opt. Networks Emerg. Technol. HONET 2011*, no. December 2011, pp. 355–358.

[32] S. Edition (1999), *Phased Array Antenna Handbook*, vol. 19, no. 2.

[33] L. Singh (2016), "A Survey on Beam Steering Techniques in," pp. 7450–7455.

[34] S. Roy, S. Sajal, and B. D. Braaten (2017), "A phase correction technique based on spatial movements of antennas in real-time for designing self-adapting conformal array antennas," *Microw. Opt. Technol. Lett.*, vol. 59, no. 12, pp. 3002–3010.

[35] X. Cheng *et al .(*2018*)*, "Millimeter-wave frequency beam scanning array with a phase shifter based on substrate-integrated-waveguide," *IEEE Access*, vol. 6, pp. 47408–47414.

[36] J. Liu,D. R. Jackson, and Y. Long (2012), "Substrate integrated waveguide (SIW) leaky-wave antenna with transverse slots," *IEEE Trans. Antennas Propag.*, vol. 60, no. 1, pp. 20–29.

[37] Y. Chen, K. Wang, Y. Li, and Y. Long (2020), "Periodic Microstrip Leaky Wave Antenna with Double-Sided Shorting Pins and Pairs of Slots," *Int. J. Antennas Propag.*, vol. 2020.

[38] M. Wang, H. F. Ma, H. C. Zhang, W. X. Tang, X. R. Zhang, and T. J. Cui (2018), "Frequency-Fixed Beam-Scanning Leaky-Wave Antenna Using Electronically Controllable Corrugated Microstrip Line," *IEEE Trans. Antennas Propag.*, vol. 66, no. 9, pp. 4449–4457.

[39] M. H. Rahmani and D. Deslandes (2017), "Backward to Forward Scanning Periodic Leaky-Wave Antenna With Wide Scanning Range," *IEEE Trans. Antennas Propag.*, vol. 65, no. 7, pp. 3326–3335.

[40] Y. L. Lyu, F. Y. Meng, G. H. Yang, P. Y. Wang, Q. Wu, and K. Wu (2018), "Periodic Leaky-Wave Antenna Based on Complementary Pair of Radiation Elements," *IEEE Trans. Antennas Propag.*, vol. 66, no. 9, pp. 4503–4515.

[41] I. J. Bahl and P. Bhartia (1982),"Microstrip Antennas," *IEEE Antennas Propag. Soc. Newsl.*, vol. 24, no. 2, pp. 29–30.

[42] B. R.Vishvakarma, “Radiation and scanning characteristics of a frequency scanning Microstrip array antenna ,” vol. 25, no. December, pp. 336–339, 1996.

[43] H. Wang, P. Ge, D. G. Fang, X. F. Ma, and W. X. Sheng (2010), “A low loss frequency scanning planar array using hybrid coupling,” *2010 Int. Conf. Microw. Millim. Wave Technol. ICMMT 2010*, pp. 1908–1911.

[44] T. Nishio, H. Xin, Y. Wang, and T. Itoh (2004), “A Frequency-Controlled Active Phased Array,” *IEEE Microw. Wirel. Components Lett.*, vol. 14, no. 3, pp. 115–117.

[45] M.Ranjbar Naeini,M. Fakharzadeh, and F. Farzaneh (2019),“Ka-band Frequency Scanning Antenna with Wide-Angle Span,” *J. Infrared, Millimeter, Terahertz Waves*, vol. 40, no. 2, pp. 231–246.

[46] Z. Sun, Z. Dai, X. Xuan, and X. Li (2013), “A wideband frequency scanning microstrip antenna array with low profile,”*Proc.-2013 Int. Conf. Mechatron. Sci. Electr. Eng. Comput. MEC 2013*, vol. 1, no. d, pp. 3081–3084.

[47] M.Ur Rahman, M. Naghshvarianjahromi, S. S. Mirjavadi, and A. M. Hamouda (2018), “Bandwidth enhancement and frequency scanning array antenna using novel UWB filter integration technique for OFDM UWB radar applications in wireless vital signs monitoring,” *Sensors (Switzerland)*, vol. 18, no. 9.

[48] S. Elements (2020), “Antenna with Bowtie and Semi-Circular Elements” pp. 1–13.

[49] R. Camblor Diaz, S. Ver Hoeye, C. Vázquez, G. Hotopan, M. Fernández, and F. Las Heras (2012) ,“Sub-millimeter wave frequency scanning 8×1 antenna array,” *Prog. Electromagn. Res.*, vol. 132, no. February 2015, pp. 215–232.

[50] W. Ma, W. Cao, S. Shi, Z. Zeng, and X. Yang (2019), “Gain enhancement for circularly polarized SIW frequency beam scanning antenna using a phase-correcting grating cover,” *IEEE Access*, vol. 7, pp. 52680–52688.

[51] W. Yin *et al.(*2020*)*, “Frequency scanning single-ridge serpentine dual-slot-waveguide array antenna,”*IEEE Access*, vol. 8, pp. 77245–77254.

[52] I. Khan, G. D., R. Gunjal, and R. Rashmitha (2018) , “Review of MSP Antenna Design for Various Substrates,” *SSRN Electron. J.*, pp. 1–4.

[53] V. Hanumante, P. Bhattacharjee, S. Roy, P. Chakraborty, and S. Maity (2014) , “Performance Analysis of Rectangular Patch Antenna for Different Substrate Heights,” *Int. J. Innov. Res. Electr. Electron. Instrum. Control Eng.*, vol. 2, no. 1.

[54] “Ulaby, F. T. (2021). Fundamentals of Applied Electromagnetics by Ulaby, Fawwaz T., Michielssen, Eric, Ravaioli, Umberto (2010) Paperback.

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APPENDIX

Matlab code for calculating Frequency scanning array antenna design

```
clc;
clear all;
close all;

N=2
%microstrip design
f0=23e9 %Hz
er=2.2
h=0.254 %mm
z0=50 %ohm
lambda0=3e08/f0 %m
w=4.96 %mm
eff=1.9443
lamdag= 0.0094      %m
  n0=60;
% n0=5:5:60
vp=3e08/sqrt(eff) %m/sec
l=n0*vp/f0    %m

beta=2*pi/lamdag    %rad/m
l0=(2*pi)/beta    %m

l1=l0      %m
l2=l0+l
l3=l0+2*l
l4=l0+3*l
f=22.5*10^9:0.125*10^9:23.5*10^9
d=(0.5*lamdag)
del=((2*pi*n0).*((f-f0)/f0))./(beta*d);
```

```
my=(del*180)/pi
theta00=acos(del);
theta=0:0.01:2*pi;
figure(1);
for i=1:length(theta00)
gamma=beta*d*(cos(theta)-cos(theta00(i)));
AF_Amp=(sin((N/2).*gamma))./(N*sin(gamma./2));
polar(theta,abs(AF_Amp)./max(abs(AF_Amp)));
pause(2);
end
W = 0.00515 %m
L = 0.00323 %m
p=0.0001;
theta_m=0+p:0.01:pi-p;
phi_m=0+p:0.01:2*pi-p;
[Ue,Uh]=radiation_pattern_patch(L,W,lambda0,theta_m,phi_m);
figure(2);
for i=1:length(theta00)
gamma=beta*d*(cos(theta_m)-cos(theta00(i)));
AF_Amp_h=(sin((N/2).*gamma))./(N*sin(gamma./2));
Array_Pattern=Uh.*AF_Amp_h;
polar(theta_m,abs(Array_Pattern)./max(abs(Array_Pattern)));
pause(2);
end
figure(3);
for i=1:length(theta00)
gamma=beta*d*(cos(phi_m)-cos(theta00(i)));
AF_Amp_e=(sin((N/2).*gamma))./(N*sin(gamma./2));
Array_Pattern=Ue.*AF_Amp_e;
polar(phi_m,abs(Array_Pattern)./max(abs(Array_Pattern)));
pause(2);
end
```

MICROSTRIP INSET FEED DESIGN

```
clc
clear all
format long
f=f*1e9;
%calculate the width
wid=(3e8/(sqrt((er+1)/2)*2*f))*1000;            %in mm
%calculate the effective dielectric constant
e_eff=((er+1)/2)+ (((er-1)/2)* (1+((12*h)/wid))^-0.5);
%calculate the extension of length L
del_l=(((e_eff+0.3)*((wid/h)+0.264))/((e_eff-0.258)*((wid/h)+0.8)))*(0.412*h);    %in mm
%calculate the effective length
l_eff=(3e8/(2*f*sqrt(e_eff)))*1000;
%calculate the actual length
L=l_eff-(2*del_l);
la=(3e8/f)*1000;
k=(2*pi)/la;
x=k*(wid);
i1=-2+cos(x)+(x*sinint(x))+(sin(x)/x);
g1=i1/(120*pi*pi);       %Conductance
a=(((sin((x./2).*cos(th))./cos(th)).^2).*(besselj(0,(k.*L.*sin(th)))).*(sin(th)).^3);
a1=integral(a,0,pi);
g12=a1/(120*pi*pi);      %in siemens
r_in=1/(2*(g1+g12));    %in ohms
inset=(L/pi)*(acos(sqrt(z/r_in)));            %in mm
Lg_min=6*h+L;
Wg_min=6*h+wid;
B=60*pi*pi/(z*sqrt(er));
m1=2*B-1;
m=log(m1);
n1=B-1;
n=log(n1);
W=(2*h/pi)*(B-1-m+(((er-1)/(2*er))*(n+(0.39*0.61)/er)));
g = (3e8*4.65e-9)/(sqrt(2*e_eff)*f*10^-9);
```