

POLYAMIDE MATERIAL BASED CONFORMAL STRUCTURE ARRAY ANTENNA FOR 5G

Submitted in partial fulfillment of the requirements for the award of
Bachelor of Engineering degree in Electronics and Communication Engineering

By

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**INSTITUTE OF SCIENCE AND TECHNOLOGY
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APRIL - 2023



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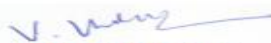
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BONAFIDE CERTIFICATE

This is to certify that this Project Report is the bonafide work of **CHILUKURI DURGAMAHESH(39130094)** and **JANANANANDA CHAKRAVARTHI(39130081)** who carried out the project entitled "**POLYAMIDE MATERIAL BASED CONFORMAL STRUCTURE ARRAY ANTENNA FOR 5G**" under our supervision from November 2022 of April 2023.


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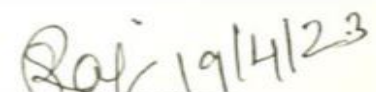
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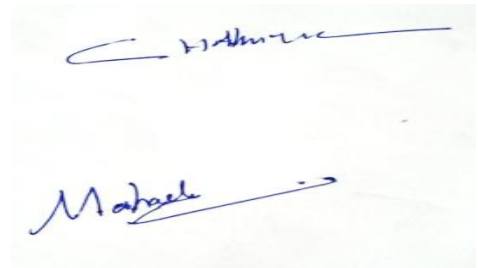
DECLARATION

We **CHILUKRI DURGAMAHESH (39130094), JANANANANANDA CHAKRAVARTHI (39130081)** here by declare that the Project Report entitled “**POLYAMIDE MATERIAL BASED CONFORMAL STRUCTURE ARRAY ANTENNA FOR 5G**”done by us under the guidance of **Dr.V.J.VIJAYAKUMAR M.TECH., Ph.D.,** is **submitted** in partial fulfillment of the requirements for the award of Bachelor of Engineering degree in Electronics and Communication Engineering.

DATE:

PLACE:

SIGNATURE OF THE CANDIDATES

The image shows two handwritten signatures in blue ink. The top signature is a cursive script that appears to read 'Chilukri Durgamahesh'. The bottom signature is also in cursive and appears to read 'Jananananda Chakravarthi'. Both signatures are written on a light-colored, slightly textured background.

ACKNOWLEDGEMENT

We, are pleased to acknowledge our sincere thanks to **Board of Management of SATHYABAMA** for their kind encouragement in doing this project and for completing it successfully. We are grateful to them.

We convey our thanks to **Dr. N. M. NANDHITHA, M.E., Ph.D., Professor & Dean, School of Electrical and Electronics** and **Dr. T. RAVI, Ph.D., Professor & Head, Department of Electronics and Communication Engineering** for providing us necessary support and details at the right time during the progressive reviews.

We would like to express my sincere and deep sense of gratitude to our Project Guide **Dr.V.J.VIJAYAKUMAR M.TECH., Ph.D.**, for his valuable guidance, suggestions and constant encouragement paved way for the successful completion of our project work.

We wish to express our thanks to all Teaching and Non-teaching staff members of the Department of Electronics and Communication Engineering who were helpful in many ways for the completion of the project.

ABSTRACT

Eight-element conformal array antenna design for 5G applications is the subject of this paper. The substrate material used here is Polyamide with 3.3 of dielectric constant and simulated by Ansys High-Frequency Structure Simulator (HFSS). The single element rectangular shaped antenna is developed first for a 3.5GHz operating frequency, and then the array antenna is added. A corporate feeding network makes up the 8-element array antenna. A 2x4-element array makes up this feeding network. The conformal design from the typical array antenna is created using the cylindrical surface. The conventional array antenna is wrapped around the cylinder with care to get the bending shape that results in a conformal construction. We will compare the results of conventional and conformal array antennas after designing the conformal array antenna. The return loss of a normal 8 element array antenna is -47.5dB, whereas the return loss of a conformal array antenna is -37.7dB. As a result, the return loss of a conformal array antenna is decreased by almost -10dB. Overall, the simulation results indicate that both the linear array antenna and the conformal array antenna provided improved results, with the conformal array antenna showing some degradation in gain and return loss. Finally, the conformal microstrip array antenna made of polyamide can be integrated into the skin of vehicles like satellites and planes, as well as used as human wearable antennas.

TABLE OF CONTENTS

ABSTRACT	IV
CHAPTER 1: INTRODUCTION	
1.1 Antenna	1
1.2 Antenna History	2
1.3 Physically Small and Electrically Large Antennas	2-3
1.4 Fundamental Parameters of Antenna	3
1.4.1 Radiation Pattern	3-6
1.4.2 Radiation Pattern Lobes	5-7
1.4.3 Beamwidth	7-8
1.4.4 Resolution	8-11
1.4.5 Radiation Power Density	11-13
1.4.6 Radiation Intensity	13-14
1.4.7 Directivity	14
1.4.8 Beam Solid Angle	14-15
1.4.9 Antenna Efficiency	15
1.4.10 Gain	15
1.4.11 Bandwidth	15
CHAPTER 2: MICROSTRIP PATCH ANTENNA	16-26
2.1 Introduction	16-17
2.2 Feed Methods	17-19
2.2.1 Probe Coupling Method	17-18
2.2.2 Microstrip Line Feeding Method	18
2.2.3 Proximity Coupled Method	18-19
2.2.4 Aperture Coupled Feed Method	19
2.3 Methods of Analysis of Microstrip Patch Antenna	20-21
2.3.1 Formulae For Calculating Parameters Of PatchAntenna	
2.3.2 Transmission Line Feed	21-22
2.3.3 Cavity Method	22
2.3.4 Multiport Network Model	22-23
2.3.5 Method of Moments	23
2.3.6 Finite Element Method	23
2.3.7 Spectral Domain Technique	23-24
2.3.8 Finite Difference Time Domain Method	24
2.4 Measurement of Antenna Characteristics	24-26

2.4.1	Return Loss and VSWR	25
2.4.2	Efficiency	25
2.4.3	Antenna Gain and Directivity	25
2.4.4	Radiation Pattern	25-26
2.5	Basic Characteristics	26
CHAPTER 3: ARRAY ANTENNA		27-29
3.1	Introduction	27
3.2	Design of Antenna Array	27
3.3	Types of Arrays	28
3.4	Types of Array Feeding	28
3.4.1	Series Feed	28
3.4.2	Corporate Feed	29
3.5	Advantages	29
3.6	Applications	29
CHAPTER 4: CONFORMAL ANTENNAS		30-32
4.1	Introduction	30-32
CHAPTER 5: SIMULATION TOOL		33-35
5.1	Introduction to HFSS	33
5.2	Mathematical Method Used in HFSS	34-35
5.3	Adaptive Solution Process	35
CHAPTER 6: LITERATURE REVIEW		36-38
6.1	Base Papers	36
6.2	Source	37
6.3	Literature Review Designs	37-38
CHAPTER 7: DESIGN OF ANTENNA		39-45
7.1	Work Plan	39
7.2	Proposed design	40
7.3	Antenna Designing	41
7.4	Single Element	41
7.5	Two Element	42
7.6	Four Element	42-43
7.7	Eight Element	43-44
7.8	Conformal Eight Element	44-45
7.9	Dimensions of Proposed Antenna Table	45
CHAPTER 10: RESULTS AND DISCUSSION		46-53
10.1	Return Loss [S_{11}]	46
10.1.1	For Single Element	46

10.1.2	For 2, 4,8 Element Array	46
10.1.3	For Conformal Array Antenna	47
10.2	Gain	48
10.2.1	For Single Element	48
10.2.2	For 2 Element Array Antenna	48
10.2.3	For 4 Element Array Antenna	49
10.2.4	For 8 Element Array Antenna	49
10.2.5	For Conformal Array Antenna	50
10.3	Radiation Pattern	50
10.3.1	For Single Element	50
10.3.2	For 2 Element Array Antenna	51
10.3.3	For 4 Element Array Antenna	51
10.3.4	For 8 Element Array Antenna	52
10.3.5	For Conformal Array Antenna	52
10.4	VSWR Plot	53
10.4.1	For Single Element	53
10.4.2	For 2, 4,8 Element and Conformal Array Antenna	53
CHAPTER 11: FABRICATION		54
11.1	Single Element	54
11.2	Conformal Array Antenna	55
11.3	Analysis Of Simulation And Fabrication Results	56
11.4	Parametric Analysis Of Conformal Antenna	56
CHAPTER 12: CONCLUSION		57
REFERENCES		58

INTRODUCTION

1.1 ANTENNA:

The IEEE standard definition of term antennas (IEEE Std- 145-1983): define the antenna or aerial as “a means for radiating or receive radio waves”, or, in other words, the antenna is a metallic device which transmits and receives electromagnetic radiations from free space. Antennas are commonly used for television broadcasting, radio broadcasting, radar, satellite communication, mobile phones, etc. Without the antenna, there is no possibility to communicate wirelessly over long distance

. Antennas are broadly categorized into wire antennas, traveling wave antennas, reflector antennas, log-periodic antennas, aperture antennas, microstrip antennas and other antennas. Antenna size is depending upon the frequency over which they are working, low-frequency antenna has large size and high-frequency antennas are small in size, this is because of the antenna size is directly proportional to wavelength and from formula $f = c/\lambda$, it is clear that frequency inversely proportional to wavelength so the size of the antenna. In general, there is basic idea that in order to work antenna properly the size of the antenna must be greater than or equal to $\lambda/2$, otherwise antenna could not radiate electromagnetic wave properly[1].

An antenna acts as an interface between a guided wave and a free-space wave. One of the most important characteristics of an antenna is its directional property, i.e., its ability to concentrate radiated power in a certain direction or receive power from a preferred direction. The directional property of an antenna is characterized in terms of a pattern which applies to the antenna as a transmitter or as a receiver. For an efficient interface between the free-space wave and the guided wave in the feed transmission line, the input impedance of the antenna must be matched to the characteristic impedance of the transmission line.

Thus, the antenna characteristics can be classified into two main categories : (a) radiation characteristics, which are used to describe the way the antenna radiates or receives energy from space and (b) input charact

eristics, which are used to specify the performance of the antenna looking into its terminals. Radiation characteristics include the radiation pattern, gain, directivity, effective aperture, polarization, etc. and the input characteristics are specified in terms of the input impedance, bandwidth, reflection coefficient, voltage standing wave ratio.

1.2 HISTORY OF ANTENNA:

The experiment that comprises the coupling of magnetism and electricity and showed a perfect relationship was done by Faraday around the 1830s. In this experiment, he moves a magnetic over the coil of a wire which was connected to a galvanometer. As magnet moves, he was in effect produce a time-varying magnetic field, and, as a result, must have a time-varying electric field, which as a result (from Maxwell's Equations), must electromagnetic radiation, which was collated by the galvanometer-means the work of an antenna Heinrich Hertz made a wireless communication system, wherein he forced an electrical spark to appear in the gap of a dipole antenna. He observed a similar disturbance by using a loop antenna as a receiver, around 1886.

In 1901, Marconi has transmitted information across the Atlantic to transmit electromagnetic radiation through the antenna, he made use of several vertical wires attached to the ground. Across the Atlantic Ocean, the receiver antenna was kept at 200- meter wire which was held up by a kite. Columbia University in 1906 had used a transmitting aerial cage as an experimented Wireless. This cage was made using wires and suspended in the air, resembling a cage. A rough outline of some major antennas and their discovery/fabrication dates are listed:

They are:

1. Yagi-Uda Antenna, 1920
2. Horn antennas, 1939.
3. Antenna Arrays, 1940
4. Parabolic Reflectors, in the period of 1940-1950.
5. Lens Antenna, 1946

6. Smart antennas, 1990
7. Wearable antenna, 2008.
- 8.

1.3 Physically small and hierarchically large Antennas:

Antennas are mapped according to its physical and electrical size. There are four categories in which antennas are divided that are physically large and electrically large antennas, physically large but electrically small antennas, physically small but electrically large and physically and electrically small antennas. In most of the system physically small and electrically, large antennas are required as because we know that electrically large antenna can work for low frequency but at the same time its physical size must low in order to match with modern wireless devices.

The patch antenna comes under the category of physically and electrically large antenna, but it has some issues that its electrical length. Sometime not much large so we have to make some adjustment like the use of shorting pin or making a slot in the given patch to increase its frequency response. But this is not in the case of fractal, fractal antennas are perfect physically and electrically large antennas. Because of space filling properties the electrical size of the antenna as we increase the number of iterations. Also, the fractal shape has self- similar properties which model antenna has a similar shape at small size works as itself an antenna at reduced scale for different frequency.

1.4 Fundamental Parameters of Antenna:

To describe the performance of an antenna, definitions of various parameters are necessary. Some of the parameters are interrelated and not all of them need be specified for complete description of the antenna performance. Parameter definitions will be given in this chapter.

1.4.1 Radiation Pattern:

Antenna radiation pattern or antenna pattern is defined as a mathematical function or a graphical representation of the radiation properties of the antenna as a function of space coordinates.

1. Defined for the far-field.
2. As a function of directional coordinates.
3. There can be field patterns (magnitude of the electric or magnetic field).
4. Often normalized with respect to their maximum value.
5. The power pattern is usually plotted on a logarithmic scale or more commonly in decibels(dB).
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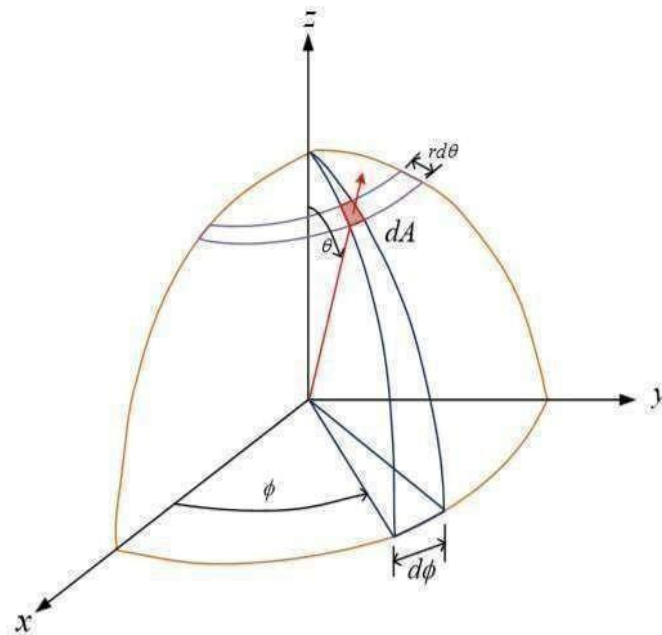


Figure 1.1 Radiation Pattern of Antenna

Radiation patterns are conveniently represented in spherical

coordinates. pattern: $E(\theta, \phi) \cdot dA = r^2 \sin \theta d\theta d\phi$

Azimuth: ϕ Elevation: $\pi/2 - \theta$.

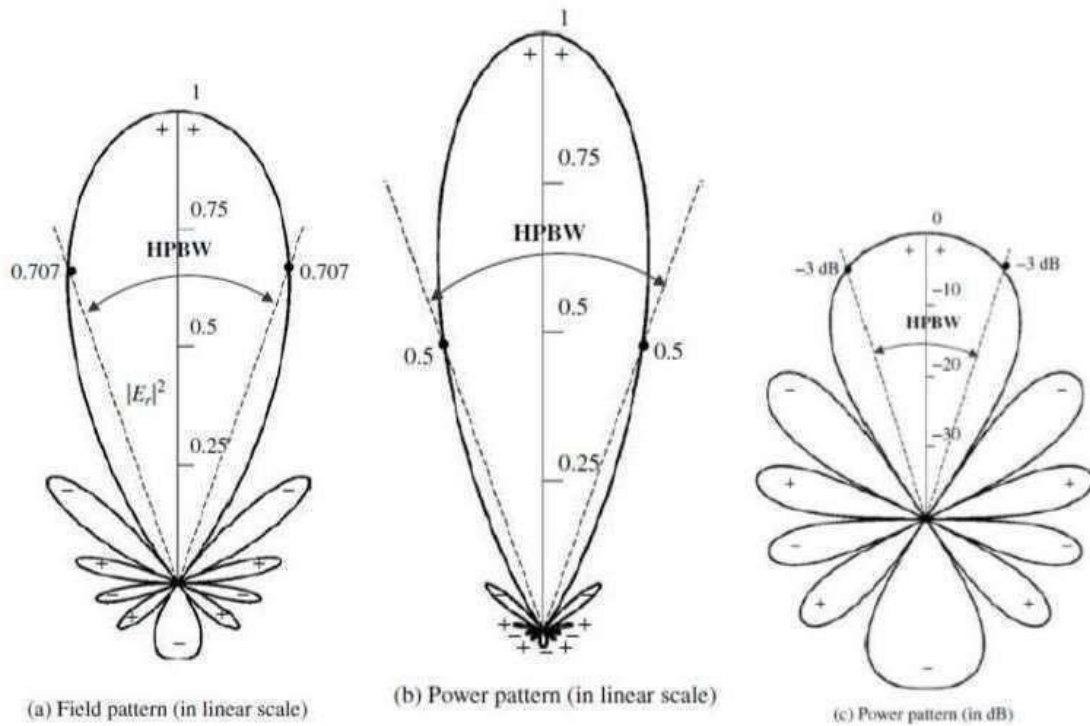


Figure 1.2 Lobes of Radiation pattern

All three patterns yield the same angular separation between the two half power points, 38.64°, on their respective patterns, referred to as HPBW.

1.4.2 Radiation Pattern Lobes:

A radiation lobe is a portion of the radiation pattern bounded by regions of relatively weak radiation intensity.

Types of lobes are:

- Main lobe

- Minor lobes
- Side lobes
- Back lobes

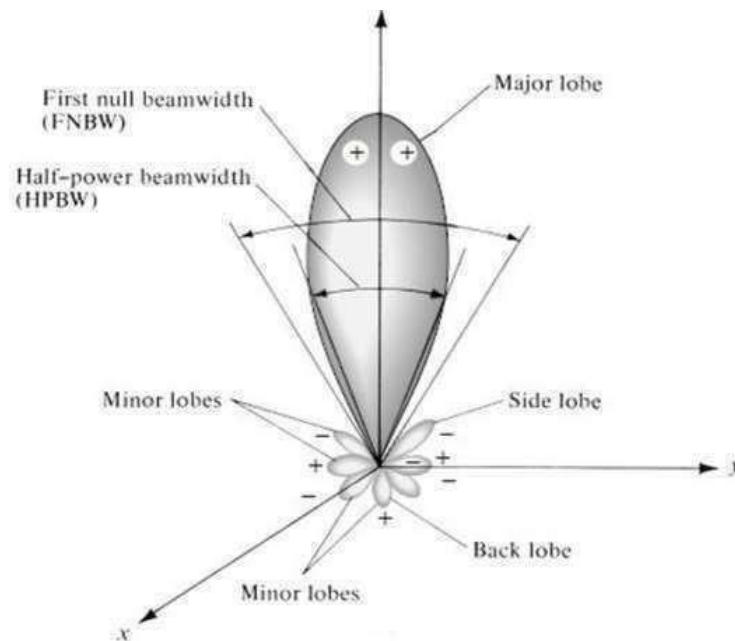


Figure 1.3 Antenna Lobes

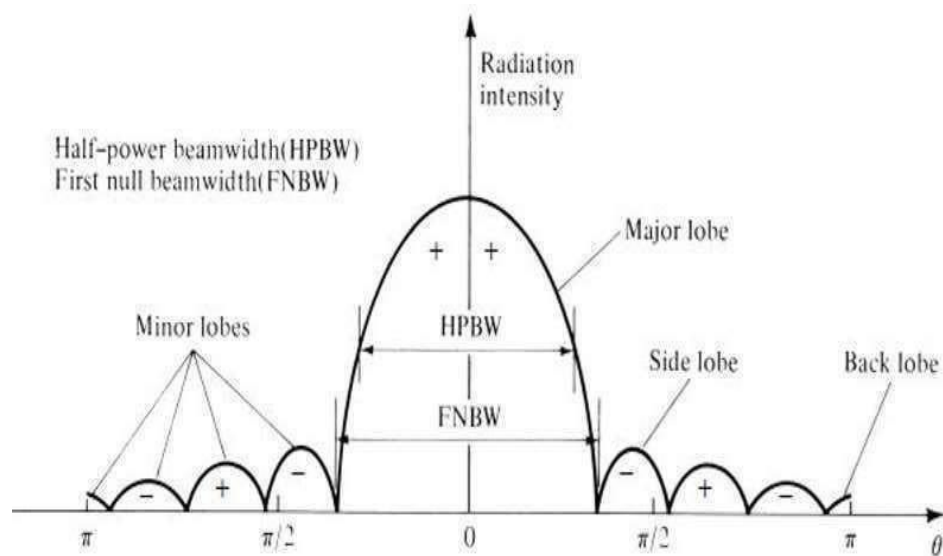


Figure 1.4 Radiation Pattern and its Lobes Representing HPBW and

FNBW

Minor lobes usually represent radiation in undesired directions, and they should be minimized. Side lobes are normally the largest of the minor lobes. The level of minor lobes is usually expressed as a ratio of the power density, often termed the side lobe ratio or side lobe level. In most radar systems, low side lobe ratios are very important to minimize false target indications through the side lobes (e.g., -30dB).

Components in the Amplitude Pattern: There would be, in general, three electric field components (E_r , E_θ , E_ϕ) at each observation point on the surface of a sphere of constant radius. In the far field, the radial E_r component for all antennas is zero or vanishingly small.

Some antennas, depending on their geometry and also observation distance, may have only one, two, or all three components.

In general, the magnitude of the total electric field would be $|E| = \sqrt{|E_r|^2 + |E_\theta|^2 + |E_\phi|^2}$

Isotropic Radiator:

A hypothetical lossless antenna having equal radiation in all directions.

Omnidirectional Radiator:

An antenna having an essentially non-directional pattern in a given plane (e.g., in azimuth) and a directional pattern in any orthogonal plane.

Directional Radiator:

An antenna having the property of radiating or receiving more effectively in some directions than in others. Usually, the maximum directivity is significantly greater than that of a half-wave dipole.

1.4.3 Beamwidth:

The beam width of an antenna is a very important figure of merit and often is used as a trade-off between it and the side lobe level; that is, as the beam width decreases, the side lobe

increases and vice versa.

Half-Power Beam Width (HPBW):

In a plane containing the direction of the maximum of a beam, the angle between the two directions in which the radiation intensity is one-half value of the beam.

First-Null Beam width(FNBW):

Angular separation between the first nulls of the pattern

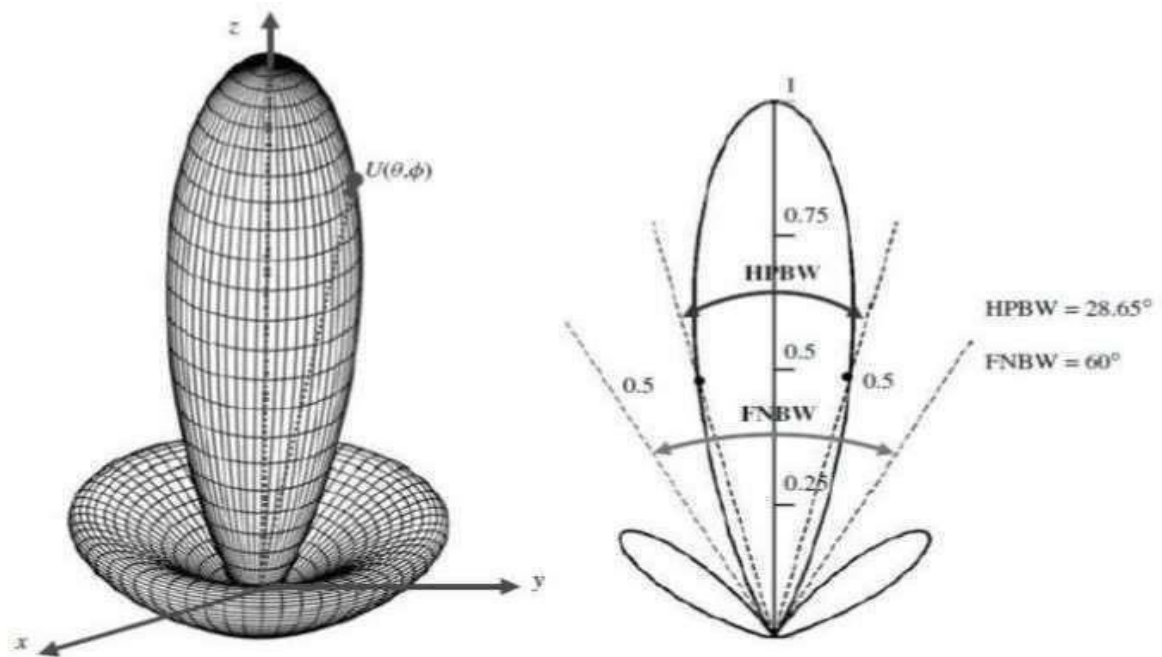


Figure 1.5 HPBW and FNBW

1.4.4 Resolution:

The most common resolution criterion states that the resolution capability of an antenna to distinguish between two sources is equal to half the first-null beam width ($\text{FNBW}/2$), which is usually used to approximate the HPBW. That is, two sources separated by angular distances equal or greater than $\text{FNBW}/2 \approx \text{HPBW}$ of an antenna with a uniform distribution

can be resolved. If the separation is smaller, then the antenna will tend to smooth the angular separation distance.

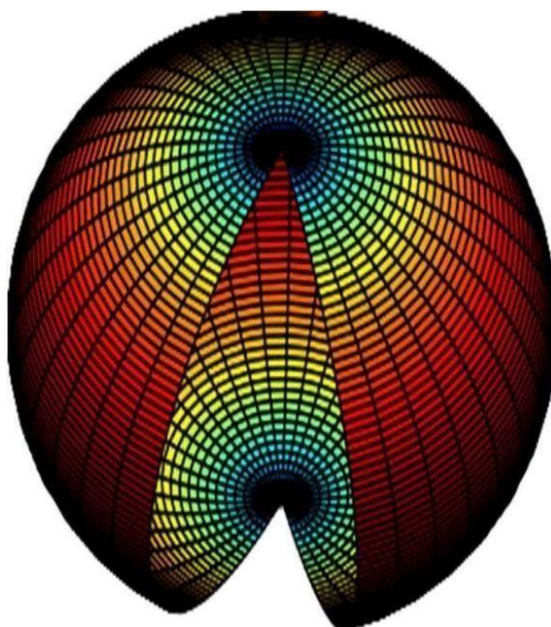


Figure 1.6 Isotropic Radiation Pattern

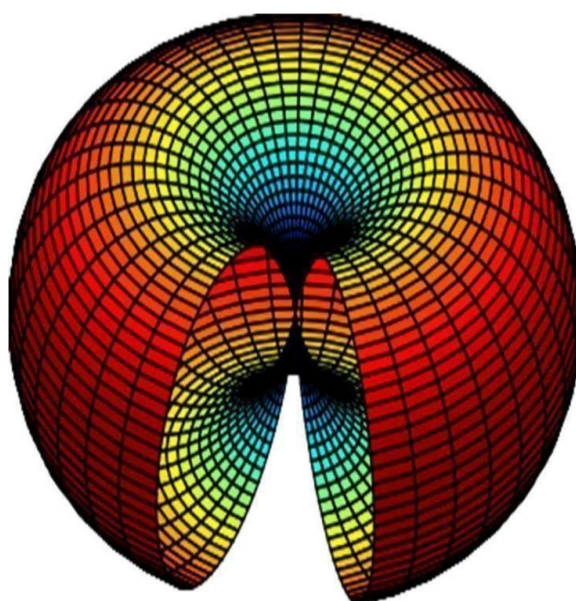


Figure 1.7 Omnidirectional Radiation Pattern

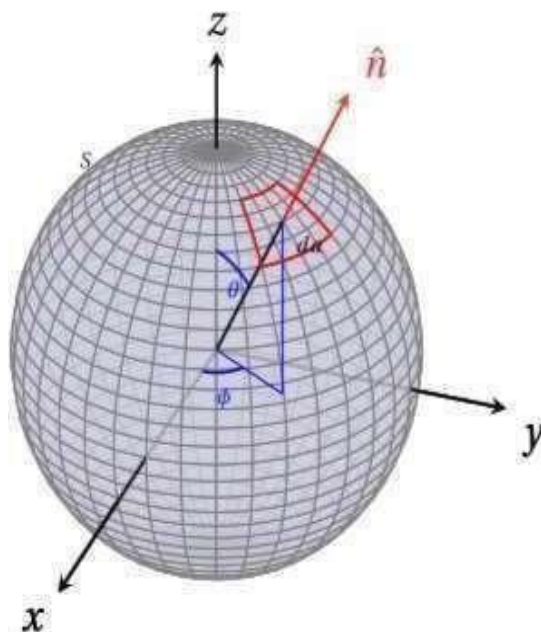
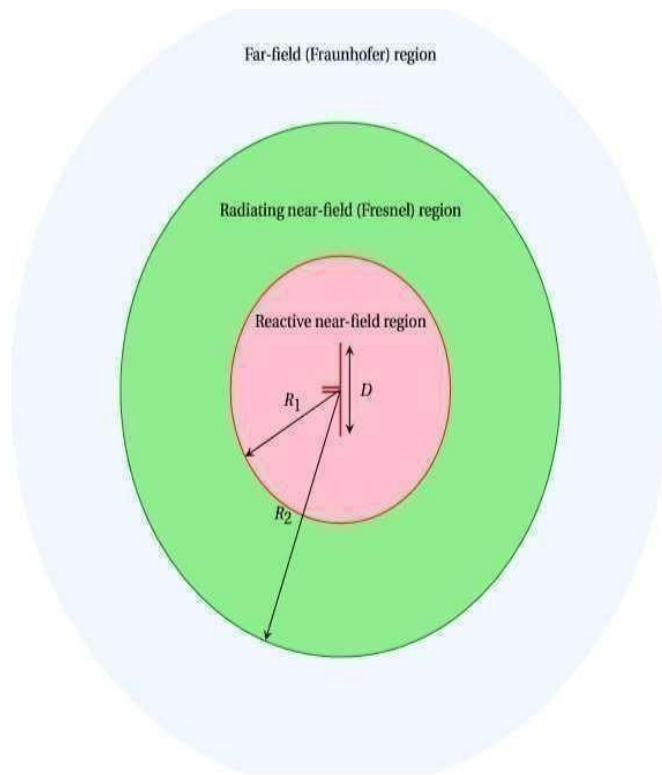


Figure 1.10 Poynting Vector Coordinate Representation Average

Power Density:

1. For applications of time-varying fields, it is desirable to find the average power density.
2. The average power density is obtained by integrating the instantaneous Poynting vector over one period and dividing by the period.
3. For time-harmonic variations of the form $e^{j\omega t}$, we define the complex fields $\mathbf{E}$ and $\mathbf{H}$ which are related to their instantaneous counterparts $\mathbf{E}$ and $\mathbf{H}$ by

$$\mathbf{E}(x, y, z; t) = \text{Re} [\mathbf{E}(x, y, z) e^{j\omega t}],$$

$$\mathbf{H}(x, y, z; t) = \text{Re} [\mathbf{H}(x, y, z) e^{j\omega t}].$$

Average Radiated Power :

The power density associated with the electromagnetic fields of an antenna in its far-field region is predominately real and will be referred to as radiation density. The average power radiated by an antenna (radiated power) can be written as

$$P_{\text{rad}} = P_{\text{avg}} = \oint_S W_{\text{rad}} \cdot \hat{n} \, da$$

Power Pattern Versus Average Radiated Power :

The power pattern of the antenna is the average power density radiated by the antenna as a function of the direction. The observations are usually made on a large sphere of constant radius. In practice, absolute power patterns are usually not desired, but the performance of the antenna is measured in terms of relative power patterns. Three-dimensional patterns cannot be measured, but they can be constructed with a number of two-dimensional cuts.

1.4.5 Radiation Intensity :**Steradian:**

One steradian is defined as the solid angle with its vertex at the center of a sphere of radius r that is subtended by a spherical surface area equal to that of a square with each side of length

r . Since the area of a sphere of radius r is $A = 4\pi r^2$, there are 4π steradians in a closed sphere.

Radiation Intensity:

Radiation intensity in a given direction is defined as the power radiated from an antenna per unit solid angle. The radiation intensity is a far-field parameter. It can be obtained by simply multiplying the radiation density by the square of the distance.

Total Radiated Power Using Radiation Intensity:

The total power is obtained by integrating the radiation intensity over the entire solid angle of 4π . Thus

$$P_{\text{rad}} = \int_0^\pi \int_0^{2\pi} U \sin\theta d\theta d\phi$$

Where $d\Omega$ is the element of solid angle $= \sin\theta d\theta d\phi$.

1.4.6 Directivity:

The ratio of the radiation intensity in a given direction from the antenna to the radiation intensity averaged over all directions. The average radiation intensity: total power radiated by the antenna divided by 4π . Stated more simply, the directivity of an isotropic source is equal to the ratio of its radiation intensity in a given direction over that of an isotropic source.

$$D_{\text{max}} = D_0 = \frac{U}{U_0} = \frac{U_{\text{max}}}{U_0} = \frac{4\pi U_{\text{max}}}{P_{\text{rad}}}$$

D = Directivity (dimensionless)

D_0 = Maximum

directivity (dimensionless) $U = U(\theta, \phi)$

= radiation intensity (W/sr)

U_{max} = maximum radiation intensity (W/sr)

U_0 = radiation intensity of isotropic

source (W/sr) P_{rad} = total radiated power (W)

1.4.7 Beam Solid Angle :

The beam solid angle Ω_A is defined as the solid angle through which all the power of the antenna would flow if its radiation intensity is constant (and equal to the maximum

value of U) for all angles within Ω_A .

$$P_{\text{rad}} = \int_0^{2\pi} \int_0^\pi F(\theta, \varphi) \sin\theta d\theta d\varphi$$

1.4.1 Antenna Efficiency :

The total antenna efficiency e_0 is used to take into account losses at the input terminals and within the structure of the antenna. e_0 is due to the combination of number of efficiency

$$e_0 = e_r e_c e_d$$

e_0 = total efficiency,

e_r = reflection (mismatch) eff., $= (1 - |\Gamma|^2)$,

e_c = conduction efficiency,

e_d = dielectric efficiency,

1.4.2 Gain:

Gain is the ratio of the intensity, in a given direction, to the radiation intensity that would be obtained if the power accepted by the antenna were radiated isotropically. The gain of the antenna is closely related to the directivity. In addition to the directional capabilities, it accounts for the efficiency of the antenna. Gain does not account for losses arising from impedance mismatches (reflection losses) and polarization mismatches (losses).

$$\text{Gain} = \frac{4\pi \text{ radiation intensity}}{\text{Total input accepted power}}$$

We can write that the total radiated power (P_{rad}) is related to the total input power (P_{in}) by $P_{\text{rad}} = e_{\text{cd}} P_{\text{in}}$

1.4.3 Bandwidth :

For broadband antennas, the bandwidth is usually expressed as the ratio of the upper- to-lower frequencies of acceptable operation. For example, a 10:1 bandwidth indicates that the upper frequency is 10 times greater than the lower.

For narrow band antennas, the bandwidth is expressed as a percentage of the f

CHAPTER - 2

MICROSTRIP PATCH ANTENNA

In high-performance aircraft, spacecraft, satellite, and missile applications, where size, weight, cost, performance, ease of installation, and aerodynamic profile are constraints, low-profile antennas may be required. Presently there are many other government and commercial applications, such as mobile radio and wireless communications, that have similar specifications. To meet these requirements, microstrip antennas can be used. These antennas are low profile, conformable to planar and nonplanar surfaces, simple and inexpensive to manufacture using modern printed-circuit technology, mechanically robust when mounted on rigid surfaces, compatible with MMIC designs, and when the particular patch shape and mode are selected, they are very versatile in terms of resonant frequency, polarization, pattern, and impedance. In addition, by adding loads between the patch and the ground plane, such as pins and varactor diodes, adaptive elements with variable resonant frequency, impedance, polarization, and pattern can be designed[1].

There are numerous substrates that can be used for the design of microstrip antennas, and their dielectric constants are usually in the range of $2.2 < \epsilon_r < 12$. The ones that are most desirable for good antenna performance are thick substrates whose dielectric constant is in the lower end of the range because they provide better efficiency, larger bandwidth, loosely bound fields for radiation into space[1], but at the expense of larger element size. Thin substrates with higher dielectric constants are desirable for microwave circuitry because they require tightly bound fields to minimize undesired radiation and coupling, and lead to smaller element sizes; however, because of their greater losses, they are less efficient and have relatively smaller bandwidths[2].

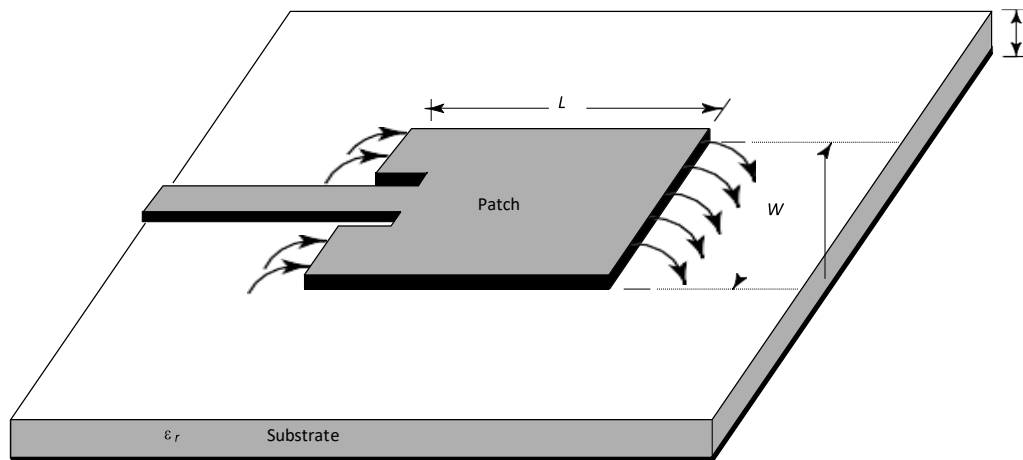


Figure 2.1 Microstrip Patch Antenna

2.1 Feed methods :

There are mainly four basic methods for the feeding to these antennas:

1. Probe Coupling Method
2. Microstrip Line Feeding Method
3. Aperture Coupled Microstrip Feed Method
4. Proximity Coupling Method

2.1.1 Probe Coupling Method :

Coupling of power to the microstrip patch antenna can be done by probe feeding method. The inner conductor of the probe line is connected to patch lower surface through slot in the groundplane and substrate material.

To get perfect impedance matching we need to find out the location of the feed point over the antenna element. Design simplicity and input impedance adjustment through feed point positioning, makes this feeding method popular. But there are some limitations also like larger lead for thicker substrate, difficulty in soldering for array elements etc.

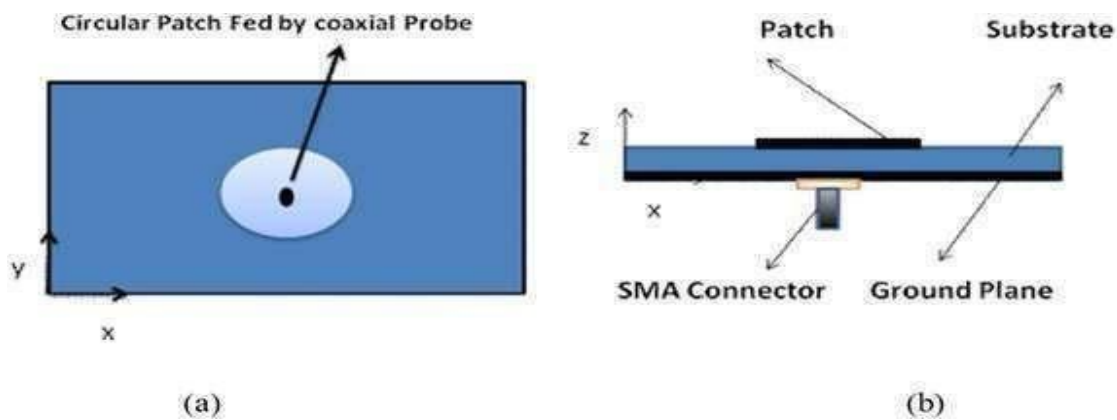


Figure 2.2 Probe Coupling Method a) Top View b) Side View

2.1.2 Microstrip Line feeding Method:

Using microstrip line we can give excitation to the antenna as shown in the figure 3.3. This method is very simple to design and fabricate. But this technique suffers from some limitations. If substrate thickness is increased in the design, then the surface waves and the spurious radiation also increases. Because of that the undesired cross polarization radiation arises. Microstrip line feeding can be used in the conditions where performance of the antenna is not a strict matter. The edge coupled feed can be improved with coplanar wave guide feeding.

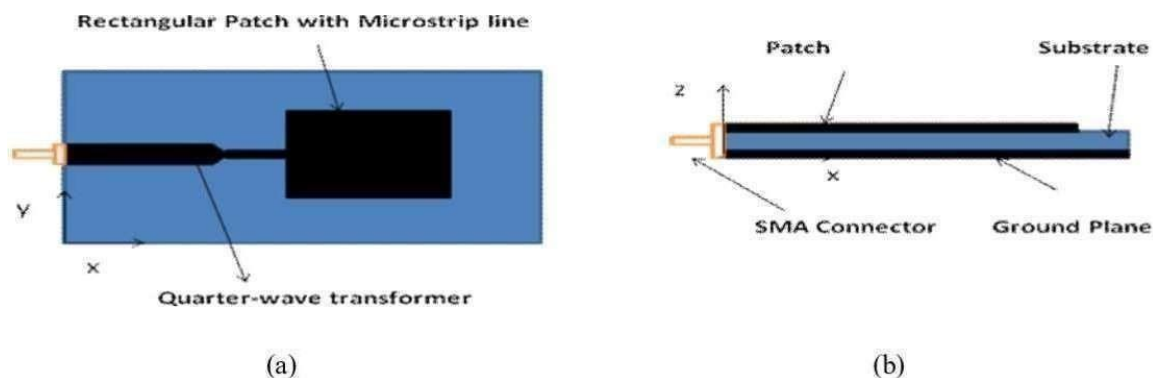


Figure 2.2 Geometry of Recessed Microstrip Line Feed Patch Antenna a) Top view
b) Side view

2.1.3 Proximity Coupled Method:

This method can be employed, where two or multilayer substrate configuration is considered. Generally, in this configuration, microstrip line will be placed on lower substrate and the patch element will be placed on the upper substrate. Other name for this feeding is electromagnetically coupled feed. Capacitive nature will appear between

feed line and patch in this case. By choosing thin lower substrate layer and placing patch on top layer will improve the bandwidth and reduce the spurious radiation. Fabrication of this feeding is slightly difficult because of alignment problems in feed and patch at proper location. Peaceful thing is soldering and related problems can be eliminated.

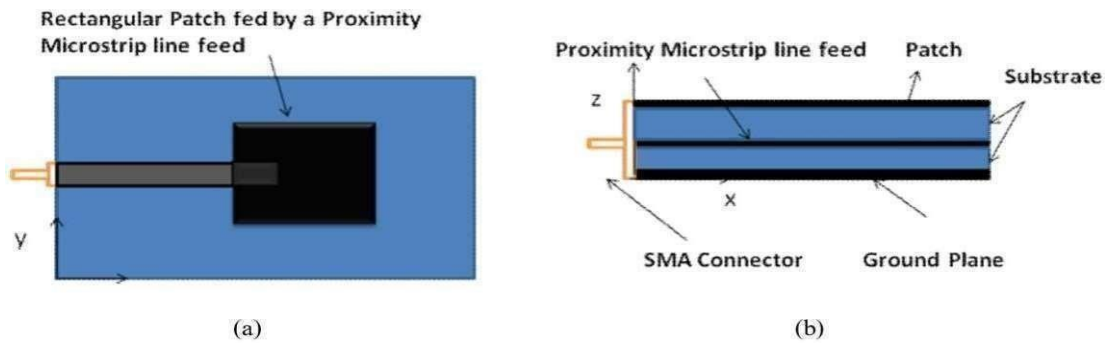


Figure 2.2 Geometry of proximity coupled microstrip feed patch antenna a) TopView b) Side view

2.1.4 Aperture Coupled Feed Method:

This method employs ground plane between two substrates. A slot will be placed on the ground plane and feed line will be placed on lower substrate. This will be electromagnetically connected to patch on the upper substrate through the ground plane slot. One should take care about substrate parameters and they have to choose in a way that feed optimization and independent radiation functioning can exist. The coupling slot should be nearly centered so that the patch magnetic field will be maximum.

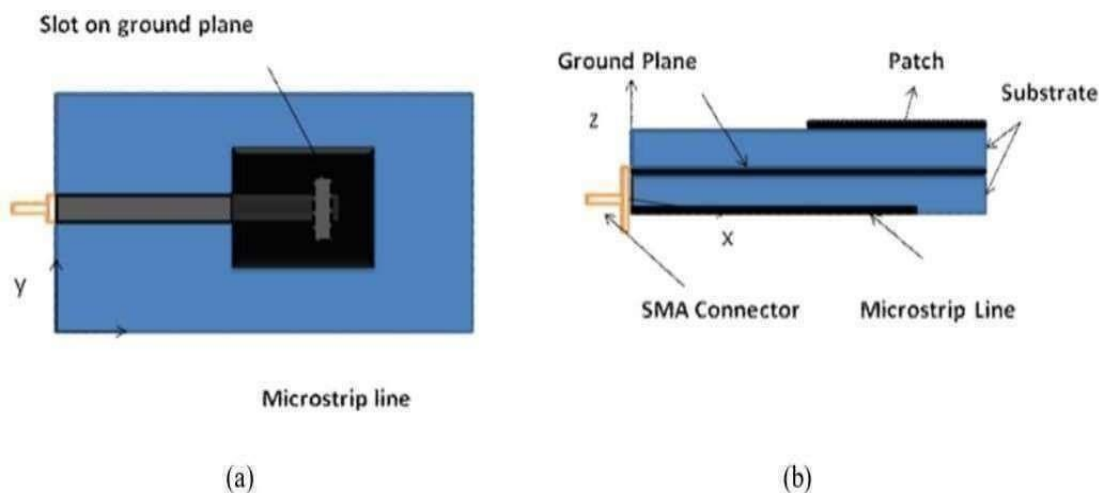


Figure 2.3 Geometry of an Aperture Coupled Feed Microstrip Patch Antenna a)Top view b) Side view

2.2 Methods of Analysis of Microstrip Patch Antenna:

The most popular methods for the analysis of microstrip patch antennas are the transmission line model, cavity model and full wave model (which include primarily integral equations/moment method). The transmission line model is the simplest of all and it gives good physical insight but it is less accurate. The cavity model is more accurate and gives good physical insight but is complex in nature. The full wave models are extremely accurate, versatile and can treat single elements, finite and infinite arrays, stacked elements, arbitrary shaped elements and coupling[1].

2.2.1 FORMULAE FOR CALCULATING PARAMETERS OF PATCH ANTENNA :

The Microstrip Patch Antenna Calculation Process :

Step 1: Calculation of the Width (W) -

$$W = \frac{c}{2f_o \sqrt{\frac{(\epsilon_r + 1)}{2}}}$$

Step 2: Calculation of the Effective Dielectric Constant. This is based on the height, dielectric constant of the dielectric and the calculated width of the patch antenna.

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

Step 3: Calculation of the Effective length

$$L_{eff} = \frac{c}{2f_o \sqrt{\epsilon_{eff}}}$$

Step 4: Calculation of the length extension ΔL

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

Step 5: Calculation of actual length of the patch

$$L = L_{eff} - 2\Delta L$$

Step 6 : Impedance matching calculation :

$$Z_0 = \sqrt{Z_{in} * Z_L}$$

$$R_{eq} = \frac{R_1 * R_2}{R_1 + R_2}$$

2.3 Transmission Line Model :

This model represents the microstrip antenna by two slots of width 'w' and height 'h', separated by transmission line of length 'L'. The microstrip is essentially an inhomogeneous line of two dielectrics, typically substrate and air.

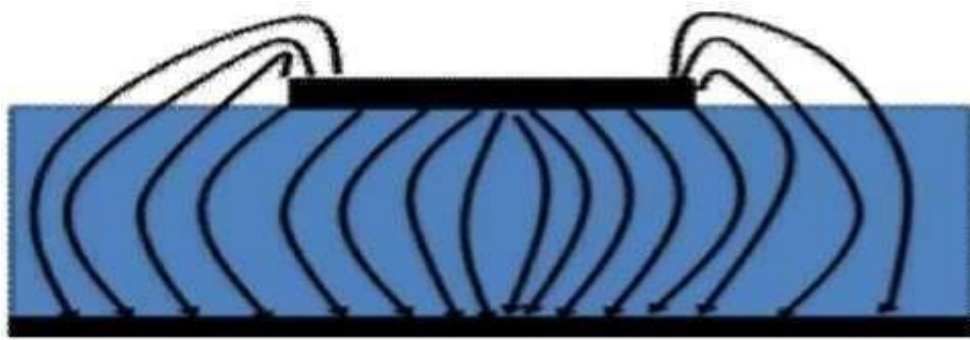


Figure 2.4: Electric Field

As seen from the Fig 2.4, most of the electric field lines lie inside the substrate and parts of some lines are in air. As a result, this transmission line cannot support pure transverse electric-magnetic (TEM) mode of transmission, since phase velocities would be different in the air and the substrate. Hence an effective dielectric constant (ϵ_{eff}) must be obtained in order to account for the fringing and the wave propagation in the line. The value of ϵ_{eff} is slightly less than ϵ_r because the fringing fields around the periphery of the patch are not confined in the dielectric substrate but are also spread in the air. The expression for ϵ_{eff} is given by

$$\epsilon_{eff} = \frac{\epsilon_r + 1}{2} + \frac{\epsilon_r - 1}{2} \left[\frac{1}{1 + \frac{12h}{w}} \right]^{0.5}$$

Where

ϵ_{reff} = Effective dielectric constant ϵ_r

ϵ_r = Dielectric constant of substrate

h = height of the dielectric

W = width of the patch

2.4 Cavity model :

In the cavity model, the region between the patch and the ground plane is treated as a cavity that is surrounded by magnetic walls round the periphery and by electric walls from the top and bottom sides. Since thin substrates are used, the field inside the cavity is uniform along the thickness of the substrate. The fields underneath the patch for regular shapes such as rectangular, circular, triangular, and sectoral can be expressed as a summation of the various resonant modes of the two-dimensional resonator.

The fringing fields around the periphery are taken care of by extending the patch boundary outward so that the effective dimensions are larger than the physical dimensions of the patch. The effect of the radiation from the antenna and the conductor loss are accounted for by adding these losses to the loss tangent of the dielectric substrate. The far field and radiated power are computed from the equivalent magnetic current around the periphery. An alternate way of incorporating the radiation effect in the cavity model is by introducing an impedance boundary condition at the walls of the cavity. The fringing fields and the radiated power are not included inside the cavity but are localized at the edges of the cavity. However, the solution for the far field, with admittance walls is difficult to evaluate.

2.5 Multiport Network Model (MNM):

The Multiport Network Model (MNM) for analyzing the microstrip antenna is an extension of the cavity model. In this method, the electromagnetic fields underneath the patch and outside the patch are modelled separately. The patch is analyzed as a two-dimensional planar network, with a multiple number of ports located around the periphery. The fringing fields along the periphery and the radiated fields are

incorporated by adding an equivalent edge admittance network. The segmentation method is then used to find the overall impedance matrix. The radiated fields are obtained from the voltage distribution around the periphery.

The above three analytical methods offer both simplicity and physical insight. In the latter two methods, the radiation from the microstrip antenna is calculated from the equivalent magnetic current distribution around the periphery of the radiating patch, which is obtained from the corresponding voltage distribution. Thus, the microstrip antenna analysis problem reduces to that the edge voltage distribution for a given excitation and for a specified mode. These methods are accurate for regular patch geometries.

2.6 Method of Moments:

In the Method of Moments (MoM) the surface currents are used to model the microstrip patch and polarization currents in the dielectric slab are used to model the fields in the dielectric slab. An integral equation is formulated for the unknown currents on the microstrip patches, feed lines and their images in the ground plane. The integral equations are transformed into algebraic equations that can be easily solved using a computer. This method takes into account the fringing fields outside the physical boundary of the two-dimensional patch, thus providing a more exact solution.

2.7 Finite Element Method :

The Finite Element Method (FEM), unlike the MoM, is suitable for volumetric configurations. In this method, the region of interest is divided into a number of finite surfaces or volume elements depending upon the planar or volumetric structures to be analyzed. These discretized units, generally referred to as finite elements, can be any well-defined geometrical shapes such as triangular elements for planar configurations and tetrahedral and prismatic elements for three-dimensional configurations, which are suitable even for curved geometry. It involves the integration of certain basic functions over the entire conducting patch, which is divided into a number of subsections. The problem of solving wave equations with inhomogeneous boundary conditions is taken by decomposing it into two boundary value problems, one with Laplace's equation with an inhomogeneous boundary and the other corresponding to an inhomogeneous wave equation with a homogeneous boundary.

2.8 Spectral Domain Technique :

In the Spectral Domain Technique (SDT), a two-dimensional Fourier transform along the two orthogonal directions of the patch in the plane of substrate is employed. Boundary conditions are applied in Fourier transform plane. The current distribution on the conducting patch is expanded in terms of chosen basis functions and the resulting matrix equation is solved to evaluate the electric current distribution on the conducting patch and the equivalent magnetic current distribution on the surrounding substrate surface. The various parameters of the antennas are then evaluated.

2.9 Finite Difference Time Domain Method :

The Finite Difference Time Domain (FDTD) method is well-suited for microstrip antennas, as it can conveniently model numerous structural in-homogeneities encountered in these configurations. It can also predict the response of the microstrip antenna over the wide bandwidth with a single simulation. In this technique, spatial as well as time grid for the electric and magnetic fields are generated over which the solution is required. The spatial discretization's along three Cartesian coordinates are taken to be same. The E-cell edges are aligned with the boundary of the configuration and H-fields are assumed to be located at the center of each E-cell. Each cell contains information about material characteristics. The cells containing the sources are excited with a suitable excitation function, which propagates along the structure. The discretized time variations of the fields are determined at desired locations. Using a line integral of the electric field, the voltage across the two locations can be obtained. The current is computed by a loop integral of the magnetic field surrounding the conductor, where the Fourier transform yields a frequency response.

The above numerical techniques, which are based on the electric current distribution on the patch conductor and the ground plane, give results for any arbitrarily shaped antenna with good accuracy, but they are time consuming.

2.9.1 Measurement of Antenna Characteristics :

The antennas, in general, are characterized by parameters like gain, input impedance, directivity, radiation pattern, effective area and polarization properties. The experimental procedure to find the parameters of the antenna is discussed in the following sections. The S parameters can be determined with Vector Network Analyzer

and radiation patterns can be computed through the antenna measurement setup in connection with Network analyzer. The cables and connectors have its losses associated at higher frequency bands. The measuring instrument should be calibrated before using it. Single port, full two port and TRL calibration methods are generally used. Return loss, VSWR and input impedance can be measured.

plane containing electric field vector and the direction of maximum radiation and H-plane is the plane containing the magnetic field vector and the direction of maximum. By placing antenna in the receiving mode inside the anechoic chamber, E-plane and H-plane radiation patterns will be taken using antenna measurement setup and network analyzer.

The radiation pattern of the antenna at multiple frequency points can be measured with single rotation of the test antenna positioner and measurement software. Positioner will stop at each angle and S21 measurement will be taken at different frequency points in operating band. This thing will be repeated till it reaches to stop angle. The measured data will be stored for the further processing to plot the graphs.

2.9.2 BASIC CHARACTERISTICS :

Microstrip patch antennas consist of a very thin (λ_0 is the free-space wavelength) metallic strip (patch) placed a small fraction of a wavelength (usually $0.003\lambda_0 \leq h \leq 0.05\lambda_0$) above a ground plane. The microstrip patch is designed so its pattern maximum is normal to the patch (broadside radiator). For a rectangular patch, the length L of the element is usually $\lambda_0/3 < L < \lambda_0/2$. The strip (patch) and the ground plane are separated by a dielectric sheet (referred to as the substrate)[1].

The ones that are most desirable for good antenna performance are thick substrates whose dielectric constant is in the lower end of the range because they provide better efficiency, larger bandwidth. Often microstrip antennas are also referred to as patch antennas. The radiating elements and the feed lines are usually photo-etched on the dielectric substrate. The radiating patch may be square, rectangular, thin strip (dipole), circular, elliptical, triangular, or any other configuration. Square, rectangular, dipole (strip), and circular are the most common because of ease of analysis and fabrication, and their attractive radiation characteristics

CHAPTER – 3

ARRAY ANTENNA

3.1 Introduction:

An antenna, when individually can radiate an amount of energy, in a particular direction, resulting in better transmission, how it would be if few more elements are added it, to produce more efficient output. It is exactly this idea, which led to the invention of antenna arrays.

An antenna array is a radiating system, which consists of individual radiators and elements. Each of this radiator, while functioning has its own induction field. The elements are placed so closely that each one lies in the neighbouring one's induction field. Therefore, the radiation pattern produced by them, would be the vector sum of the individual ones.

The spacing between the elements and the length of the elements according to the wavelength are also to be kept in mind while designing these antennas. The antennas radiate individually and while in array, the radiation of all the elements sum up, to form the radiation beam, which has high gain, high directivity and better performance, with minimum losses [4] [5].

3.2 Design of antenna arrays:

In an antenna array providing a fixed radiation pattern, we may consider that the feed network is a part of the antenna array. If, in addition, the amplitude of the excitation received by each element (during emission) is also well chosen, it is possible to synthesize a single-port array having a radiation pattern that closely approximates a specified pattern. [4] Many methods have been developed for array pattern synthesis. Additional issues to be considered are matching, radiation efficiency and bandwidth [6] [7].

The design of an electronically steerable antenna array is different, because the phasing of each element can be varied, and possibly also the relative amplitude for each element. Here, the antenna array has multiple ports, so that the subject matters of matching and efficiency are more involved than in the single-port case. Moreover, matching and efficiency depend on the excitation, except when the interactions between the antennas can be ignored.

3.3 Types of Arrays:

The basic types of arrays are –

- Collinear array
- Broad side array
- End fire array
- Parasitic array
- Yagi-Uda array
- Log-periodic array
- Turnstile array
- Super-turnstile array

3.4 Types of Feeding Networks in Array Antennas:

Arrays can be fed in many ways, but the two general types of feed arrangement for microstrip patch arrays are series feed and corporate feed. Microstrip patch array in a series feed network is fed by a single transmission line, whereas patch array in a corporate feed network is fed by multiple transmission lines[8].

3.4.1 Series feed :

Series feed network is much easier to design and fabricate compared to the corporate feed network. However, this method will result in progressive phase delay between elements thus making unsuitable for phase scanning. Another problem with series feed arrangement is the high VSWR that is caused by the additive mismatches at the various junctions between the elements (Zurcher and Gardiol, 1995).

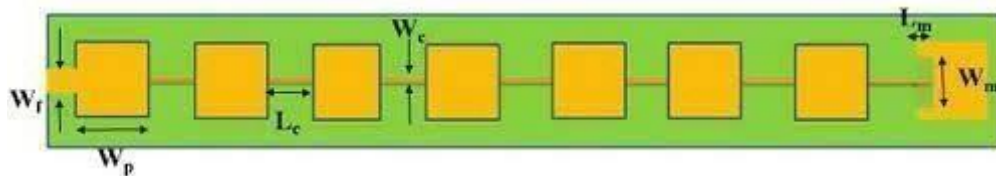


Fig 3.4.1 Series Feed

3.4.2 Corporate Feed :

Corporate feed network is more flexible and offers better phase control over the performance of each array element. It is best suited for scanning phased array, multi beam arrays or shaped beam arrays. However, the use of corporate feed network is more preferable over series feed network as it is less affected by frequency scan. A corporate feed network supplies excitation individually to each array element and use equal line lengths and power dividers for each element[9].

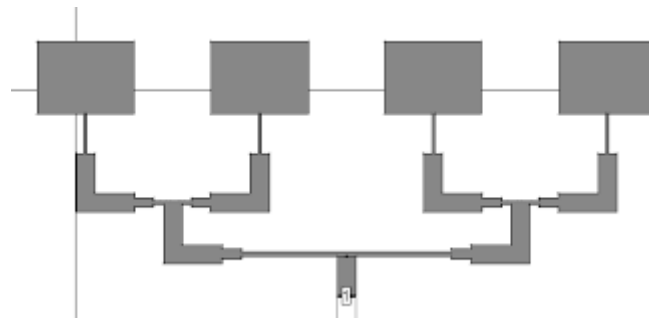


Fig.3.4.2 Corporate Feed

3.5 Advantages:

The following are the advantages of using antenna

- The signal strength increases
- High directivity is obtained
- Minor lobes are reduced much
- High Signal-to-noise ratio is achieved
- High gain is obtained
- Power wastage is reduced
- Better performance is obtained

3.6 Applications:

The following are the applications of array antennas –

- Used in satellite communications
- Used in wireless communications
- Used in military radar communications
- Used in the astronomical study

CHAPTER - 4

CONFORMAL ANTENNAS

4.1 Introduction:

Conformal antennas as name implies is “to conform” or to take the shape of the host or the platform over which it operates. The IEEE standard definition for antennas gives the following definition: ‘An antenna that conforms to a surface whose shape is determined by considerations other than electromagnetic; for example, aerodynamic or hydrodynamic’. When a surface like a cylinder is taken into consideration for arrays, it inherently improves the beam scanning capability compared to traditional linear or planar arrays. Applications of conformal arrays are vast especially for military application, these arrays would preserve the aerodynamic structure of the aircraft or missile or U A V s. While the civilian applications include the communication base stations that do not look congested with different sectorial antennas rather uses a cylindrical antenna, and can be used on highspeed automobiles as collision warning radars etc. Since the antenna takes the shape of the platform, so its performance and radiation pattern drastically changes from conventional planar arrays[10]. This paper presents a brief study on

the behaviour of conformal antennas placed on a cylindrical surface.

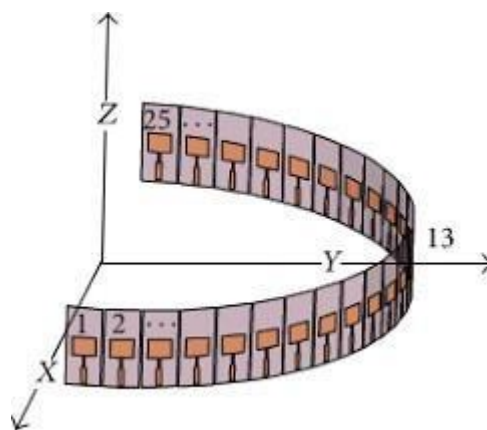


Fig.4.1 Conformal Array

Conformal antennas are a form of phased array antenna. They are composed of an array of many identical small flat antenna elements, such as dipole, horn, or patch antennas, covering the surface. At each antenna the current from the transmitter passes through a phase shifter device which are all controlled by a microprocessor (computer). By controlling the phase of the feed current, the nondirectional radio waves emitted by the individual antennas can be made to combine in front of the antenna by the process of interference, forming a strongbeam (or beams) of radio waves pointed in any desired direction. In a receiving antenna the weak individual radio signals received by each antenna element are combined in the correct phase to enhance signals coming from a particular direction, so the antenna can be made sensitive to the signal from a particular station and reject interfering signals from other directions[11].

In a conventional phased array the individual antenna elements are mounted on a flat surface. In a conformal antenna, they are mounted on a curved surface, and the phase shifters also compensate for the different phase shifts caused by the varying path lengths of the radio waves due to the location of the individual antennas on the curved surface[11] –[12]. Because the individual antenna elements must be small, conformal arrays are typically limited to high frequencies in the UHF or microwave range, where the wavelength of the waves is small enough that small antennas can be used.

The circular array antenna can be seen as an elementary building block of conformal array antennas with rotational symmetry, just as the linear array is a building block of planar antenna arrays. In a linear array the radiating elements are identical with spacing 'd' and they all point to the same direction. The far field radiation pattern of linear array in azimuth plane is $E(\phi) = EL(\phi) \sum_n V_n e^{jknd \sin(\phi)}$

where, V_n is the excitation amplitude of element 'n' and k is the propagation constant, $k = 2\pi/\lambda$. $EL(\phi)$ is the Element factor. The radiation function is the product of the element factor and array factor.

The corresponding far field expression for the circular array in the azimuth plane is

$$E(\phi) = \sum_n V_n EL(\phi - n\Delta\phi) e^{jkR \cos(\phi - n\Delta\phi)}$$

The phase in Equation-II has been referenced to the center of the circle. The identical Elements are placed $R\Delta\phi$ along the circle, each element pointing in the radial direction. The element function cannot be brought outside the summation, since it is a function of the element position, there is no common element factor. Another difference compared to a linear array is the complicated phase expression due to the array curvature. A circular array can be scanned to a direction by imposing phase values to each element so that they add up coherently in the direction ϕ_0 . The radiation function for the scanned array is

$$E(\phi) = \sum_n V_n E_L(\phi - n\Delta\phi) e^{jkR[\cos(\phi - n\Delta\phi) - \cos(\phi_0 - n\Delta\phi)]}$$

CHAPTER-5

SIMULATION TOOL

5.1 Introduction to HFSS:



Ansys HFSS is 3D electromagnetic (EM) simulation software for designing and simulating high-frequency electronic products such as antennas, antenna arrays, RF or microwave components, high-speed interconnects, filters, connectors, IC packages and printed circuit boards. Engineers worldwide use Ansys HFSS software to design high- frequency, high-speedelectronics found in communications systems, advanced driver assistance systems (ADAS), satellites, and internet-of-things (IoT) products.

High Frequency Structure Simulator (HFSS) is a 3D electromagnetic (EM) simulation tool used to design a broad range of high frequency products such as antennas, filters, and IC packages. HFSS has advanced 3D electromagnetic field solvers based on finite elements and other integral equation methods supported by high performance computing technology that enable engineers to perform rapid and accurate design of high- frequency and high-speed electronic components.

These designs include:

- Coaxial resonator model using Eigenmode solver.
- Driven terminal design of a complex package.
- Driven modal design of a coaxial-fed helical antenna with a dielectric support on a finite ground plane.

5.2 Mathematical Method Used in HFSS:

Ansoft HFSS has evolved over a period of years with input from many users and industries. In industry, Ansoft HFSS is the tool of choice for high-productivity research, development, and virtual prototyping. The numerical technique used in HFSS is the Finite Element Method (FEM). In this method a structure is subdivided into many small subsections called finite elements. In HFSS these finite elements are in the form of tetrahedra. The entire collection of tetrahedra constitutes the finite element mesh. A solution is found for the fields within these tetrahedra. These fields are interrelated so that Maxwell's Equations are satisfied across inter element boundaries yielding a field solution for the entire original structure. Once the field solution is found, the generalized S-matrix solution is determined.

Ansoft HFSS can be used to calculate parameters such as S-Parameters, Resonant Frequency, and Fields. Typical uses include:

- Package Modeling – BGA, QFP, Flip-Chip.
- PCB Board Modeling – Power/Ground planes, Mesh Grid Grounds, Backplanes.
- Silicon/GaAs - Spiral Inductors, Transformers.
- EMC/EMI – Shield Enclosures, Coupling, Near- or Far-Field Radiation.
- Antennas/Mobile Communications – Patches, Dipoles, Horns, Conformal Cell Phone Antennas, Quadrifilar Helix, Specific Absorption Rate (SAR), Infinite Arrays, Radar Cross Section (RCS), Frequency Selective Surfaces (FSS).
- Connectors – Coax, SFP/XFP, Backplane, Transitions.

- Waveguide – Filters, Resonators, Transitions, Couplers.
- Filters – Cavity Filters, Microstrip and Dielectric

HFSS is an interactive simulation system whose basic mesh element is a tetrahedron. This allows you to solve any arbitrary 3D geometry, especially those with complex curves and shapes, in a fraction of the time it would take using other techniques. The name HFSS stands for High Frequency Structure Simulator. Ansoft pioneered the use of the Finite Element Method (FEM) for EM simulation by developing/implementing technologies such as tangential vector finite elements, adaptive meshing, and Adaptive Lanczos-Pade Sweep (ALPS). Today, HFSS continues to lead the industry with innovations such as Modes-to-Nodes and Full Wave Spice.

5.3 Adaptive Solution Process:

HFSS uses the automatic adaptive mesh refinement process to solve an EM problem. Automatic adaptive mesh refinement is a critical part of the overall solution process and the key to producing accurate results. This meshing technique helps you focus on setting up your design efficiently rather than spending time in determining and creating the best mesh. To set up the design, you need only to create the geometry and specify material properties, boundary conditions.

CHAPTER-6

LITERATURE REVIEW

6.1 BASE PAPERS :

- Comparison Of Eight Elements Array Structure Design For Coastal Surveillance Radar
- A Wideband L-Probe Fed Conformal Antenna Array Using Meta Surface.
- Design, Fabrication, and Testing of Flexible Antennas
- Antenna Theory Analysis and Design

The first paper proposed two different array of antenna designs for coastal surveillance radar application. The material antenna used Epoxy FR-4 with 4.6 of dielectric constant The basic antenna is designed using a single rectangular shape at operating frequency 3 GHz, and then it continues to add 8-element of the array antenna. In conclusion, specifies both structures have good agreement with radar antenna specifications[8].

The second paper proposed a Wideband conformal Meta Surface (MTS) antenna array with high gain is designed .The cooperation of the MTS and L-probe feeding of the antenna element realizes a wide bandwidth of 28.1%, which exhibits only one resonant mode. Then, the planar and conformal arrays consisting of 4×8 MTS antenna elements are investigated. The planar and conformal antenna arrays are fabricated and measured in the second paper[13].

From the above text book reference we studied about different flexible materials and their dielectric substrate values and applications of those materials and selected the Polyamide material for this project of dielectric constant 3.3 which is useful for the applications like wearable antennas and many more[2].

From Antenna Theory Analysis and Design textbook we first understood the concept regarding microstrip patch antenna designing and calculation of antenna parameters and impedance matching concept and also about the array antennas and applications of array antennas types of feeding networks present in array antennas

and from that concept we used the corporate feeding network in this project for designing the Conformal Eight element array antenna and understood the difference in gain, return loss and vswr between conventional and conformal array antennas.

6.2 Source :

[1]. S. Huang *et al.*, "A Wideband L-Probe Fed Conformal Antenna Array Using Metasurface," in *IEEE Open Journal of Antennas and Propagation*, vol. 2, pp. 1175-1183, 2021, doi: 10.1109/OJAP.2021.3131242.

[2]. 2020 3rd International Seminar on Research of Information Technology and Intelligent Systems (ISRITI) | 978-1-7281-8406-7/20/\$31.00 ©2020 IEEE | DOI: 10.1109/ISRITI51436.2020.9315394

[3]. Haider R. Khaleel, 'Design, Fabrication, and Testing of Flexible Antennas', in *Advancement in Microstrip Antennas with Recent Applications*, Hussain M. Al-Rizzo, Ed.

Rijeka: IntechOpen, 2013, p. Ch. 15. doi: 10.5772/50841

[4]. Antenna Theory Analysis and Design 4th Edition by Constantine A. Balanis,

6.3 LITERATURE REVIEW DESIGNS :

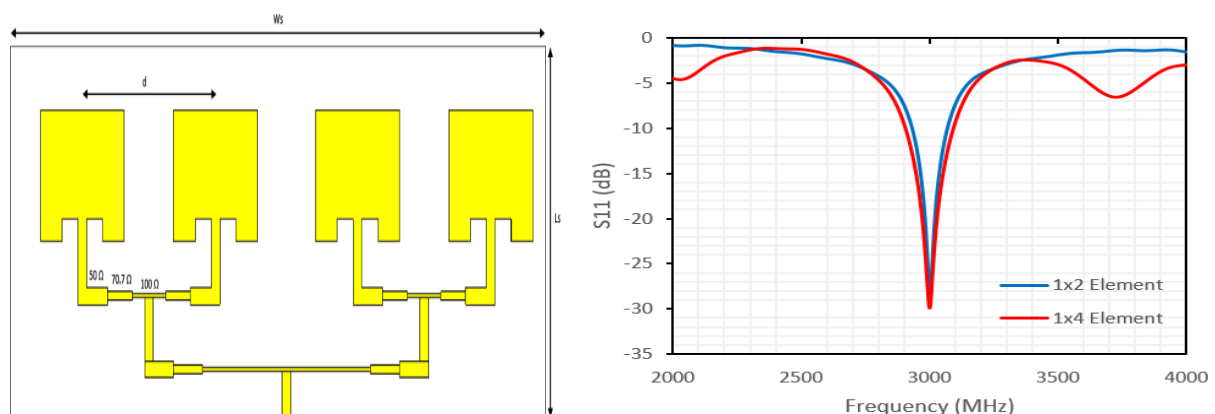


Fig. 6.3 Paper 1

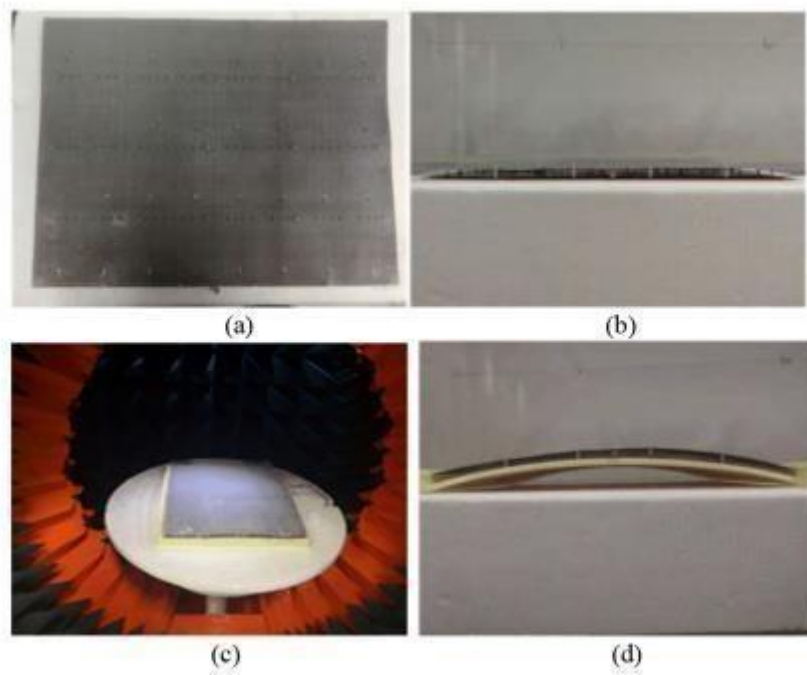


Fig. 6.3 Paper 2



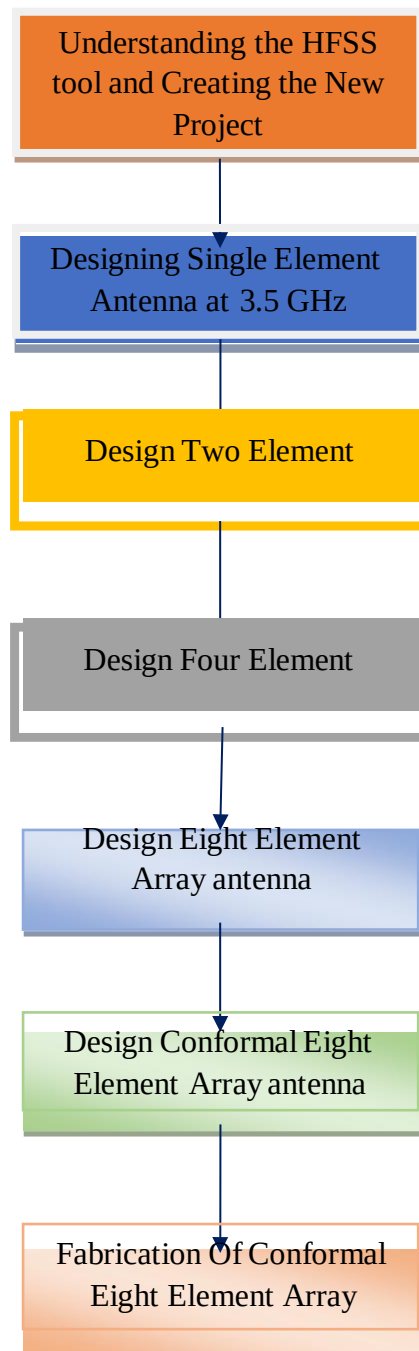
Fig. 6.4 Flexible Substrate

CHAPTER – 7

ANTENNA

DESIGNING

7.1 WORK PLAN :



7.2 PROPOSED DESIGN :

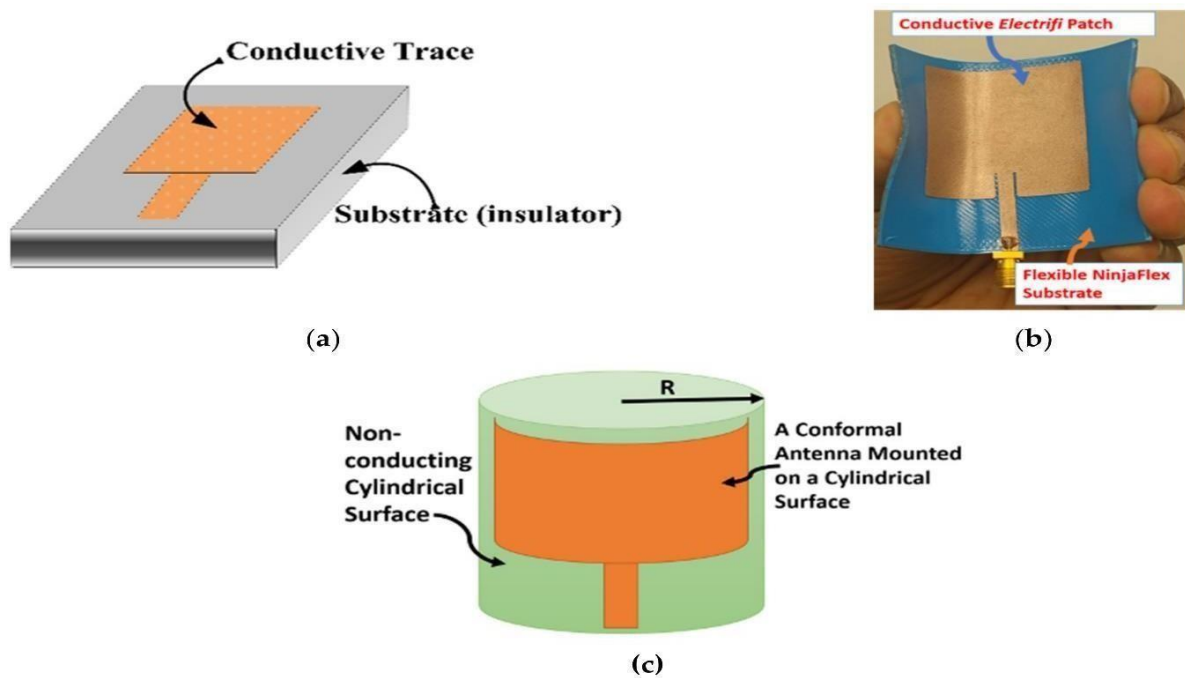


Fig.7.1 Proposed Design

7.3 ANTENNA DESIGNING :

As the antenna substrate material, we utilised polyamide, which does have a ϵ_r of 3.3 and a height of 1mm, while copper has a thickness of 0.035mm. We begin by constructing the single element, then the eight-element array structure, and ultimately the conformal structure after designing the antenna array structure. There have been two types of techniques an 8- element array structure in this particular instance: The corporate feeding linear array structure [1x8] element is the first, and the corporate feeding parallel array structure [2x4] element is the second. The corporate feeding parallel array structure [2x4] element is being followed here. S11, Radiation Pattern, and Gain and VSWR are the antenna parameters that have observed[8].

7.4 SINGLE ELEMENT DESIGN :

The antenna of a one component has a rectangular patch and a copper ground. The antenna's width and length, W_1 and L_1 , are 29.2 mm and 19.3 mm, respectively. The single element antenna design with the edge feed and impedance matching employing quarter-wave transformer dimensions are illustrated in Fig. 1 below. The entire substrate dimensions of this design are W_s and L_s - 41.2mm x 46.1mm.

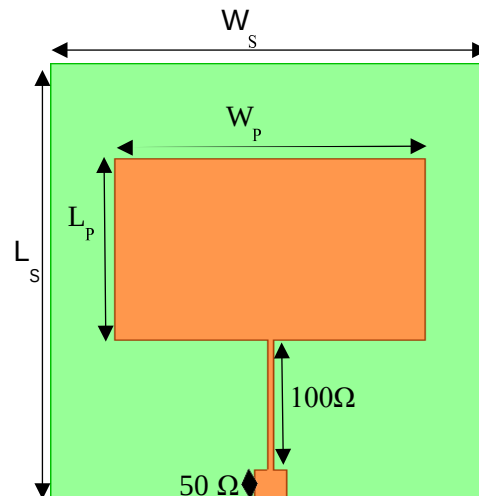


Fig.7.2 Single Element

7.5 ARRAY ANTENNA DESIGN WITH TWO ELEMENTS :

It start implementing the array design of 2 element, 4 element, and 8 element for 5G applications after developing the single element at the operating frequency of 3.5GHz for 5G applications. The 1x2 pattern is being used in a two-element array antenna, and this antenna array parameters are 90.2mm x 57.4mm. The effectiveness result after each cycle of W_5 is 19mm

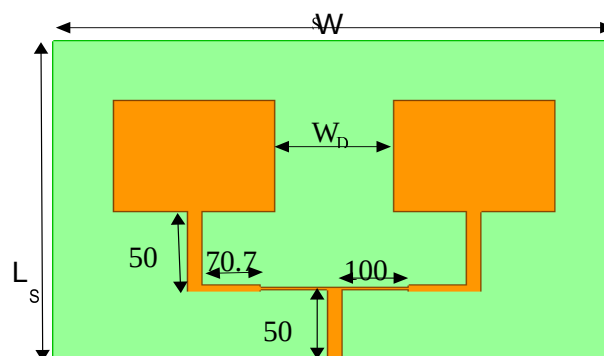


Fig.7.3 Two Element arra

7.6 ARRAY ANTENNA DESIGN WITH FOUR ELEMENTS :

The 1x4 pattern is utilised in a two-element array antenna, with the W_s and L_s antenna array specifications of 180.395mm x 70.92mm. As depicted in Fig. 3, the quarter-wavelength impedance transformers with values of 50, 70.7, and 100 are employed in the 4 element array antenna, analogous to the 2 element array antenna.

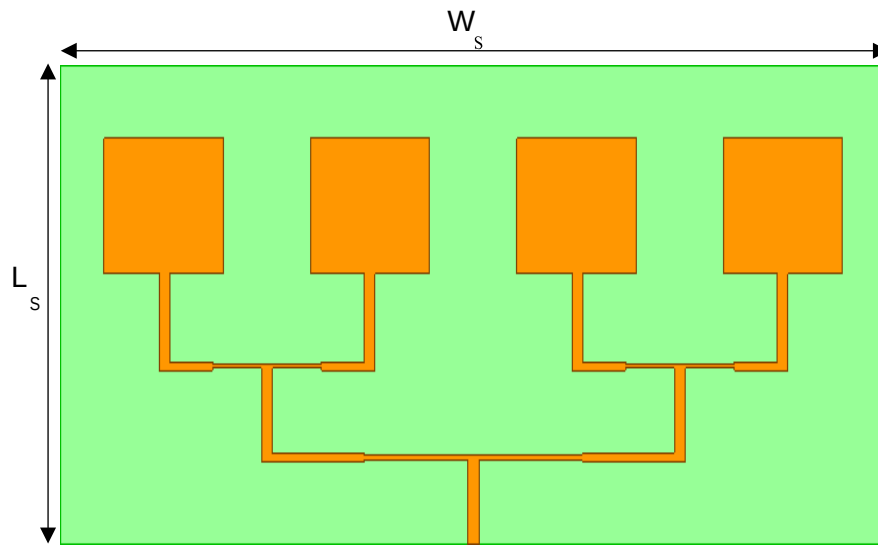


Fig.7.4 Four Element array

7.7 ARRAY ANTENNA DESIGN WITH EIGHT ELEMENTS :

The optimal dimension of a four-element array antenna is used to construct an eight- element antenna. The antenna structure in this study is composed of two feed networks. There are two types of feed networks: one-dimensional and two-dimensional. As illustrated in Fig. 4, depicts a construction of a two-dimensional feeding network established by a 2x4 element antenna. Overall, the W_s and L_s parameters are 180.4 mm x 189.64 mm.

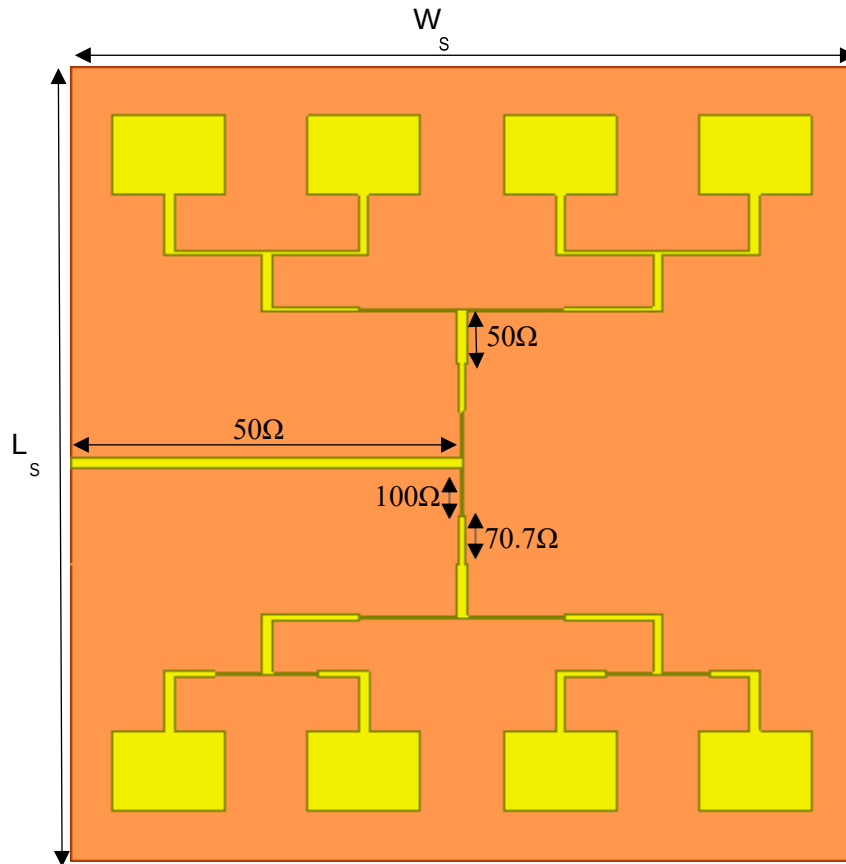


Fig.7.5 Eight Element Conventional array antenna

7.8 CONFORMAL ARRAY ANTENNA DESIGN WITH EIGHT ELEMENTS :

Both feed networks are constructed with a conformal structure. This can be created by bending a regular array antenna into a conformal shape using a cylindrical surface. The cylinder used has a radius of 200mm and a height of 600mm. This can be accomplished by wrapping a traditional array antenna around a cylindrical surface[5].

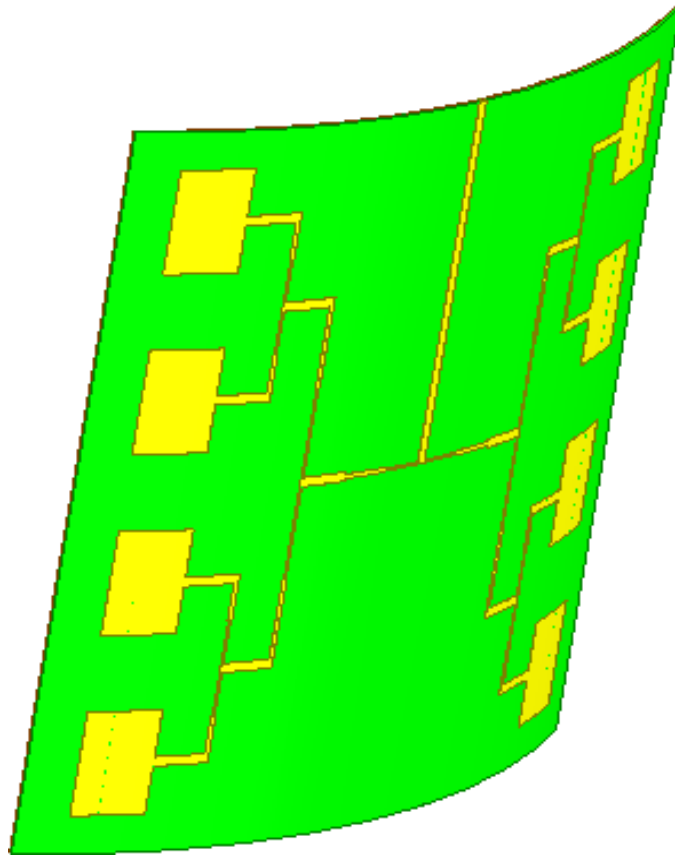


Fig.7.6 Conformal Eight Element array

7.9 DIMENSIONS OF PROPOSED ANTENNA TABLE :

Parameter	Size in mm	Parameter	Size in mm
W_s	180.4	50Ω	90.49
L_s	189.64	70.7Ω	11.38
W_p	29.2	100Ω	11.34
L_p	19.3	$50_1\Omega$	12.6
W_D	19.2	radius	200
W_{D1}	45.2	height	600

CHAPTER – 8

RESULTS AND DISCUSSION

The specifications from the traditional two component design, four-component, and eight-component design, including the conformal Design of eight-element, have been simulated using ANSYS HFSS 19.0 VERSION in this part. Some parameters are recorded in the simulation, including return loss, vswr, gain, and radiation pattern.

8.1 RETURN LOSS [S_{11}]:

8.1.1 FOR SINGLE ELEMENT :

Based on the 5G band specification, simulation outcomes of a Single antenna exhibited effective result. As shown in Fig. 6, the return loss value at 3.5 GHz is -24 dB.

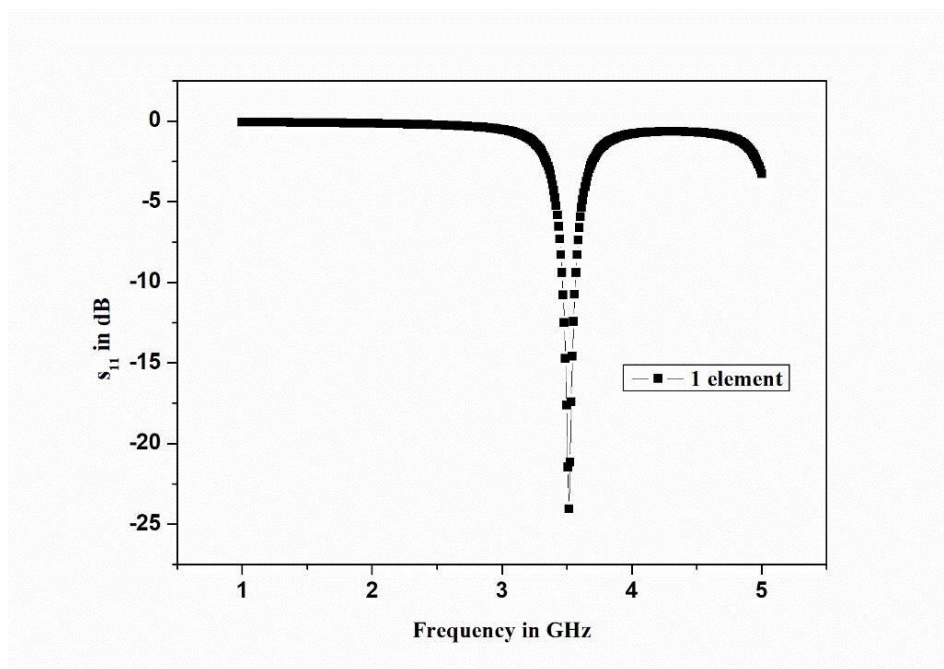


Fig.8.1.1 For Single Element

8.1.2 FOR 2- ELEMENT , 4-ELEMENT , EIGHT – ELEMENT ARRAY ANTENNA :

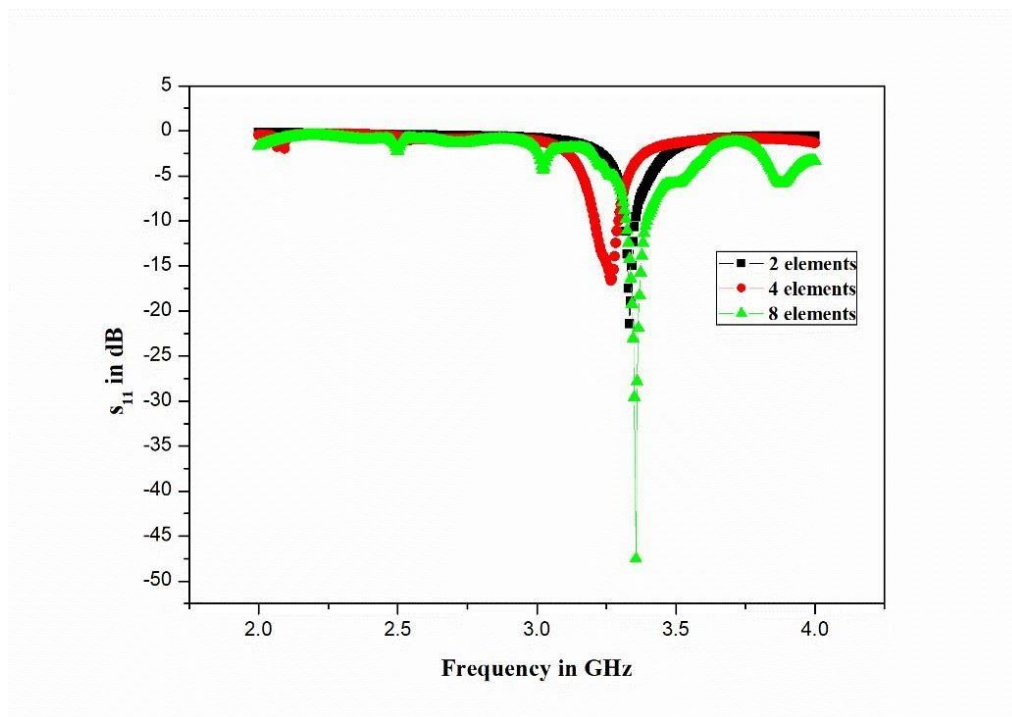


Fig.8.1.2 For 2 Element , 4 Element , 8 Element Array Antenna

8.1.3 FOR CONFORMAL ARRAY ANTENNA :

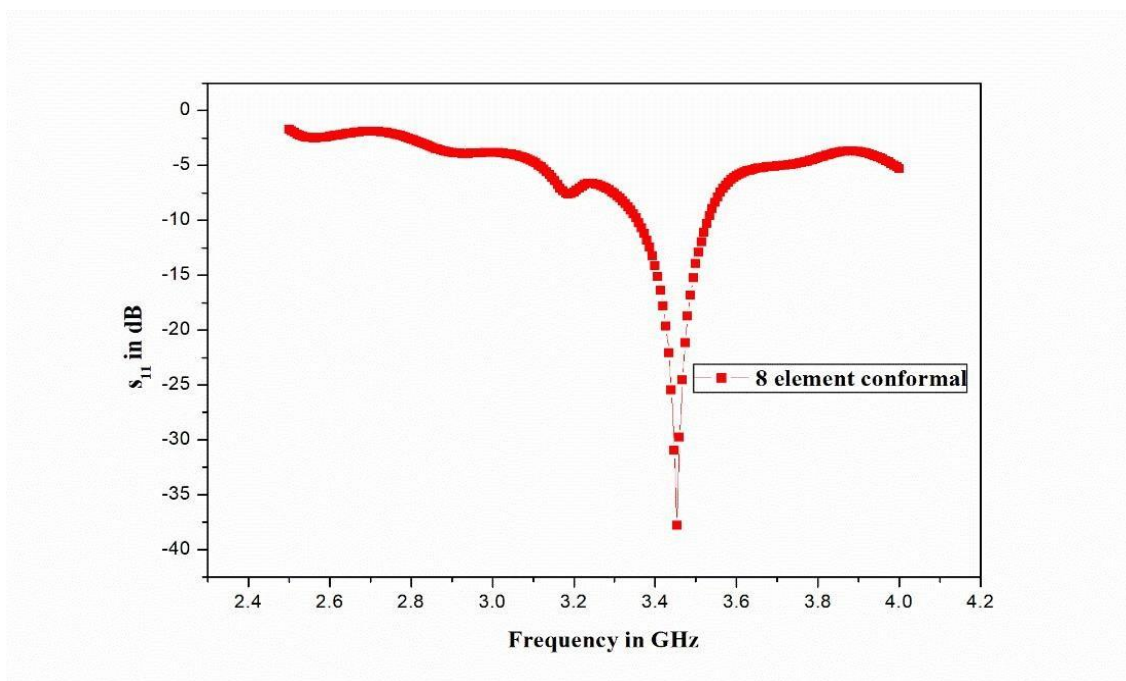


Fig.8.1.3 For Conformal 8 Element Array Antenna

8.2 GAIN :

8.2.1 FOR SINGLE ELEMENT :

The gain for the single antenna design is 4.4dB, as represented in the diagram below.

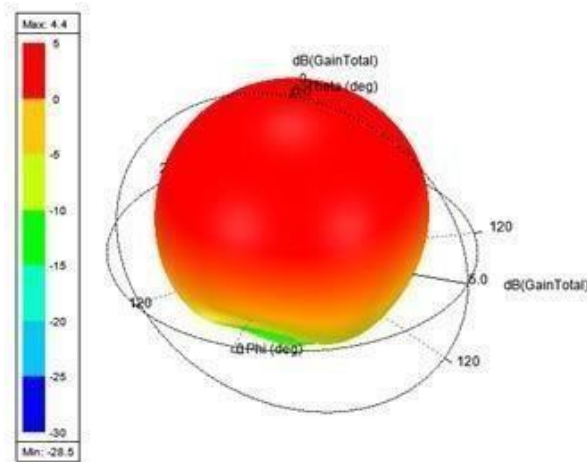


Fig.8.2.1 For Single Element

8.2.2 FOR TWO ELEMENT :

The gain of the Two element array antenna is 7.5 dB shown in figure below .

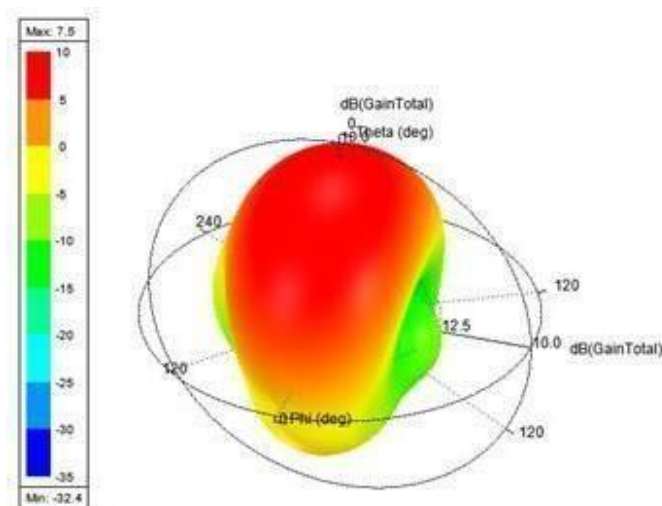


Fig.8.2.2 For 2 Element Array Antenna

8.2.3 FOR FOUR ELEMENT :

The gain of Four element array antenna is 8.7 dB show in figure below .

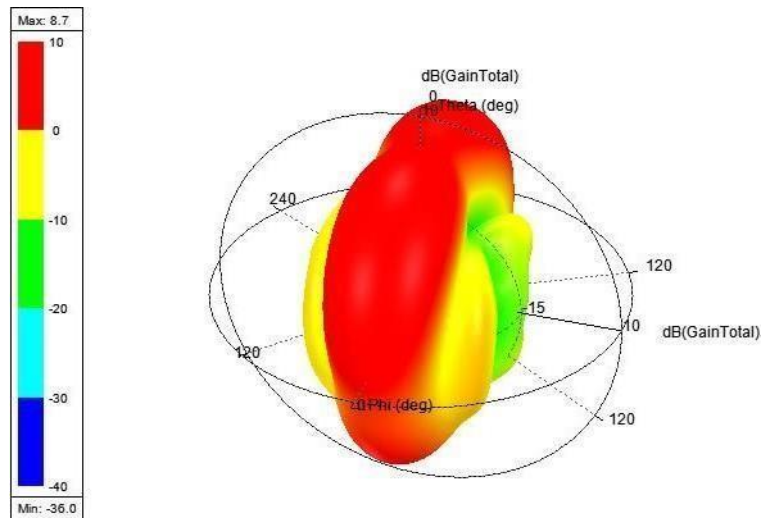


Fig.8.2.3 For 4 Element Array Antenna

8.2.4 FOR EIGHT ELEMENT :

The gain of Eight element array antenna is 10.8 dB is shown below .

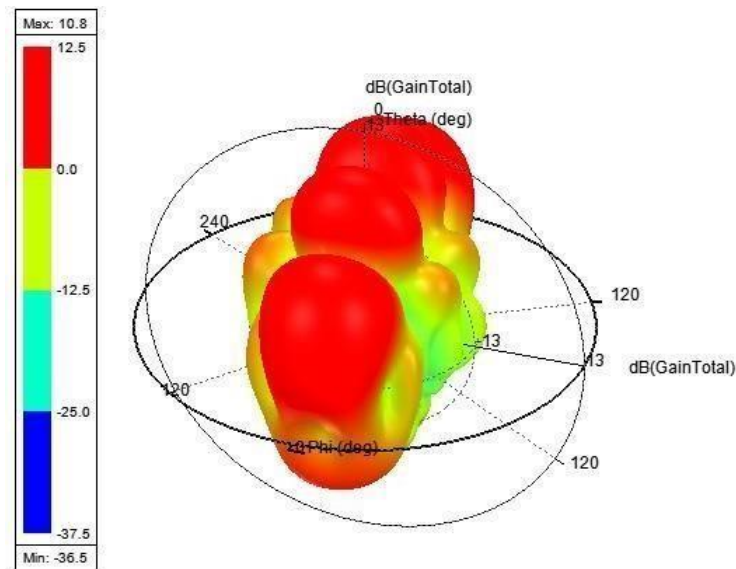


Fig.8.2.4 For 8 Element Array Antenna

8.2.5 FOR CONFORMAL ANTENNA :

The gain of Conformal array antenna gain is 12 dB shown in below diagram.

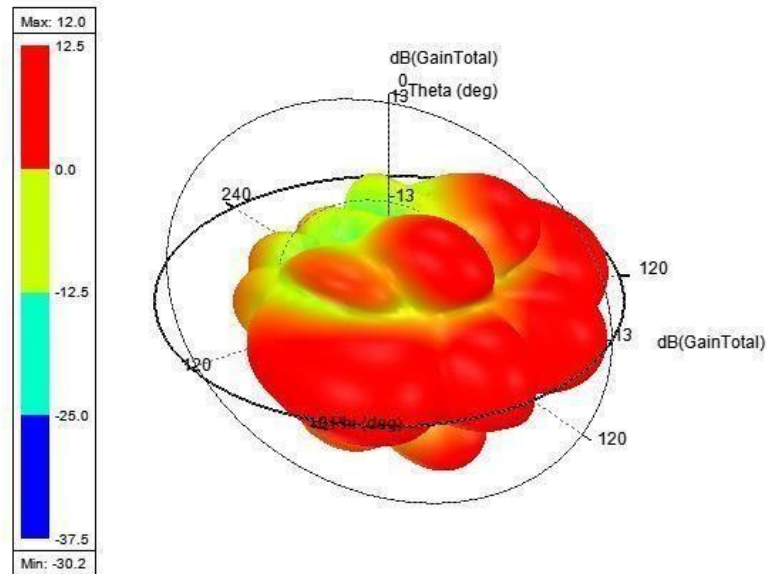


Fig.8.2.5 For Conformal 8 Element Array Antenna

8.3 RADIATION PATTERN :

8.3.1 FOR SINGLE ELEMENT :

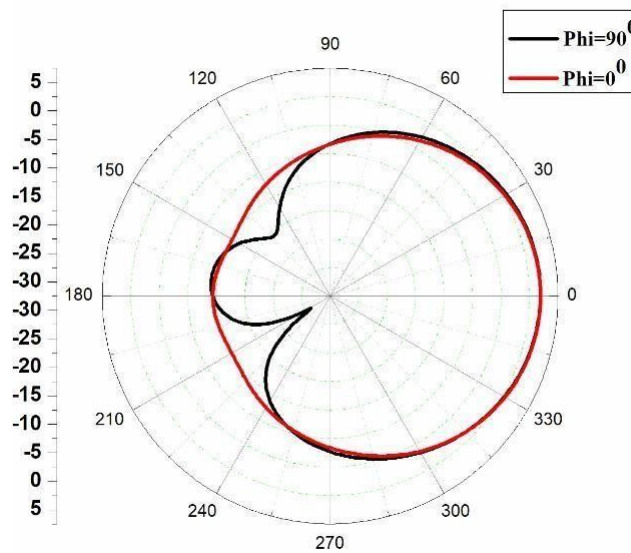


Fig.8.3.1 For Single Element

8.3.2 FOR 2- ELEMNET :

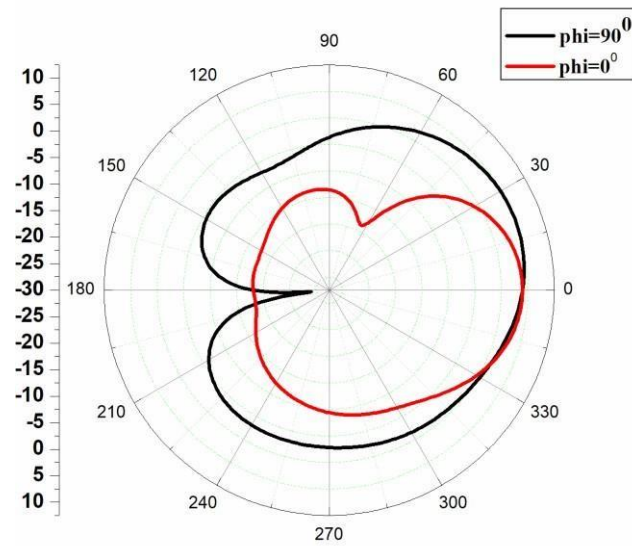


Fig.8.3.2 For 2 Element Array Antenna

8.3.3 FOR 4- ELEMENT :

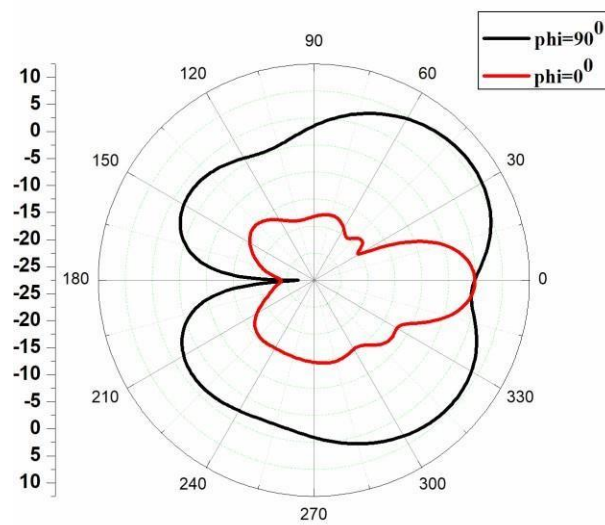


Fig.8.3.3 For 4 Element Array Antenna

8.3.4 FOR EIGHT ELEMENT :

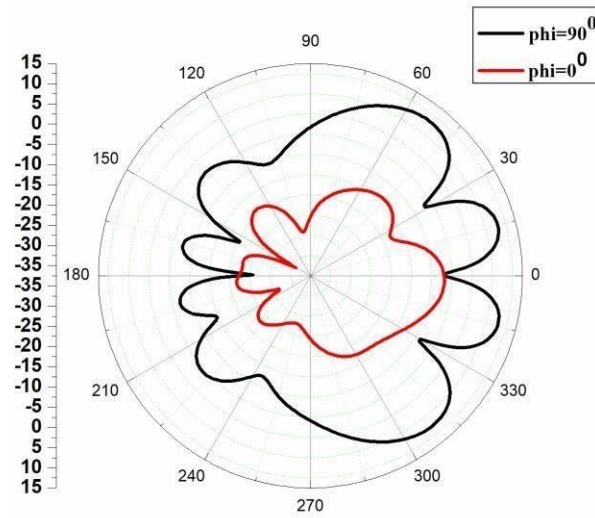


Fig.8.3.4 For 8 Element Array Antenna

8.3.5 FOR CONFORMAL ARRAY ANTENNA :

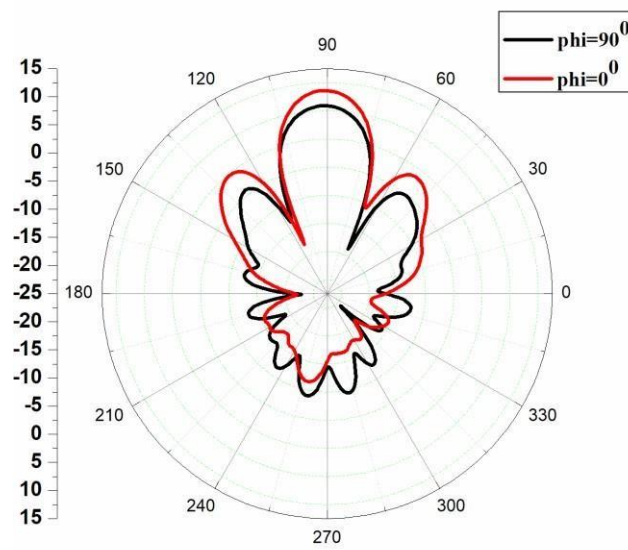


Fig.8.3.5 For Conformal 8 Element Array Antenna

8.4 VSWR PLOT :

8.4.1 FOR SINGLE ELEMENT :

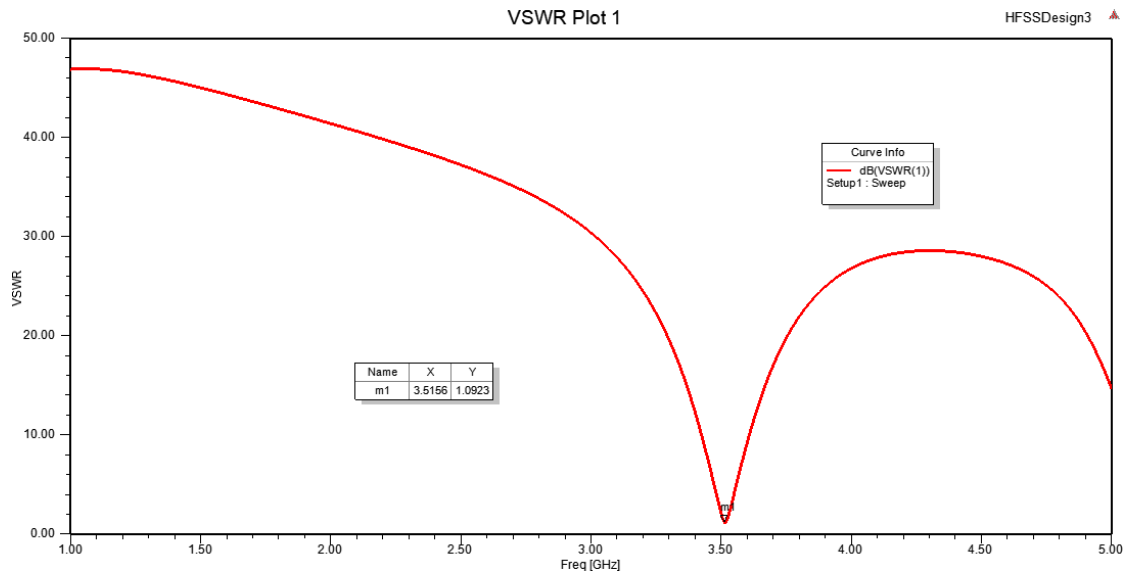


Fig.8.4.1 For Single Element

8.4.2 FOR 2,4,8 AND CONFORMAL ARRAY ELEMENTS :

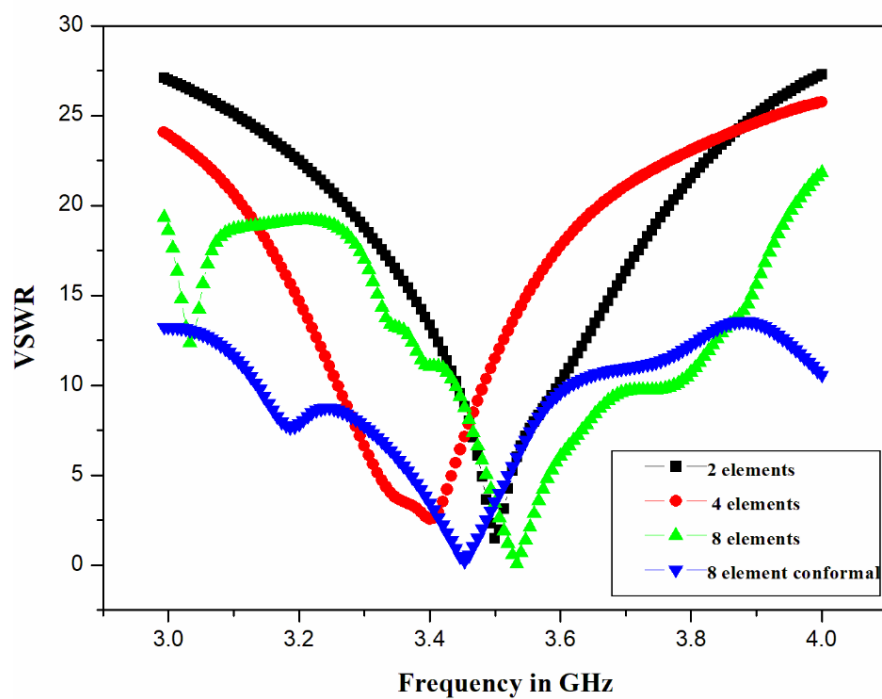


Fig.8.4.2 For 2 Element , 4 Element , 8 Element And Conformal Array Antenna

CHAPTER – 9

FABRICATION

9.1 SINGLE ELEMENT :

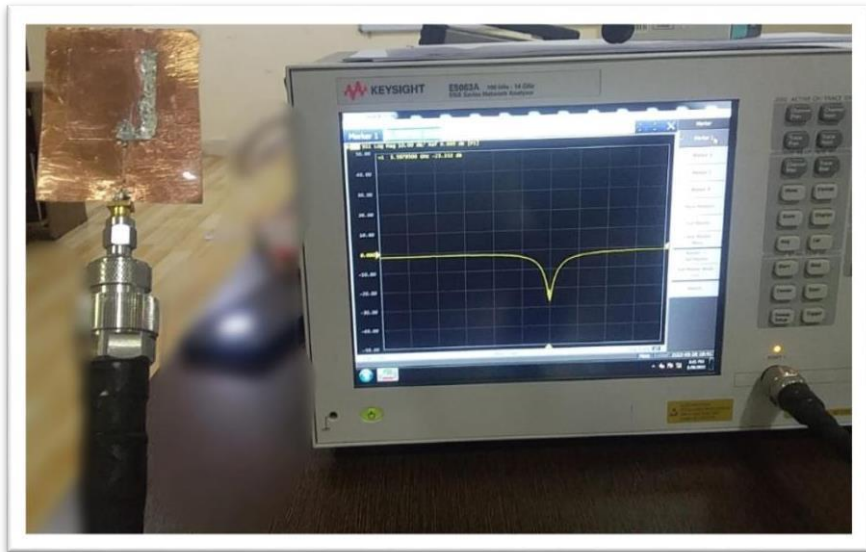


Fig. 9.1 Single Element

9.2 CONFORMAL ARRAY ANTENNA :

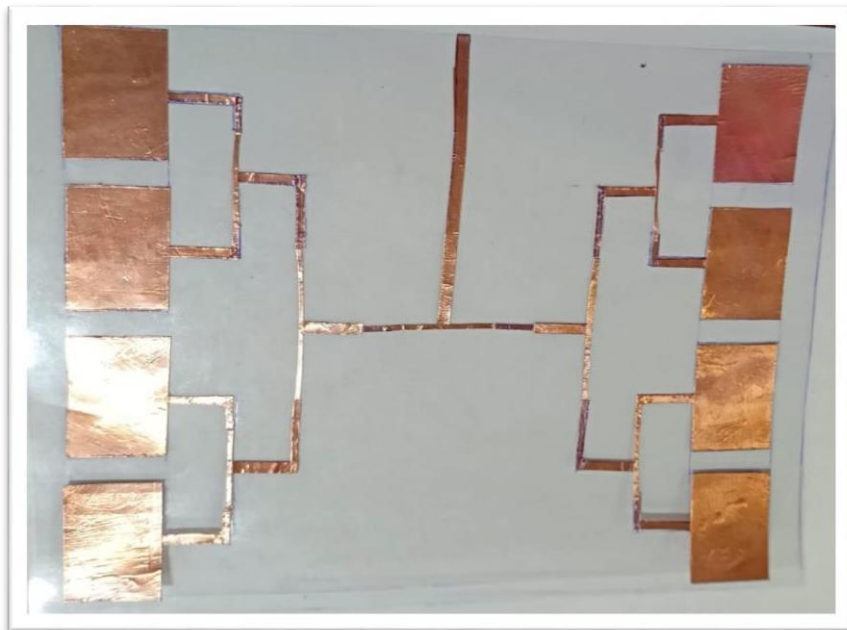


Fig .9.2.1 Conformal Array Antenna -Step 1

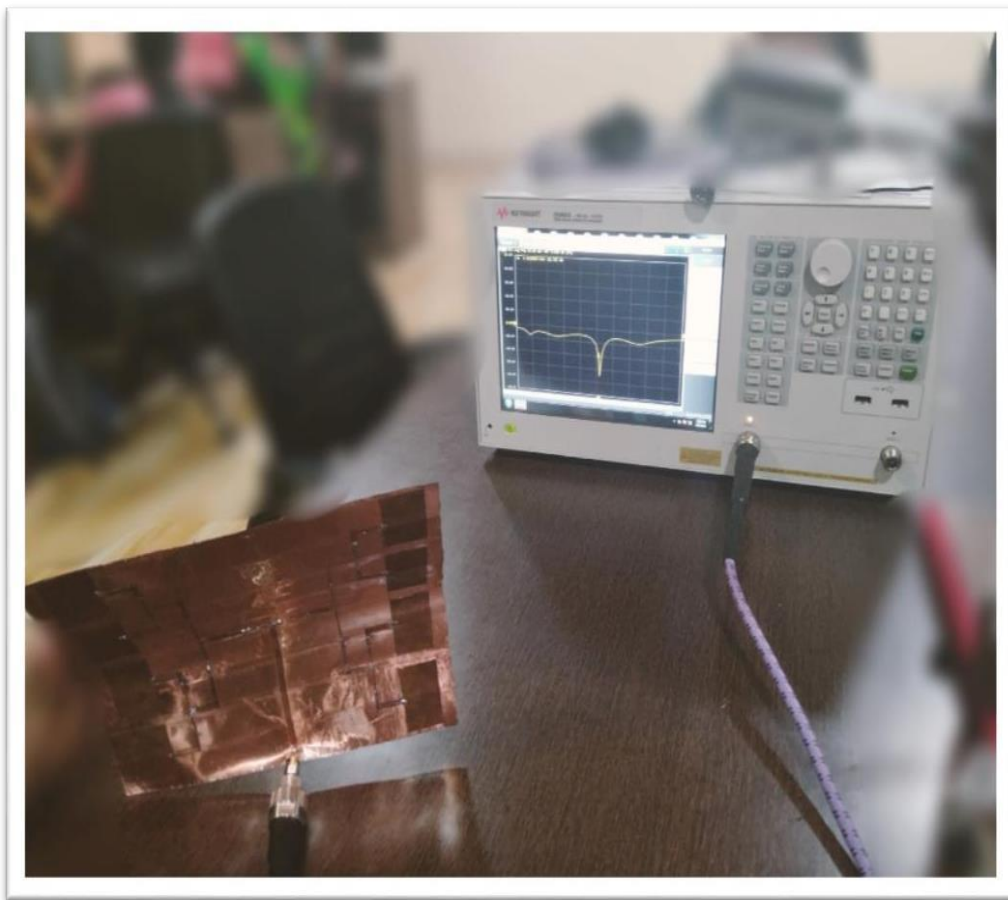


Fig.9.2.2 Conformal Array Antenna- Final

9.3 ANALYSIS OF SIMULATION AND FABRICATION RESULTS :

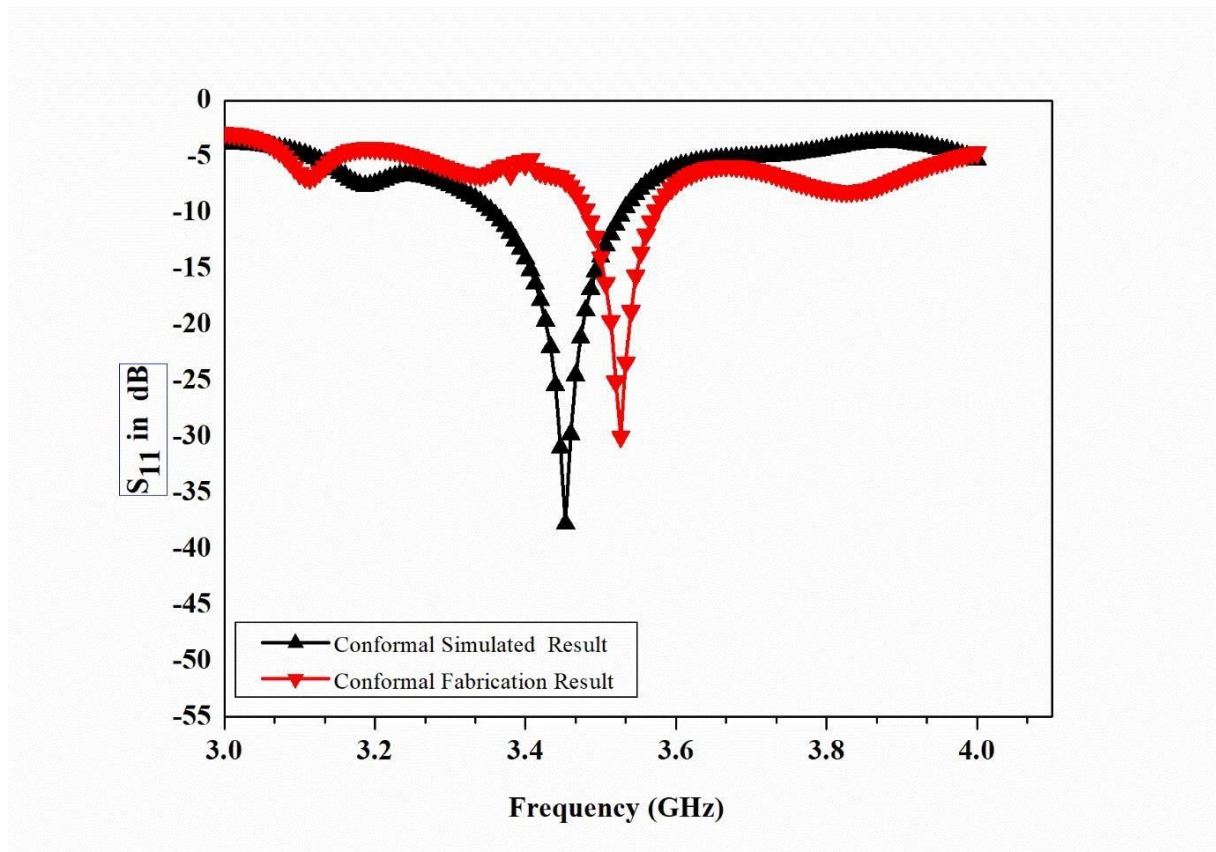


Fig.9.3 Return Loss Comparison for Simulated and Fabricated Result

9.4 PARAMETRIC ANALYSIS OF CONFORMAL ARRAY ANTENNA :

S.n o	Radius	Return loss	Gain
1	200 mm	-37.7 dB	12 dB
2	195 mm	-36.8 dB	11.7 dB
3	190 mm	-34	10.6 dB

CHAPTER-10

CONCLUSION

Designing of the Eight element conformal array antenna is completed and from the simulation results it is observed that the return loss in linear array antenna is -47.5 dB whereas the return loss in conformal array antenna is -37.7 dB. The VSWR of the ensuing conformal array antenna is desirable, and the radiation pattern is End-fire, with the gain of the antenna increasing as the number of array components grows. The conformal array antenna that was devised has a high gain and is acceptable for 5G applications. The Fabricated design shown a better results in terms of return loss and gain and can be used for the 5G applications as a flexible wearable anten

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