ELECTRONICALLY SCANNED SHORT-RANGE RADAR FRONT END FOR S-BAND APPLICATIONS

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in partial fulfillment for the requirements of B.E Degree in Electrical (Telecom) Engineering.

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In the name of ALLAH, the Compassionate, the Glorious

CERTIFICATE OF CORRECTNESS AND APPROVAL

This is to officially state that the thesis work contained in this report

"Electronically scanned short-range radar front end for s-band applications"

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under my supervision and that in my judgement, it is fully ample, in scope and excellence, for the degree of Bachelor of Electrical (Telecom.) Engineering in Military College of Signals, National University of Sciences and Technology (NUST), Islamabad.

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Date:22nd May,2022

DECLARATION OF ORIGINALITY

We therefore declare that no part of the work presented in this thesis is submitted in support of any other award or degree in this institution or elsewhere.

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ABSTRACT

The final year project is a research-oriented work. The principal objective is to design electrically scanned short range front-end for S-band applications. The front end consists of two modules; antenna and novel phase-shifting network. These modules are designed at 3.5 GHZ. The antenna structure consists of a 4x4 planar array. HFSS and CST is used for the design of an antenna.FR4 material is used for fabrication. The measured gain of antenna 10dB at design frequency. The results are measured in a chamber. The S11 of each patch is below 10 and this phase shifter gives a range of phases from 0 to 320 degrees. Silicon hyper-abrupt varactor diodes are used. Beam steering using Phase Shifter is done using a phase matrix which is comprised of progressive phases given 16 elements in an array antenna. These phase shift are fed by a Wilkinson power divider having one input port and sixteen output ports. The S11 for this power divider is below 10dB and insertion loss is below 16dB.The beam of the antenna is steering up to 28 degrees from its central axis. Hence, this research accomplished the task of steering the main beam of the antenna with the help of software codes, phase shifters network, and microstrip antennas for conical beam radars.

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Chapter 1: Introduction

1.1 Radar:

A device that is used for the determination of the presence and/or the location of the object by the measurement of the time for the of radio waves to return from it and the direction from which it returns.

There are many different types of radar. The radar equation is the basic work of the principle of all the radars;

$$P_r = \frac{P_t G_t A_r \sigma F^4}{(4\pi)^2 R_t^2 R_r^2}$$

Where;

Pr= power returned from the receiving antenna from a target

Pt= power transmitted by the transmitting antenna

G=Antenna gain of the radar

A_r= effective aperture area of the receiving antenna σ= radar

cross-section or scattering co-efficient of the target

F= pattern propagation factor

R_t=distance from the transmitter to the target

R_r=distance from target to the receiver

1.2 Beam Radars:

Conical beam radars are exceptionally directive with a conical beam-shaped sample of the important lobe. The radar rotates electronically or mechanically its main lobe of the beam in a circle alongside the boresight line. When the target is on the boresight line, maximum strength is back and amplitude variant is zero. When the target is shifting away from the boresight line, returning signal will be of a sinusoidal shape whose amplitude is proportional to the distance of the target away from the boresight. Using the region of the-maximum strength acquired (and monitoring the place of-scanning beam), the goal area can be determined. More accurate is target tracking, the smaller the amplitude of –sine-wave; zero-ample implies radar is boresighted ate target.

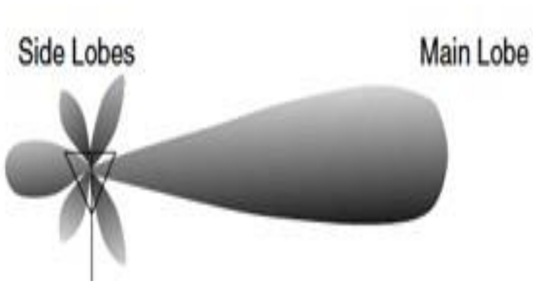


Figure 1.1: Beam pattern of conical beam radars

1.3 Why S Band?

The radar will be operating in **S-band (2-4 GHz)** with central frequency of **3.5 GHz.** This band is used for long-distance radio telecommunications such as satellite communications transmission and terrestrial radio etc. In S band the communication equipment is relatively in-expensive; frequencies in this band are also low enough that they are not appreciably attenuated by rainfall, which is the the principal cause of signal degradation in the atmosphere.

1.4 Problem statement:

- Designing of prototype RF front end module for S-band Radars which can be used as a transmitter as well as the receiver.
- The basic problem is to design an antenna system that will give us beam with appropriate gain of up to 10 to 16 dB and side lobe level less than -15dB. While designing such an antenna, another problem which arises is the use of appropriate feeding method for our antenna. This will be solved by using coaxial feed for 4×4 micro-strip patch antenna whose details and reasons for designing and using such feed will be given later on in our work. Firstly,

- we will start by designing single patch antenna as a sample whose details are covered in this report and then we will move onto 4×4 array antenna.
- Another problem is to design a power divider which is lossless, isolated at the output ports, reciprocal and also matched at all ports. We will solve this problem by designing a sophisticated and very much efficient Wilkinson power divider which will fulfill basic requirements and which will result in power division with very less or theoretically no losses.

1.5 Academic objectives:

- Comprehensive study of RF front end and particularly array antennas (Here the work of previous syndicates will be used as foundation)
- Learn how power dividers and phase shifters operate, deployment of different algorithms with the application
- Learn to develop array antenna
- Development and implementation of a RF front end Learn to use software tools like HFSS, ADS 2009 etc.

1.6 Application objectives:

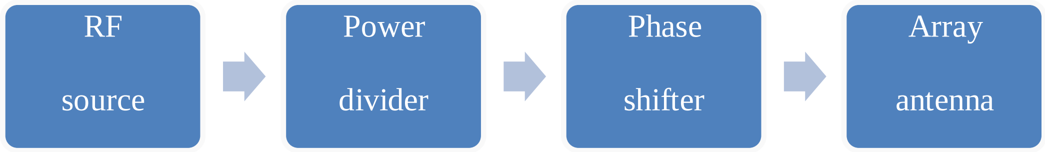
- Beam steering mechanism in radars is very significant for fighter aircraft like F-16. There is no need to rotate the entire antenna, rather only the phases associated with antenna array are changed.
- Fire control radars use conical scanning to a fire-control system in order to calculate a firing solution.
- Conical scanning radars are also used for tracking and detection of air-borne targets.

1.7 Approach:

Our project RF front end consists of three modules:

- Antenna

- Phase shifter
- Power divider



After the initial deployment, the power divider will equally distribute the RF source power to all its channels, phase shifter providing the electrical steering allows forming a conical beam from the array antenna.

CHAPTER 2: Literature Review

2.1 Antenna:

An antenna (or aerial) is a steel electrical device-which converts-electric power-into radio waves, and vice-versa. In transmission, a transmitter resources an oscillating-radio frequency-electric current-to the-antenna's terminals and-the antenna-radiates the power from-the modern as-electromagneticwaves. In reception, an antenna intercepts some of the electricity of an electromagnetic wave-in order to-produce a tiny voltage-at its-terminals that is applied-to a-receiver to-be amplified.

2.1.1 Types of antenna:

Commonly, there are two antenna types;

- Theoretical antennas
- Practical antennas

Theoretical antennas include isotropic antennas which radiates the same depth of radiation in all directions.

It has no-preferred direction-of radiation. It radiates uniformly in all directions over a-sphere headquartered on-the source. Isotropic radiators are used as reference radiators with which other sources are-compared. Practical antennas consist of omnidirectional antennas and directional antennas. Omnidirectional antennas are those radiates radio wave-power uniformly in all instructions in one plane, with the radiated power lowering with elevation perspective above or beneath the plane, dropping to zero on the antenna's axis. This radiation sample is often described as "doughnut shaped". e.g.; coaxial antenna, cage- ariel, ground-plane antenna, helical antenna, monopole -antenna, random wire, rubber ducky antenna. A directional antenna or beam antenna is an antenna which radiates larger energy in one or extra instructions permitting for accelerated performance on transmit and receive and decreased interference from unwanted sources. E.g.; dipole antenna, horn antenna, inverted vee antenna, loop antenna, microstrip antenna, yagi-uda.

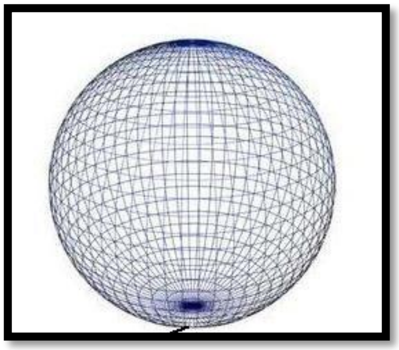


Figure 2.1: Isotropic antenna

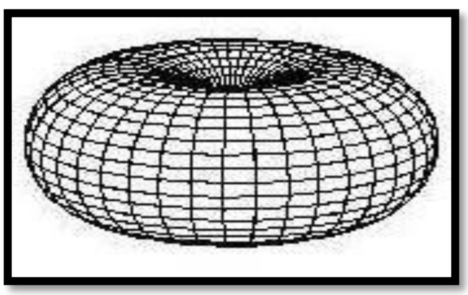


Figure 2.2: Omnidirectional antenna

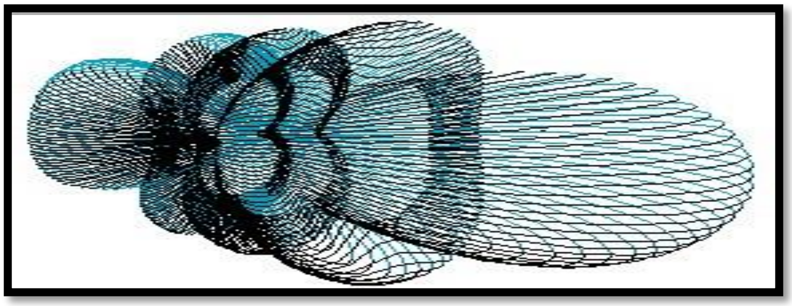


Figure 2.3: Directional antenna

2.1.2 Microstrip antenna:

A microstrip or patch-antenna is a-low profile antenna-that has a wide variety -of blessings overother antennas; it is

- Light weight
- Inexpensive
- And handy to integrate-with accompanying electronics
- While the antenna can be 3¬D, (wrapped around an object, for example) the elements are usually flat; hence the name, planar antennas.

The following-drawing indicates a patch antenna in its fundamental form:

A flat plate over a floor aircraft (usually a PC board). The core conductor of a coax serves as the feed probe-to couple EM electricity in and/or out of-the patch. The electric powered subject distribution-of a rectangular-patch excited in its-fundamental mode is additionally indicated.

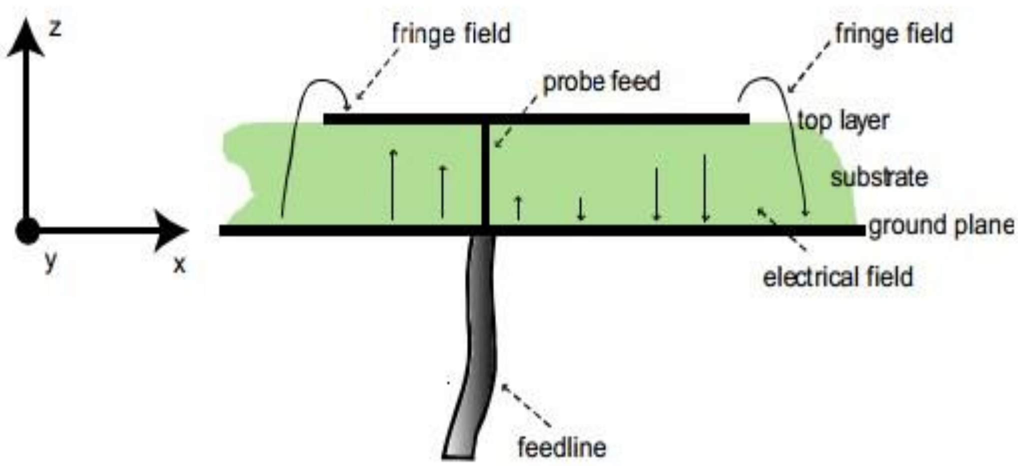


Figure 2.4: Microstrip Patch Antenna

The formulae commonly used for microstrip antennas in transmission line model are as follows;

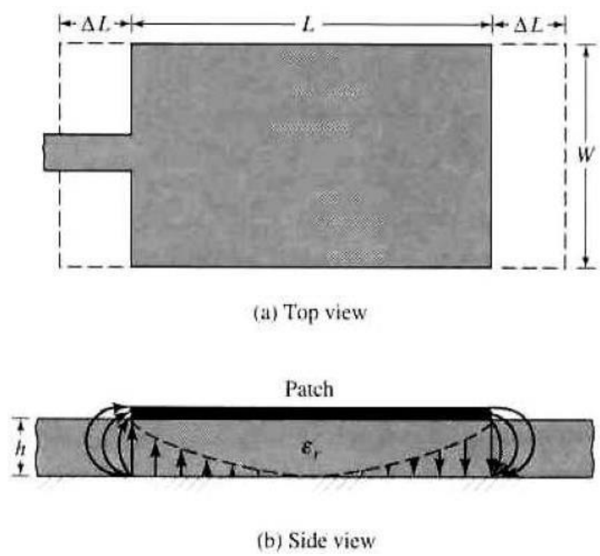


Figure 2.5: top view and side view of patch antenna

W/h>=1

$$\text{Ereff} = \frac{er+1}{2} + \frac{er-1}{2}\left[1 + 12\,\frac{h}{W}\right]^{\wedge\ -1/2}$$

Here;

e_{reff} = effective dielectric constant e_r = Dielectric constant of the substrate used h= height of the substrate used

W= Width of the patch

The length of patch is-extended due to fringing effect and its formula is given as;

$$\frac{\Delta L}{h} = 0.412 \frac{(ereff+0.3)(\frac{W}{h}+0.264)}{(ereff-0.258)(\frac{W}{h}+0.8)}$$

Where;

ΔL= extension in the length of the patch due to fringing effect.

Since length of patch has extended on each sides, the effective length of patch is given as;

L_{EFF} =L + 2ΔL

The formula for calculation of width of the patch is as follows;

$$W = \frac{1}{2fr\sqrt{\mu o \epsilon o}}\sqrt{\frac{2}{\epsilon r+1}} = \frac{vo}{2fr}\sqrt{\frac{2}{\epsilon r+1}}$$

Where;

W= width of the patch

f_r = resonant frequency for design

μ_o= free space permeability

ε_o = free space permittivity

v_o= free space velocity

The actual length of the patch is calculated as;

$$L=\frac{1}{2fr\sqrt{\epsilon reff}\sqrt{\mu o\epsilon o}}-2\Delta L$$

2.1.3 Array Antennas:

Increasing the scale of single things generally ends up in additional directive properties. Another way to extend the scale of the associate degree assembly of diverging components in an electrical and geometrical arrangement, additionally to essentially increasing the scale of the individual components. This new antenna, created with the assistance of multiple components, is named associate degree array. In most cases, the weather of associate degree array square measure identical. this is not necessary, however it has always easier, simpler, and a lot of sensible. The individual components of a sequence will be of any form (wires, openings, etc.). The total state of the array is decided by vector-addition of the fields emitted by the person components. This assumes that fashionable time is in each method identical because the so much factor (neglecting the link). This can be not typically the case and it depends on the separation between the weather. To form multi-directive patterns, fields from the weather of the array got to be constructively mixed (added) within the desired directions and constructively mixed (cancelled) within the remaining house. Ideally - this can be doable, however just about utterly approached.

In a set of equal components, there square measure a minimum of 5 controls that may be accustomed from the sample of the antenna.

- Geometric configuration of the fundamental array (linear, circular, rectangular, spherical, etc.)
- Relative displacement between components (distance \ time)
- Excitation-amplitude of individual components
- Stimulation section of individual things
- Relative model of individual things.

The array component is defined-as the-function of pure mathematics of array and excited section. Generally, we have a tendency to square measure handling the linear and two-dimensional array. The 2 factors of linear array is ;

$$AF = \sum_{n=1}^{N} e^{j(n-1)\psi}$$

where $\psi = kd\cos\theta + \beta$

Similarly for planar arrays, the formula is;

$$AF_n(\theta, \phi) = \left\{ \frac{1}{M} \frac{\sin\left(\frac{M}{2}\psi_x\right)}{\sin\left(\frac{\psi_x}{2}\right)} \right\} \left\{ \frac{1}{N} \frac{\sin\left(\frac{N}{2}\psi_y\right)}{\sin\left(\frac{\psi_y}{2}\right)} \right\}$$

where

$\psi_x =$

$\psi_y =$

$$AF = \sum_{n=1}^{N} e^{j(n-1)\psi}$$

where $\psi = kd\cos\theta + \beta$

Similarly for-planar arrays, the formula is;

$$AF_n(\theta, \phi) = \left\{ \frac{1}{M} \frac{\sin\left(\frac{M}{2}\psi_x\right)}{\sin\left(\frac{\psi_x}{2}\right)} \right\} \left\{ \frac{1}{N} \frac{\sin\left(\frac{N}{2}\psi_y\right)}{\sin\left(\frac{\psi_y}{2}\right)} \right\}$$

where

$$\psi_x = kd_x \sin\theta\cos\phi + \beta_x$$
$$\psi_y = kd_y \sin\theta\sin\phi + \beta_y$$

2.2 Phase shifter:

The last subject of the project is to design phase shifter which will shift the antenna beam practically as shown theoretically above. The core reason of the phase shifter is to provide each array individual element with a phase shifted RF signal. To make such type of phase shifter we are using hybrid quadrature coupler in combination with the varactor diodes.

2.2.1 Hybrid quadrature coupler:

Quadrature-hybrid three dB directional-couplers with a 90◦ phase difference in-the outputs of the through- and coupled-arms. This kind of hybrid-is frequently made in-microstrip linear strip line and is also-knownas a branch-line hybrid

The scattering matrix has the following form:

$$[S] = \frac{-1}{\sqrt{2}} \begin{bmatrix} 0 & j & 1 & 0 \\ j & 0 & 0 & 1 \\ 1 & 0 & 0 & j \\ 0 & 1 & j & 0 \end{bmatrix}$$

This symmetry is reflected in the scattering matrix, as each row can be obtained as a transposition of the first row.

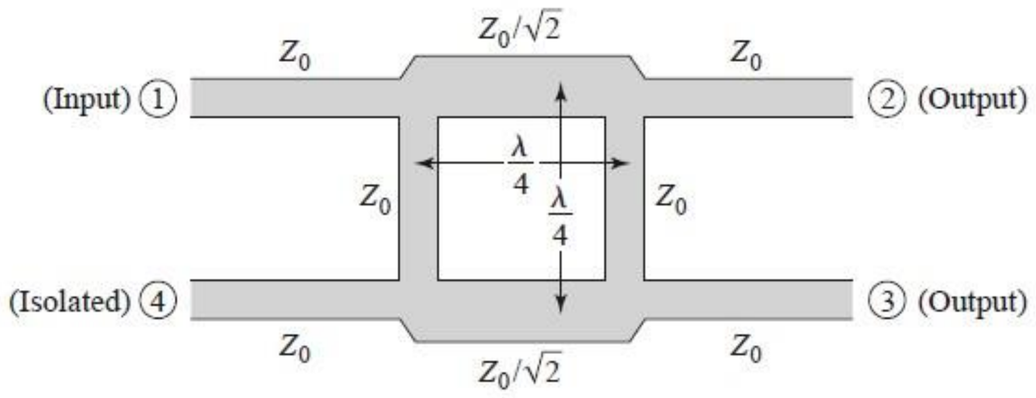


Figure 2.6: Geometry of the hybrid quadrature coupler

2.2.2 Varactor diodes:

A varactor diode uses a p-n junction in reverse--bias and has--a structure such that the capacitance of the diode varies with the--reverse voltage. A voltage-controlled capacitance-is useful-for tuning applications. The capacitance is controlled by the method of doping in the depletion layer. Typical values are fromtens to hundreds of picofarads.

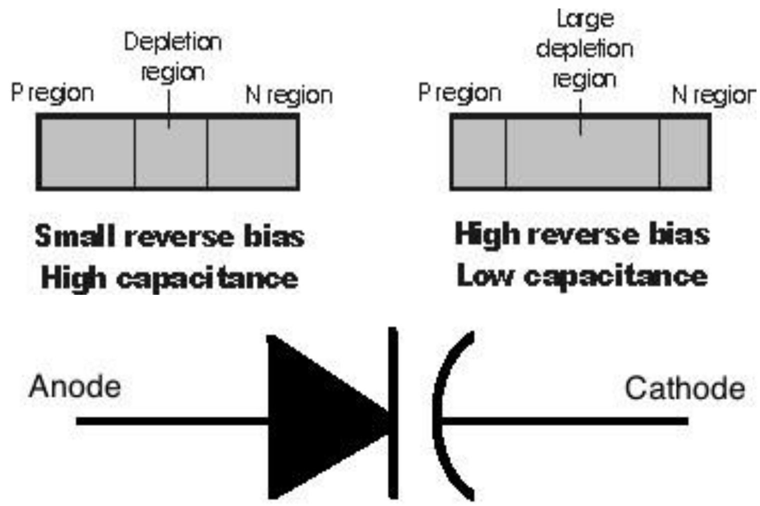


Figure 2.7: Varactor diodes

2.3 Wilkinson Power divider:

Power dividers and directional couplers are passive microwave components used for power division or power combining, as illustrated in Figure here;

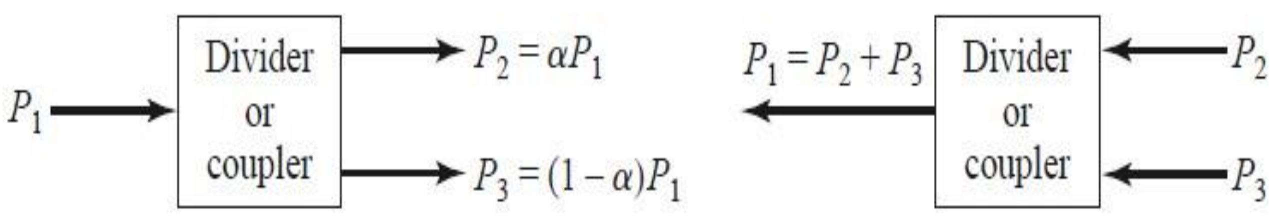


Figure 2.8: Wilkinson Power divider (a) Power division (b) Power combining

In power-division, an-input signal is-divided-into 2 (or more) output alerts of-lesser power, while a power-combiner-accepts-two or more-input signals and combines-them at an-output port. The-coupler or-divider may-have-three ports, four-ports, or more, and-may is (ideally) lossless. Three-port-networks take-the form of T-junctions and-other power dividers, while four-port-networks take-the form-of-directional-couplers and-hybrids. Power dividers normally offer in-phase output indicators with associate equal energy division quantitative relation (3 dB), however unequal-power division-ratios square measure also-possible. Directional-couplers-can be designed for-arbitrary power-division, whereas hybrid junction usually-have equal-power division. Hybridjunctions have-either a-90 degrees-or a one hundred eighty degrees-phase shift-between the output ports. The simplest-of the-power dividers is T-junction electricity divider. It are often used-for energy division--or power-combining, and it will be-implemented in--virtually any-type of transmission-line-medium. Here square measure some samples of T-junction.

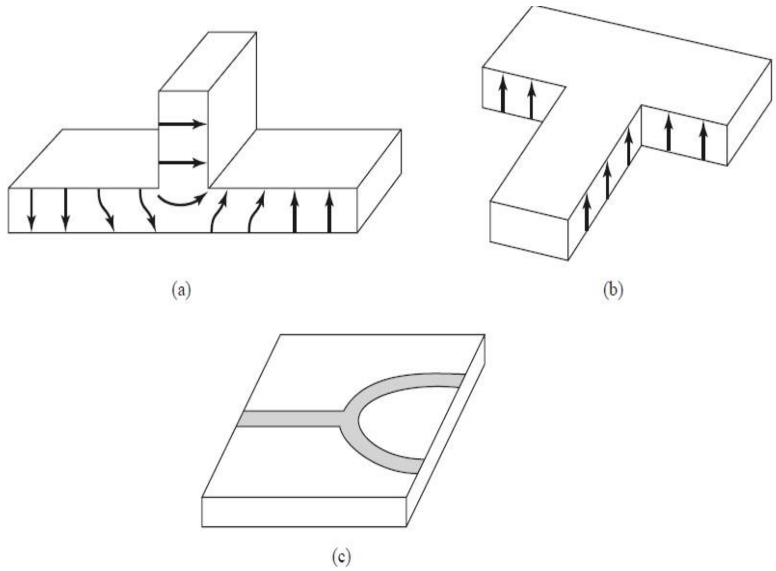


Figure 2.9: T junction realizations

T-junction power-divider can be lossless or it can be lossy (resistive). Figure below shows both of them.

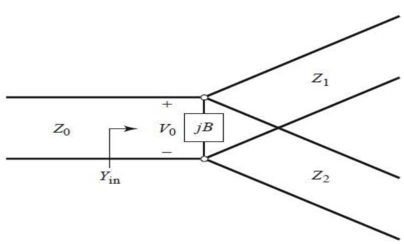


Figure 2.10: Transmission line model of a lossless T-junction divider

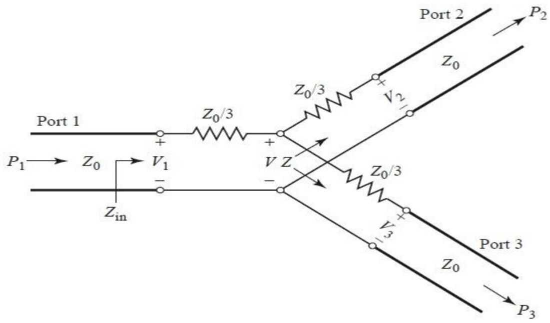


Figure 2.11: An equal-split three-port resistive power divider

The lossless junction divider suffers from the disadvantages of not being matched in any respect ports and it does not have isolated between output ports. The resistive divider may be matched at all ports, however even though it is not lossless, isolation is still not achieved. However, a lossy three port network may be created having all ports matched, with isolation between output ports. The Sir Geoffrey Wilkinson power divider is such a network, with the useful property of appearing lossless when the output ports are matched; that is, solely reflected power from the output ports is dissipated.

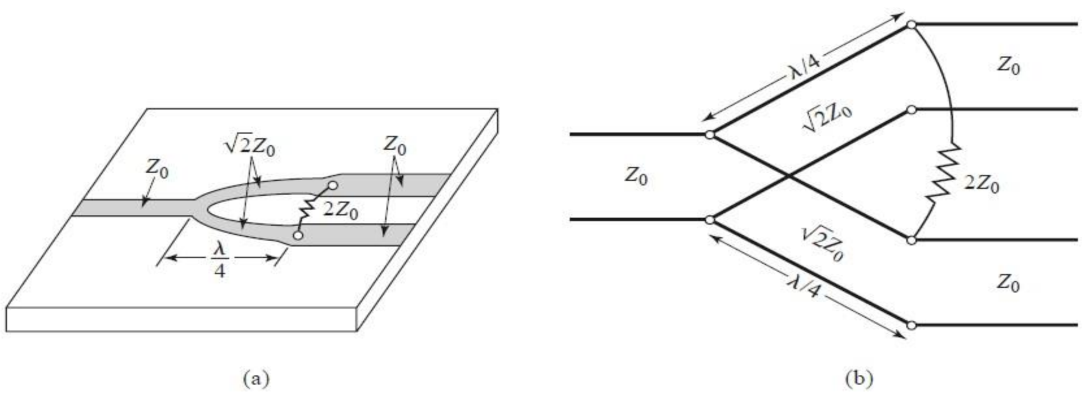


Figure 2.12: The Wilkinson power divider. (a) An equal-split Wilkinson power divider in micro-strip line form. (b) Equivalent transmission line circuit.

The Wilkinson power divider is a three port device with a scattering matrix of:

$$S = \begin{bmatrix} 0 & -j/\sqrt{2} & -j/\sqrt{2} \\ -j/\sqrt{2} & 0 & 0 \\ -j/\sqrt{2} & 0 & 0 \end{bmatrix}$$

Note the device is matched at port 1 (S_{11} =0), and we find that magnitude of column 1 is:

$|S_{11}|^2 + |S_{21}|^2 + |S_{31}|^2 = 1$

Thus, just look like the lossless divider, the incident power on port 1 is evenly and efficiently divided between the outputs of port 2 and 3:

$P_2^- = |S_{21}|^2 P_1^+ = P_1^+/2$ $P_3^- = |S_{31}|^2 P_1^+ = P_1^+/2$

Looking closer at the scattering matrix. We also note that the ports 2 and 3 of the device are matched.

S22 =S33= 0

Similarly, we note that ports 2 and 3 are isolated:

S23 =S32= 0

It's nearly the ideal 3dB power divider.

CHAPTER 3 DESIGN AND DEVELOPMENT

3.1 Designing Antenna

3.1.1 Theoretical Calculations

First of all, probe feed single patch antenna was designed on HFSS

The calculated dimensions of patch were;

$$W=\frac{vo}{2fr}\sqrt{\frac{2}{er+1}}$$

$$W=\frac{3e10}{2x5.8e9}\sqrt{\frac{2}{4.4+1}}$$

W=1.5739 cm (0.6197 inches)

The effect of dielectric constant of the patch we found using the formula;

$$E_{reff} = \frac{er+1}{2} + \frac{er-1}{2}\left[1 + 12\frac{h}{w}\right]^{-1/2}$$

$$E_{reff} = \frac{4.4+1}{2} + \frac{4.4-1}{2}\left[1+12\frac{0.16}{1.5739}\right]^{-1/2}$$

e_{reff}=6.4738

The extended incremental length of the patch ΔL was;

$$\Delta L = 0.412h\frac{(ereff+0.3)(\frac{W}{h}+0.264)}{(ereff-0.258)(\frac{W}{h}+0.8)}$$

$$\Delta L = 0.412h\frac{(6.4738+0.3)(\frac{1.5739}{0.16}+0.264)}{(6.4738-0.258)(\frac{1.5739}{0.16}+0.8)}$$

ΔL=0.0681cm (0.0268 inches)

The real length of the antenna was calculated and approximated by;

$$L = \frac{\lambda}{2} - 2\Delta L$$

$$L = \frac{3e10}{2x5.8e9\sqrt{6.4738}} - 2x0.0681$$

L_e=1.0164 cm (0.4002 inches)

3.1.2 Simulation Design

3.1.2.1 Design of Single Patch

Using these dimensions, antenna was designed on HFSS. The antenna design contains a ground plane having very small thickness of 0.017um. Above the ground plane, there is substrate FR4 having thickness of 1.6mm. And then radiating patch is designed above the substrate having dimensions calculated above.

The patch edge is at a distance of λ/3 from substrate edge. After this assembly, probe feed was designed.

For this purpose, first of all, a circular cut is drilled in ground and substrate to insert the feed pin and to connect the feed pin with radiating patch. Then for probe feed three cylinders are drawn. One is called feed pin followed by coax pin, and then coax pin (these are conducting) is surrounded by Teflon coax cylinder.

Designing of probe feed is not an easy task. But its fabrication is quite simple as it requires only a PCB mounted SMA connector having a pin in it.

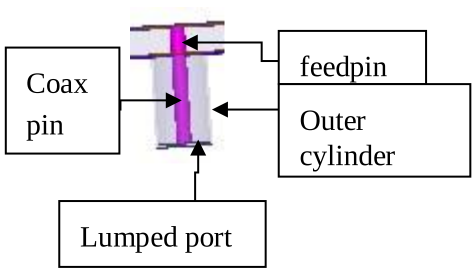


Figure 3.2: probe feed design

In the designing of probe feed, in the end we design lumped port at the end of feed as shown above.

Then Air Box is designed for far field calculations of gain of the antenna and other parameters.

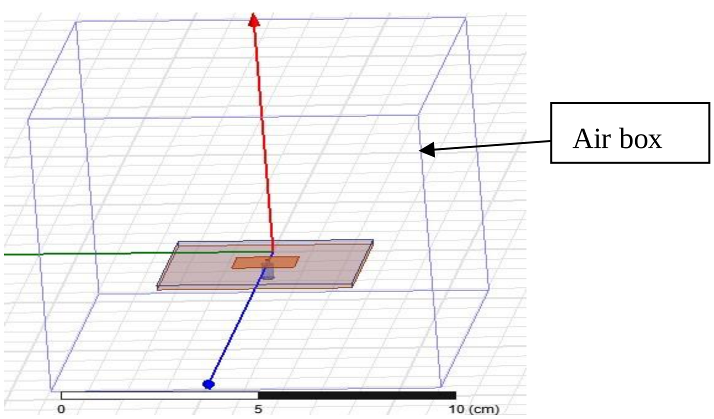


Figure 3.3: patch antenna in air box

After designing, we assign perfect electric field boundaries to conductors and radiation boundary to the Air box. Then we validate the design and simulate it.

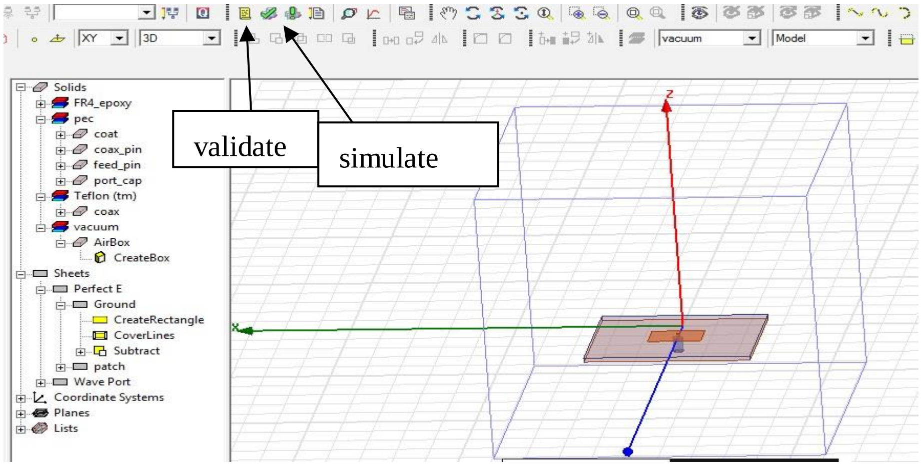


Figure 3.4: validating and simulating patch antenna

After simulation we go for the results of our design.

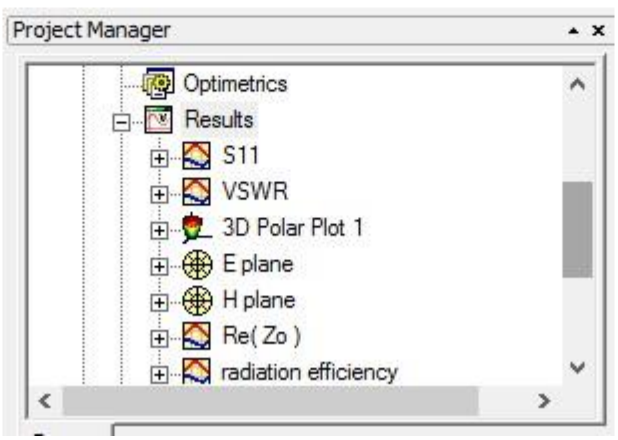


Figure 3.5: getting simulation results

The results which we got are discussed in the next section.

3.1.2.2 Design of Array Antenna

After designing single patch antenna, we moved on to array antenna designing on HFSS as we had learnt how to use this software effectively. The inter-element spacing is kept to be λ/2 ideally. In this case it comes out to be 2.6cm almost center to center of patches. We get gain up to 6 dB in case of single patch antenna. Our main purpose is to get conical beam pattern and gain greater than 15 dB for our project which we achieved by designing 4×4 array antenna. In the similar manner as discussed for single patch, we designed

4×4 array antenna on CST.

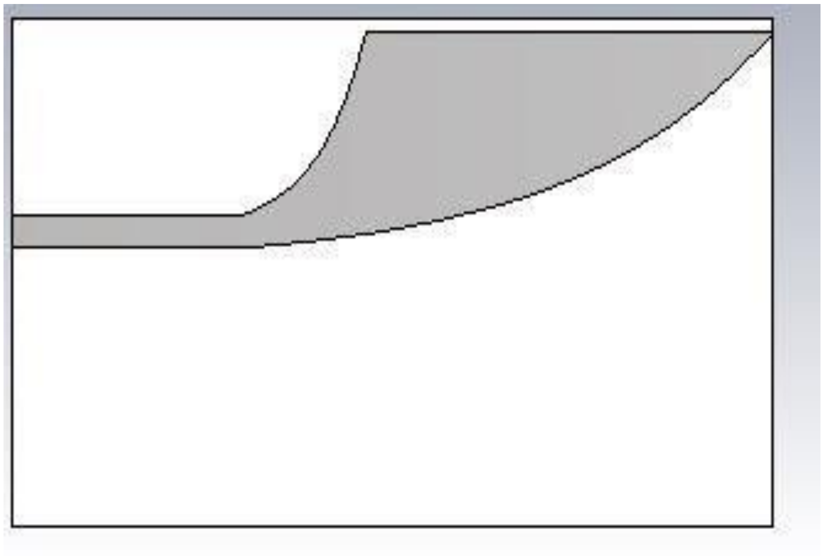


Figure 3.5: Top View

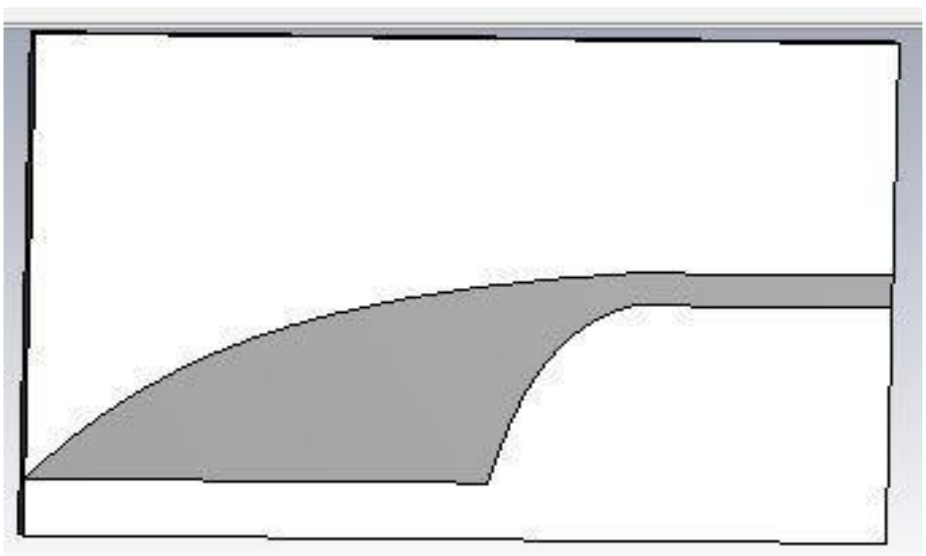


Figure 3.5: Bottom View

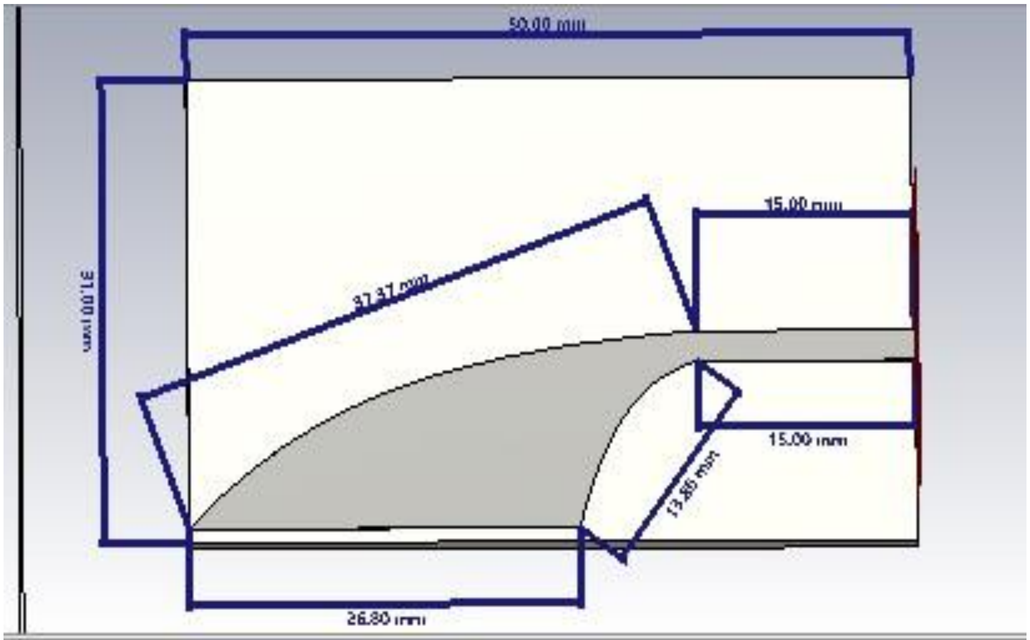


Figure 3.5: Dimensions

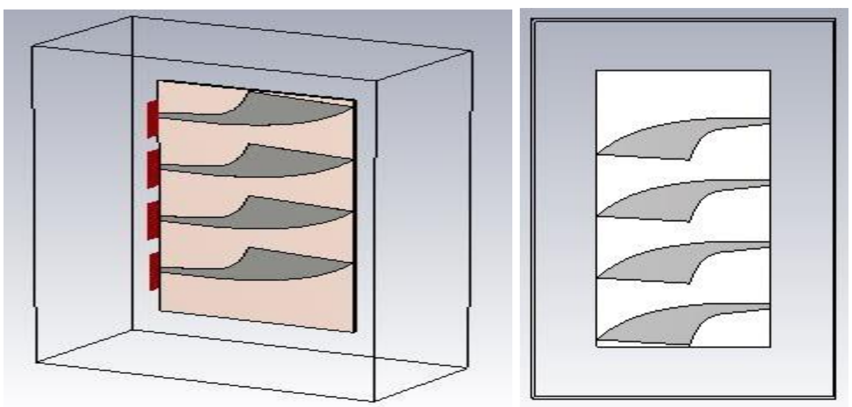


Figure 3.5: 4 Array Elements

The major issue which arises is the inter element spacing between the array patches. Also the S_{11} is changed significantly for all ports by changing the dimensions of the patches and inter-element spacing between them.

It is the extraneous task to do the tuning of the design to get the desired results in acceptable range that is S_{11} should be less than -10 dB, VSWR should be less than 1.5 for port matching and gain should be maximum. Coupling between the elements is the major issue also which actually cause s-parameter to become inappropriate and port matching is disturbed. That’s why it is preferred to keep the patches apart from each other at a suitable specified distance from each other to keep low coupling effect. Also fabrication losses in results alterations from the desired level as there is no perfect fabrication in reality.

3.2 Designing Power Divider

3.2.1 Design of 1×4 Power Divider

We designed 1×4 Wilkinson power divider on ADS2009 whose simulation and results are given hereafter. The simulation design is as follows;

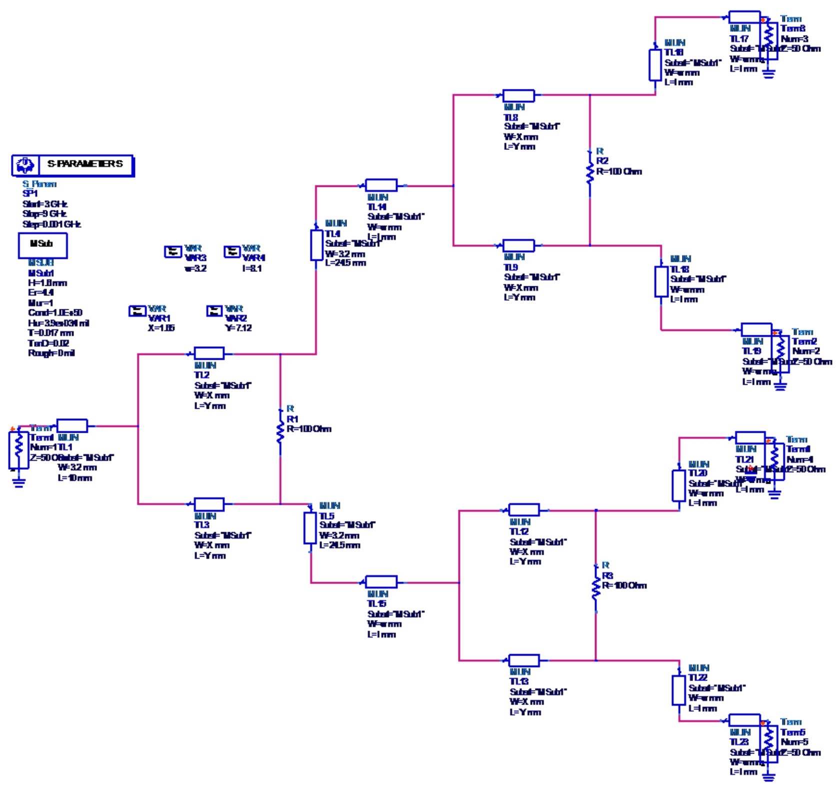


Figure 3.7: 1× 4 Wilkinson power divider

The AutoCAD alignment for this design is as follows;

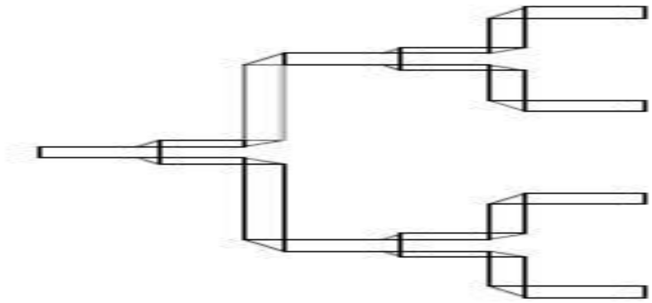


Figure 3.8: AutoCAD design of 1to 4 power divider

3.3 Designing Phase Shifter:

In order to steer the main beam of antenna electronically, we designed phase shifter using hybrid coupler and varactor diodes. Firstly we designed single hybrid coupler in order to check the reflection from the individual ports and insertion loss from one port to the other. The ADS design for single coupler is;

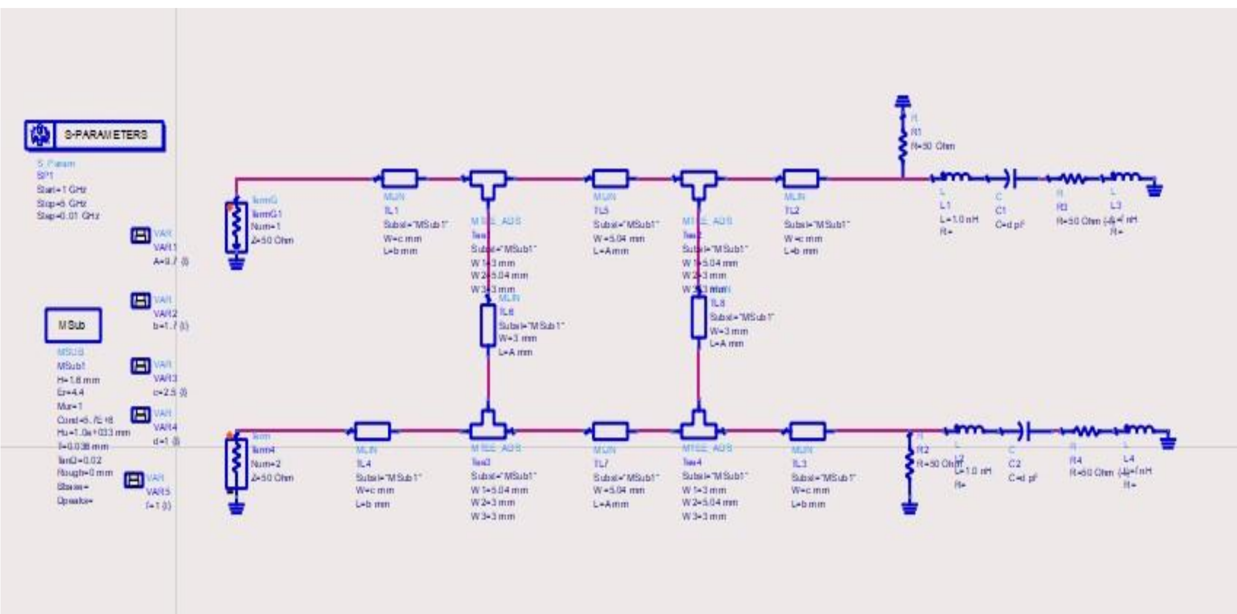


Figure 3.9: Design of single hybrid coupler in ADS

Now, the AutoCAD layout for this coupler is as follows

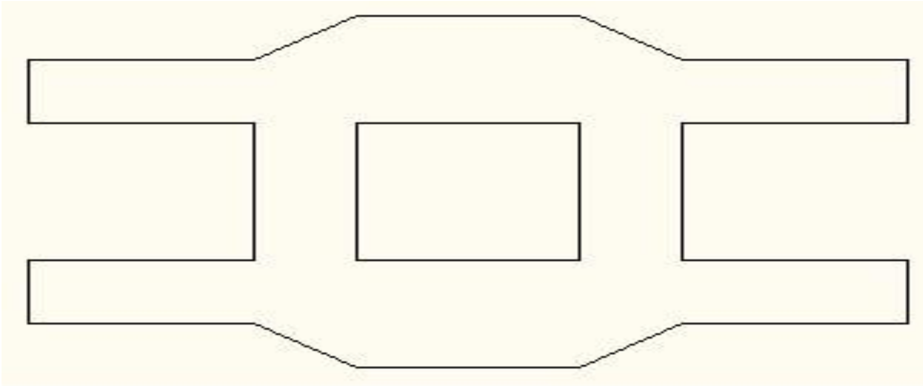


Figure 3.10: AutoCAD design of single coupler

After designing single coupler, we moved on to design a complete phase shifter with hybrid coupler and varactor diodes. The simulation design of ADS is as follows:

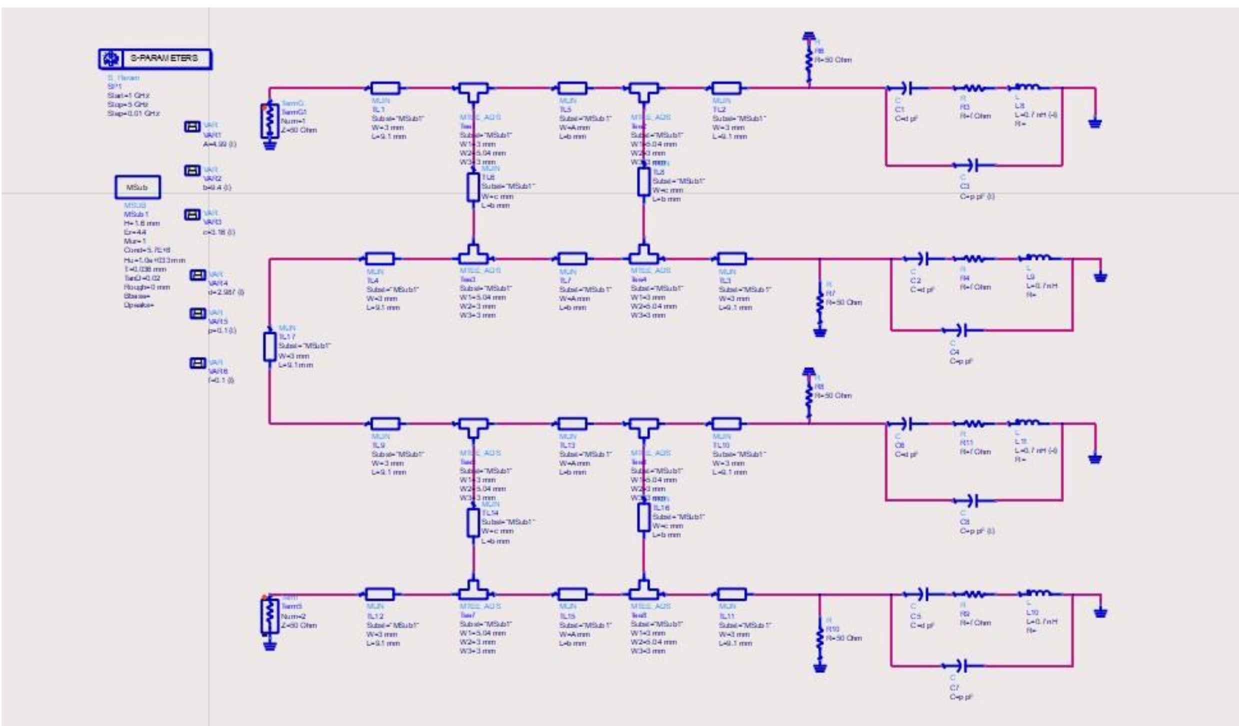


Figure 3.11: design of power divider in ADS

The AutoCAD layout of power divider is;

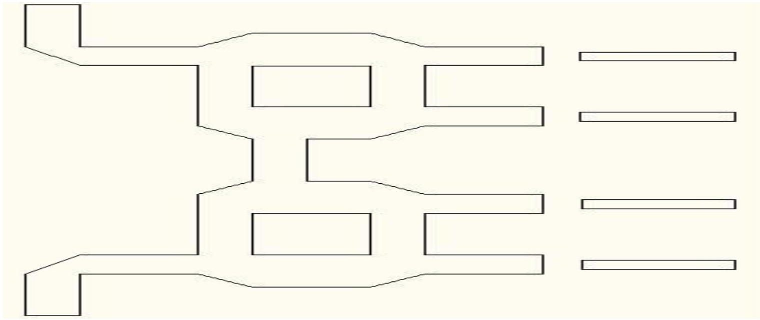
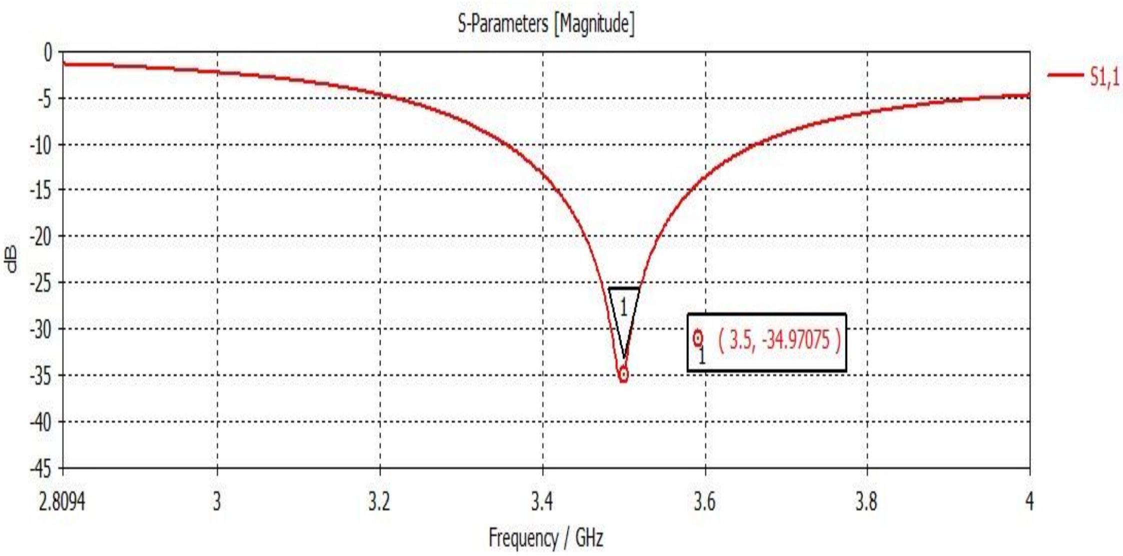


Figure 3.12: AutoCAD design of power divider

CHAPTER 4: ANALYSIS AND EVALUATION

4.1 Simulated Results of Single Patch Antenna

The simulated and practical results of single patch antenna are as follows;



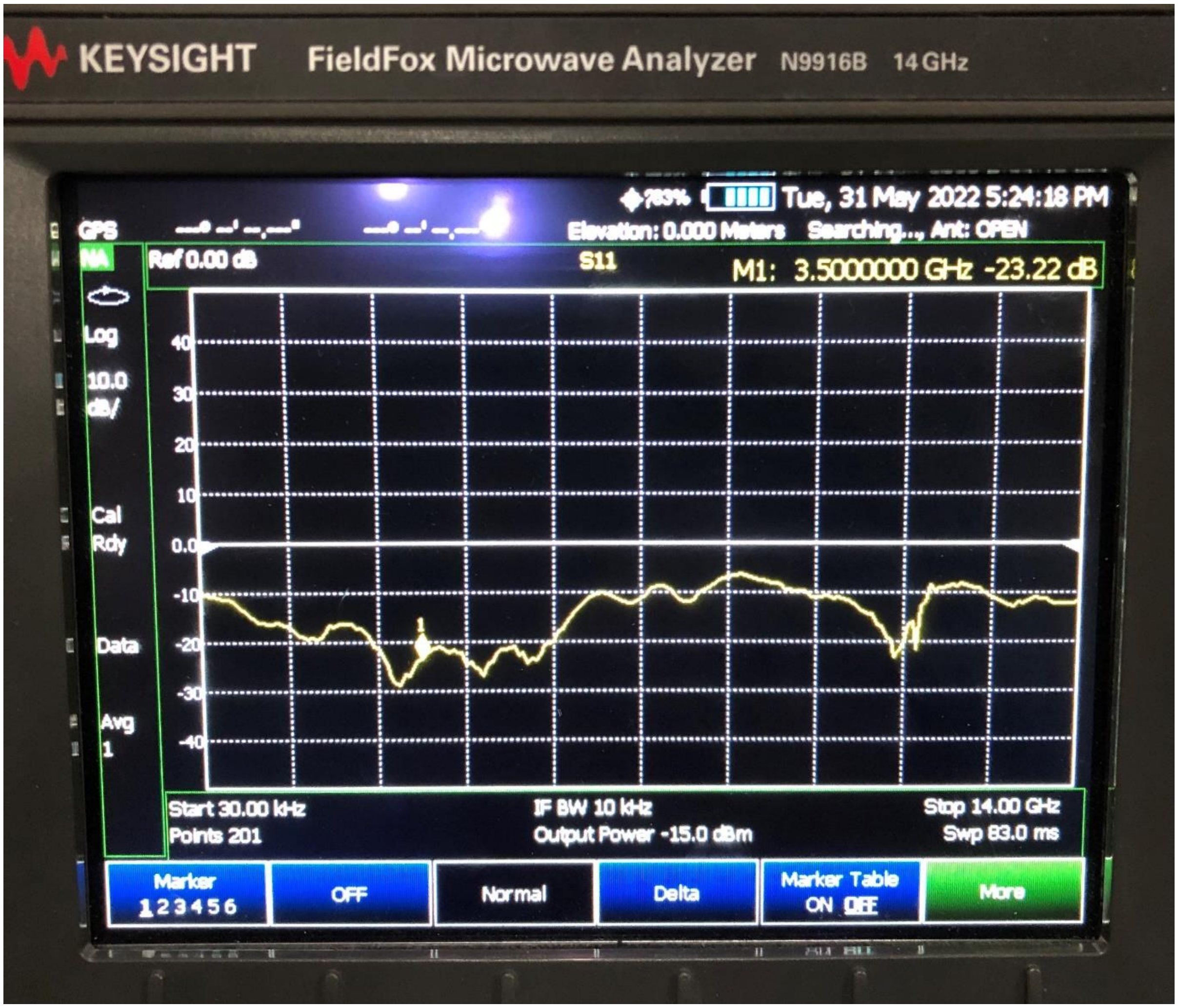
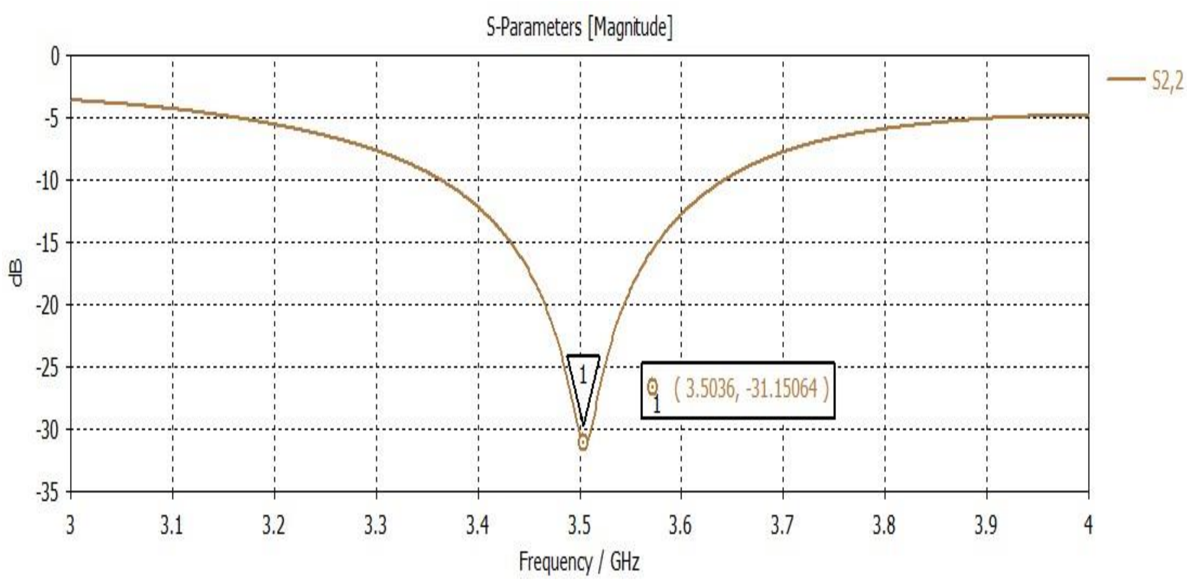


Figure 4.1: S11 at 3.5 GHz is -23.22 dB



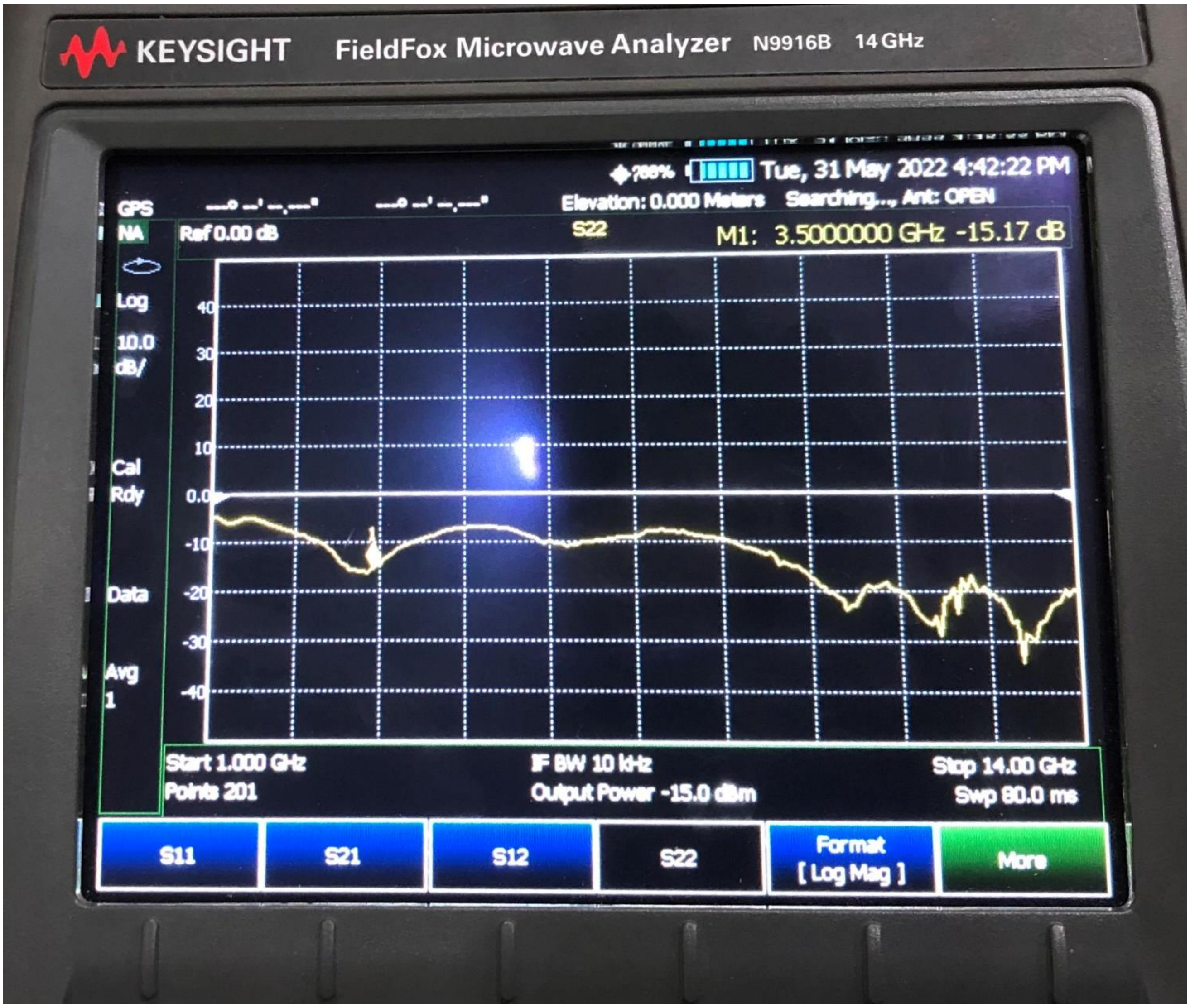


Figure 4.2: S22 at 3.5 GHz is -15.17 dB

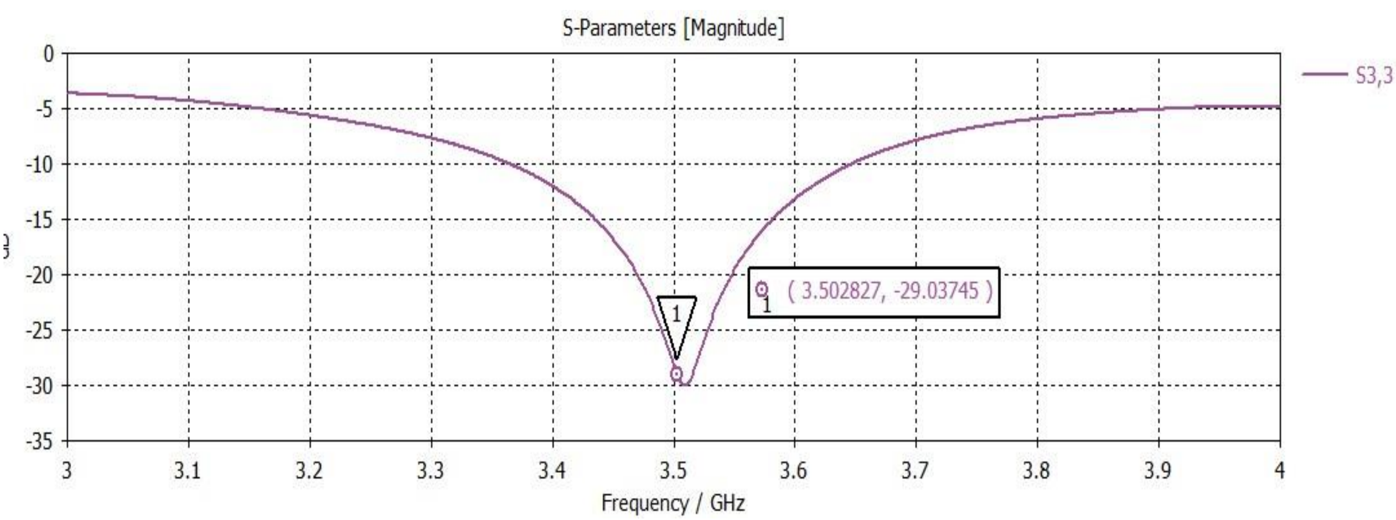


Figure 4.3: S33 at 3.5 GHz is -29.03 dB

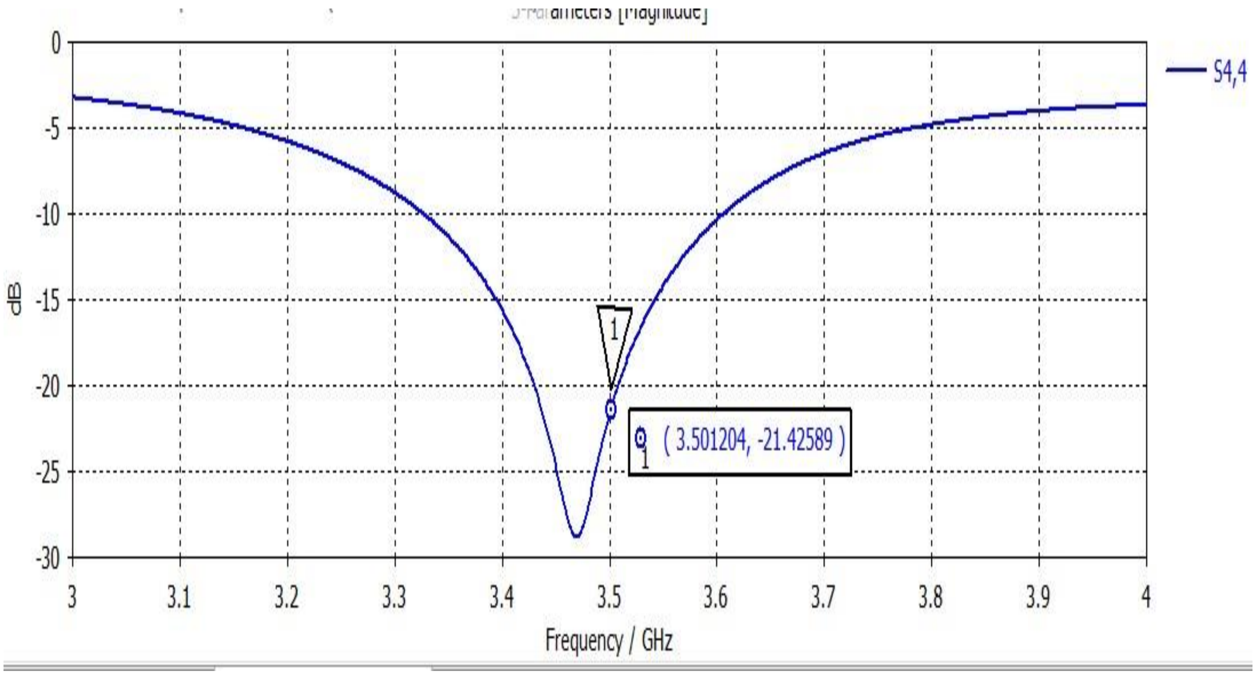


Figure 4.4: S44 at 3.5 GHz is -21.4 dB

The reflection from the port is considered to be zero theoretically. In simulation, it is said that it is less than -10dB. We got this reflection to be -28.25665 dB at 3.5 GHz which is acceptable.

4.3 Simulated Results of Array Antenna

Similar results are obtained for all the 16 ports of antenna array.

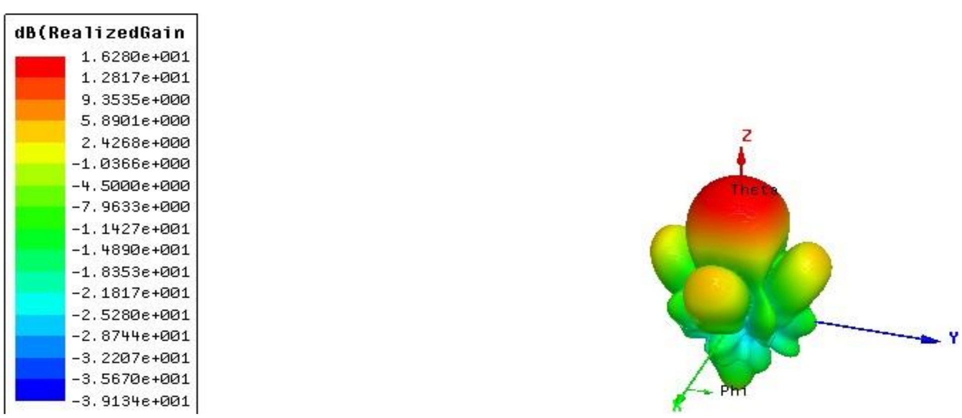


Figure 4.6: Gain of 4×4 is16.28 dB

4.4 Practical Results of Array Antenna

Following the same procedure we get this array fabricated for getting desired results practically.

Figure 4.7: Fabricated 4×4 array (a) front view (b) rear view

The practical results from VNA are;

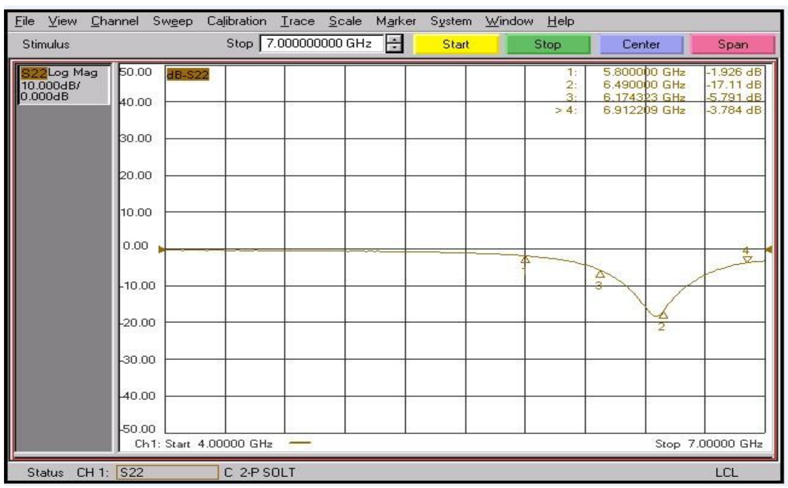


Figure 4.8: practical results of 4×4 array antenna

We got undesired results in this case. There may be several reasons for this error, some of which are as follows; there is Tin coating on the fabricated antenna which is not present in simulation. Also soldering of connectors may result in these distorted results. Another reason may be the less number of passes in simulation which actually give us results very far away from real world. More number of passes in HFSS simulation, more accuracy in practical and simulation results.

If we look in the practical s-parameter result, the dip gets shifted at 6.49 instead of 5.8 GHz. This may be due to little changes in patch dimensions by the fabricator. Normally when we decrease the width of patch the dip moves towards right of the graph and when we increase the width of the patch, the dip moves towards left in the s-parameter graph. Therefore we need to correct these results.

4.5 Practically measured Parameters

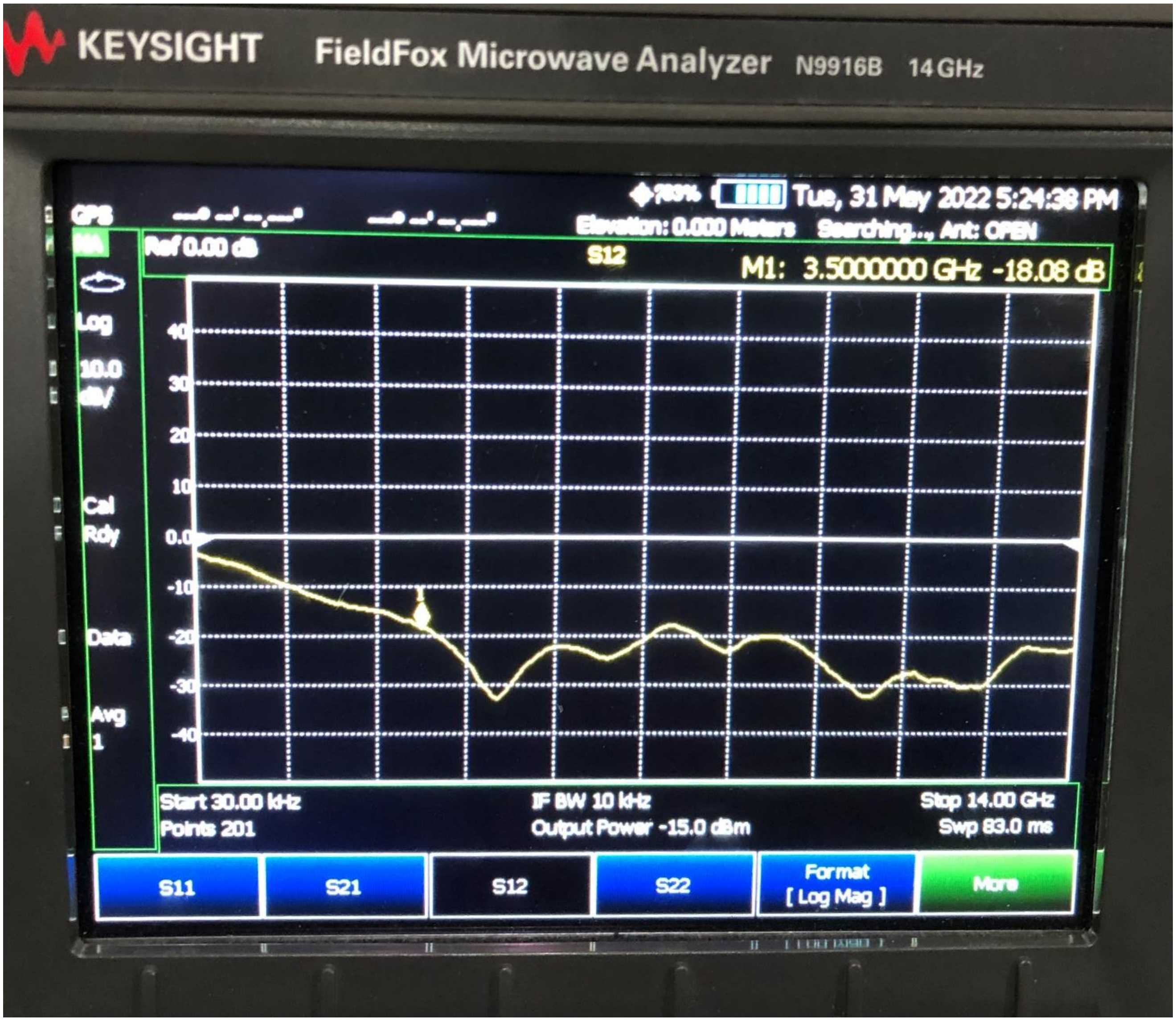


Figure 4.9: S12

Figure 4.10: S21

4.5 Simulated Results of Wilkinson Power Divider

For this purpose, we learned to use ADS and got the results as follows;

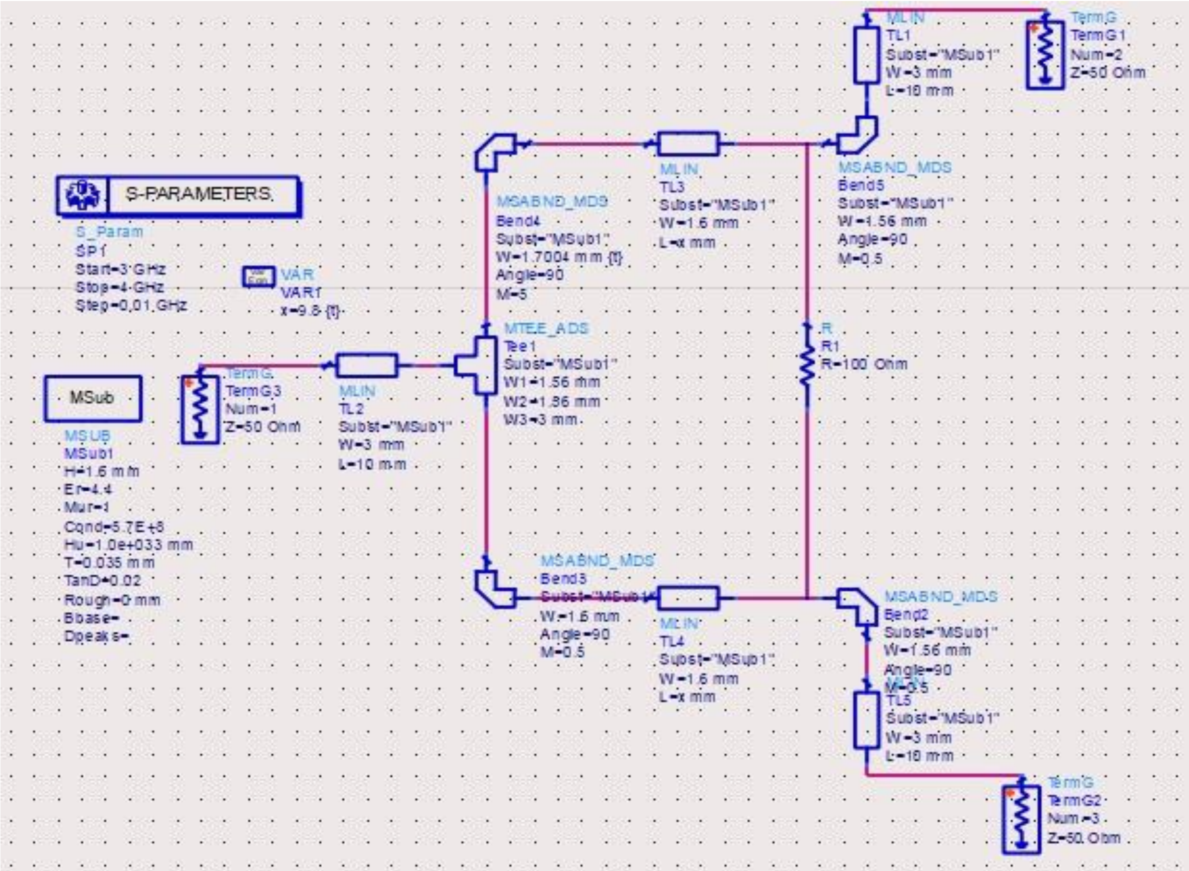


Figure 4.9: simulated results of matching ports

In ADS, it is said that S11 parameter should be less than 20 dB because ADS gives approximate simulation results which when fabricated results in inappropriate microwave circuits or faulty circuits. We got S11 less than 30 dB which is considered to be good in simulation.

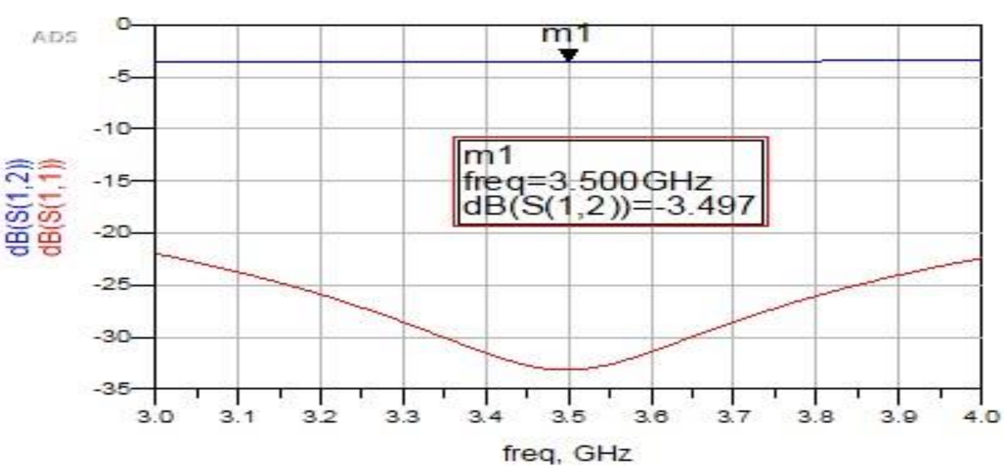
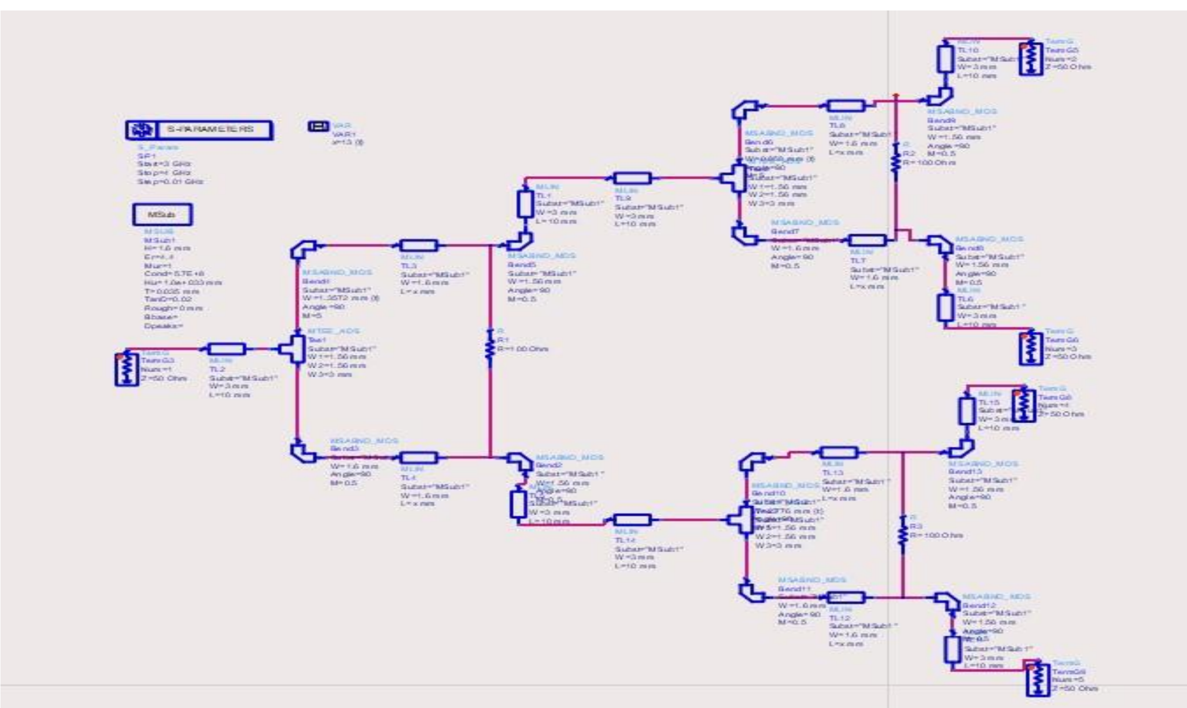


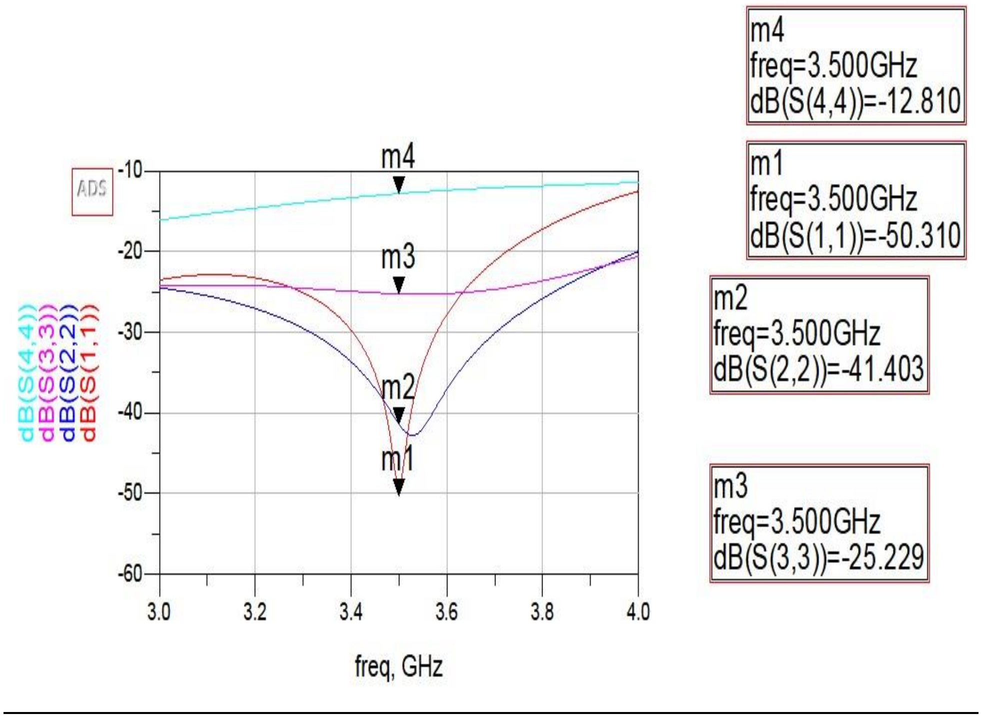
Figure 4.10: Output power at each port

The loss from one port (port 1) to the other (all other remaining ports like port 2, port 4 is said to be insertion loss. In case of 1×16 power divider theoretically, it should be below 12dB. In simulation, we got insertion loss of up-to 14dB.

After getting these simulated results, layout of 1×4 power divider is prepared. Then five 1×4 power dividers combine to form 1×16 network, this will be clear shortly. The fabricated 1×4 Wilkinson power divider is;

Figure 4.11: Fabricated 1× 4 power divider





4.6 Practical Results of Wilkinson Power Divider

The practical results which we get for 1×16 power divider are nearly the same as simulated. The small difference appears because of lossy substrate and connector losses.

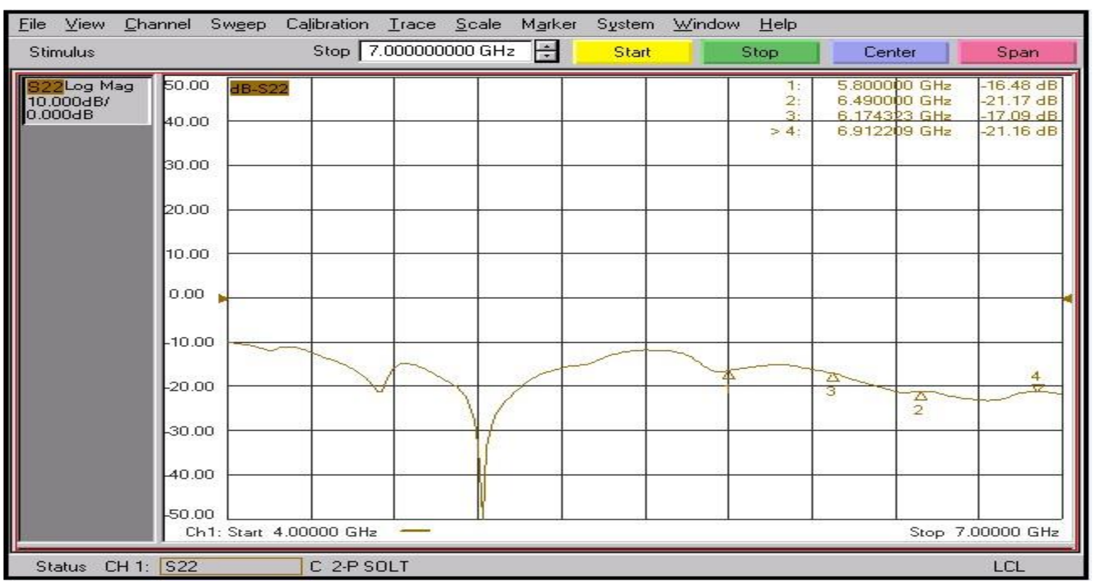


Figure 4.12: practical results of matching port

The reflection loss comes out to be below 16 dB which in simulation was below 30dB. This is acceptable.

More the reflection loss, less signal will be reaching from one port to other.

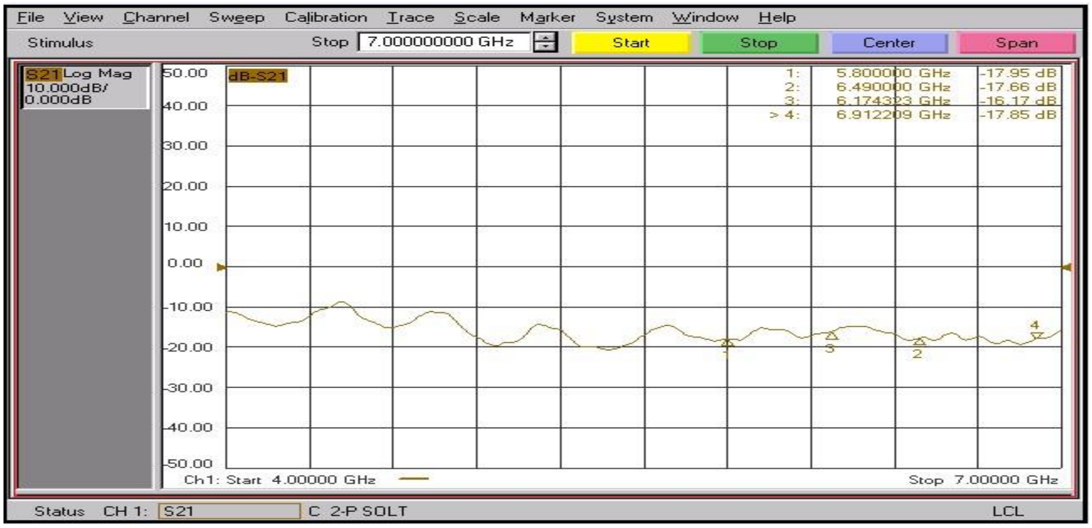


Figure 4.13: practical results of output ports

The insertion loss practically comes out to be below 17 dB which in simulation was below 14dB. More the insertion loss, less signal will be reaching from one port to the other.

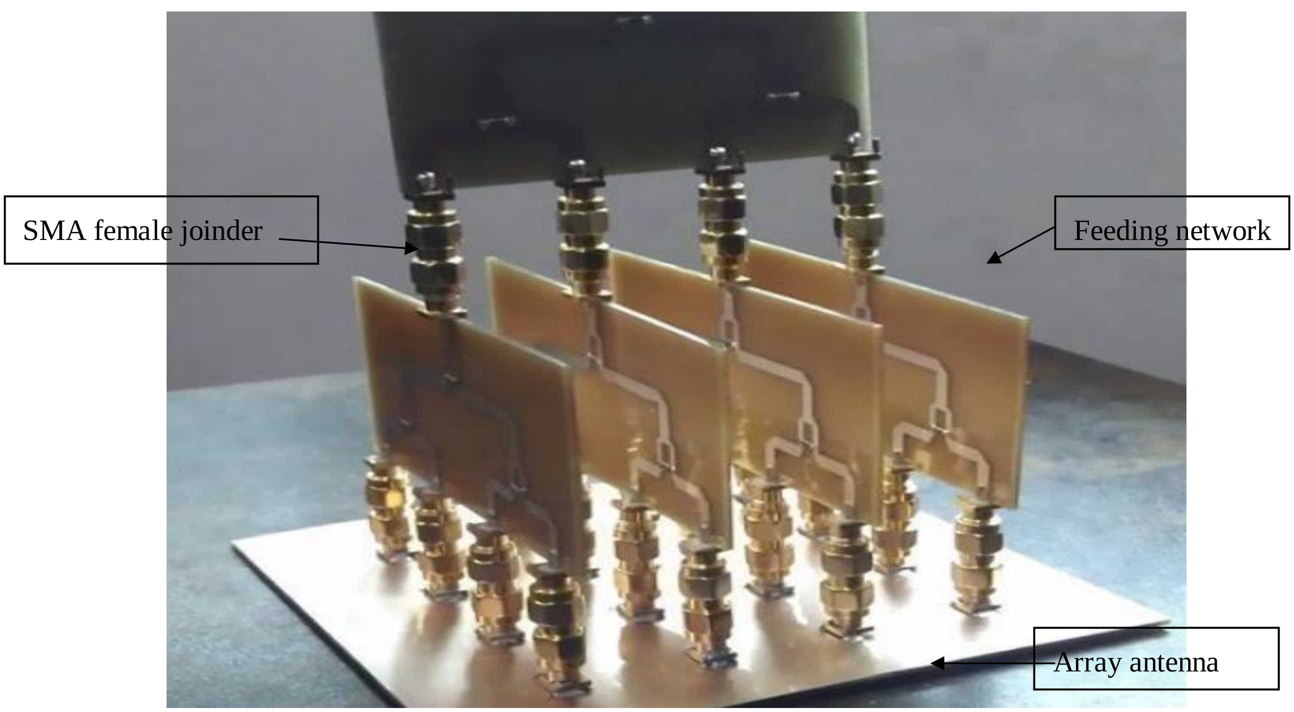


Figure 4.14: 1×16 fabricated power

This is the fabricated array antenna with its feeding network

4.7 Simulated Results of Phase Shifter

The single coupler results are given as:

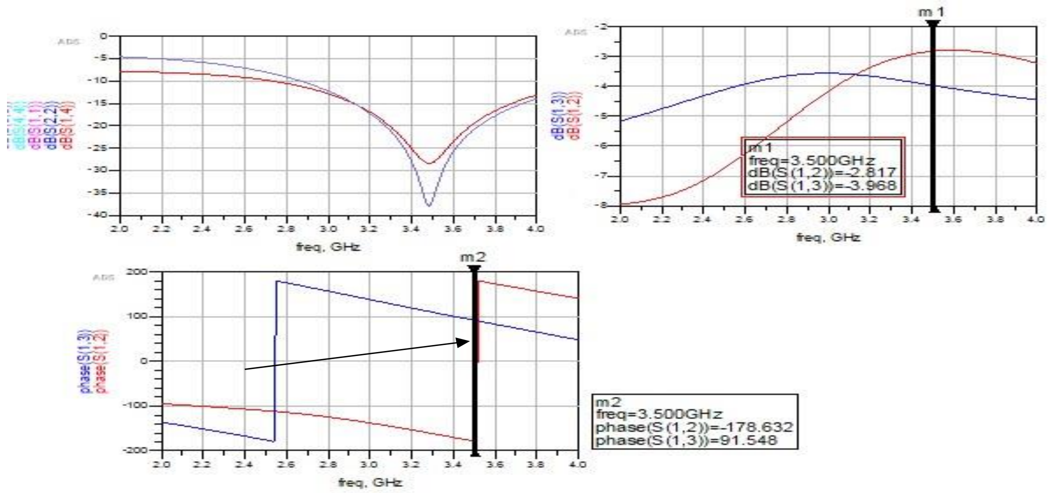


Figure 4.16: Measured results of Phase Shifter

CHAPTER 5: ELECTRONIC BEAM STEERING

As we have designed the hybrid coupler which is then modified to phase shifter by using varactor diode [8] which re-mentioned. It will be used for beam steering purpose.

5.1 Designing Phase Shifter:

In order to steer the main beam of antenna electronically, we designed phase shifter using hybrid coupler and varactor diodes. Firstly we designed single hybrid coupler in order to check the reflection from the individual ports and insertion loss from one port to the other. The ADS design for single coupler is;

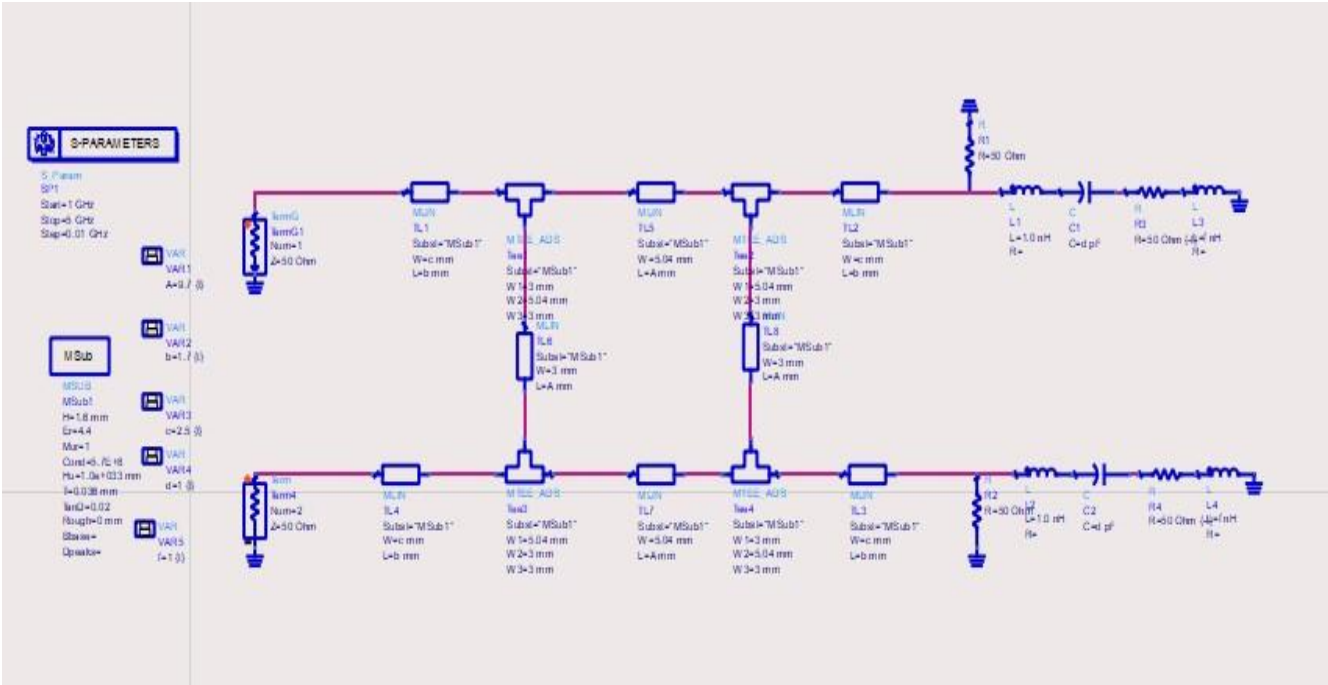


Figure 5.10: Design of single hybrid coupler in ADS

5.2 Autocad Design of Phase Shifter:

Now, the AutoCAD layout for this coupler is as follows

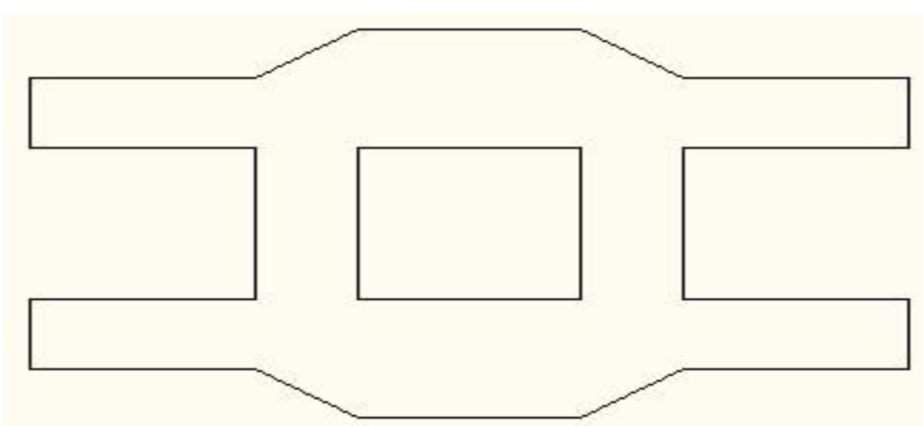


Figure 5.11: AutoCAD design of single coupler

5.3 Fabricated Design of Phase Shifter:

After designing single coupler, we moved on to design a complete phase shifter with hybrid coupler and varactor diodes. The simulation design of ADS is as follows:

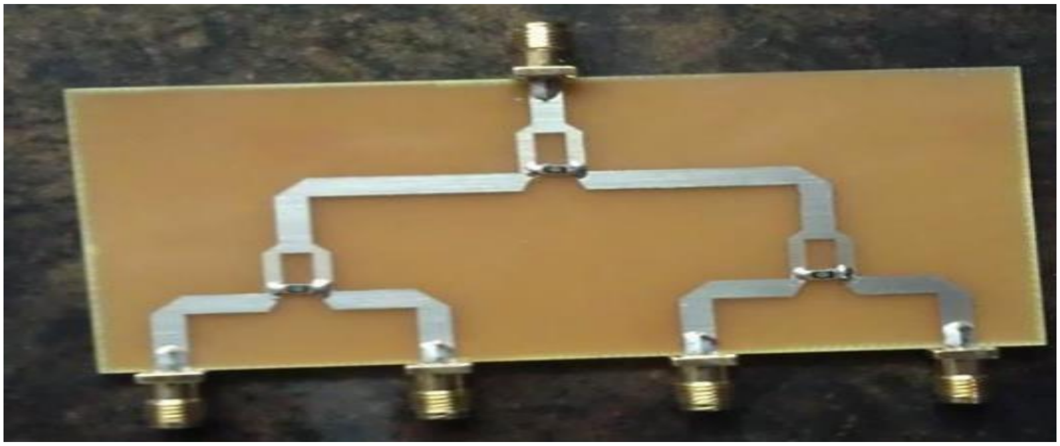


Figure 5.12: Design of power divider in ADS

5.4 AutoCAD design of power divider

The AutoCAD layout of power divider is,

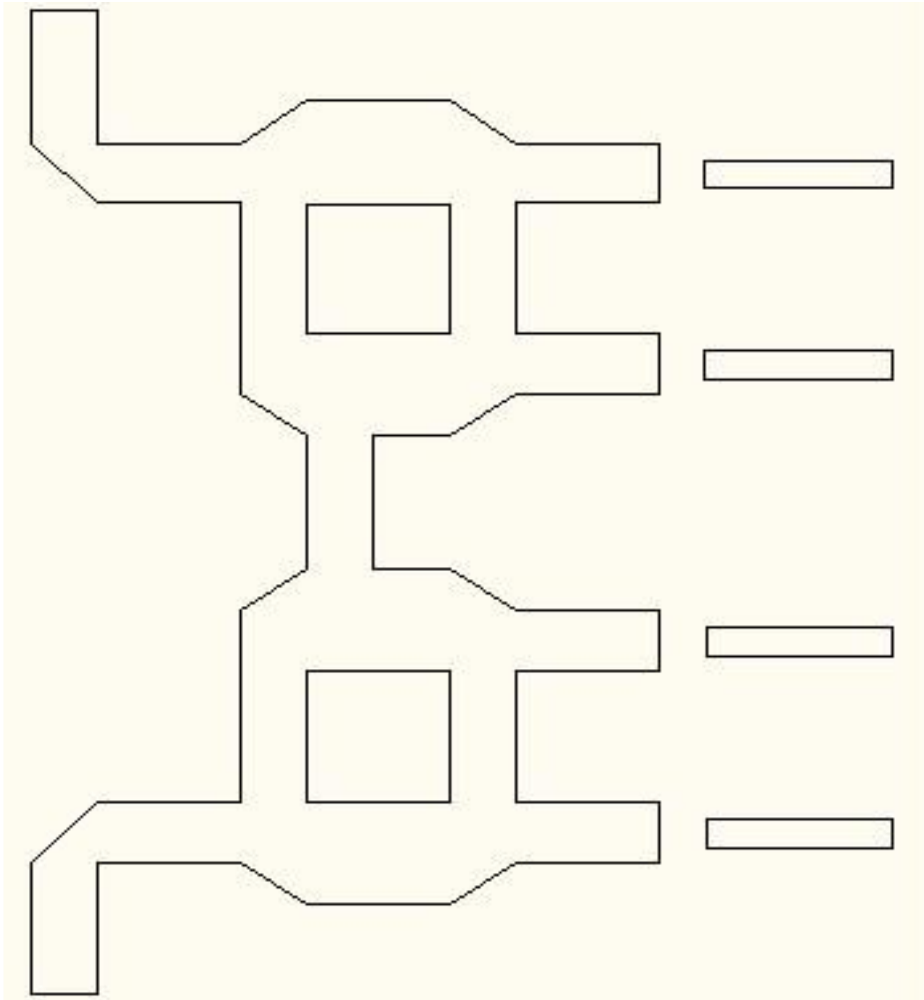


Figure 5.13: AutoCAD design of power divider

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