ULTRA WIDE BAND MONOPOLE ELIPTICAL PATCH ANTENNA

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ABSTRACT

ULTRA WIDE BAND MONOPOLE ELIPTICAL PATCH ANTENNA

Telecommunication industry has always competed against limited resources, various upcoming application and increasing number of users. This aspect has given a significance importance to the microwave radio band. Numerous telecommunication equipment and devices are operating in this band in today's world. Ultra Wideband (UWB) Antennas are now becoming attractive tool for them as they can cover the large portion of microwave band. Telecommunications systems operating at various frequencies are currently using number of RF Antennas for provision of various services which are occupying range of frequency bands. The requirement of an UWB antenna which can operate on all frequencies of that particular system has gained significance. In recent times there has been an increase in the tendency of using UWB antennas for various applications in communication systems where the manufactures desire to have a single antenna that can it is desirable to have a single antenna that can cover an ultra-wideband.

The project intends to develop an indigenous UWB antenna which can operate on a frequency range from 1-30 GHz. The project started with the design of single element monopole antenna with maximum gain and minimum losses. Later on series array design consisting of two monopole antennas and finally a corporate fed array design of four antennas with Wilkinson power divider are designed. Tapering technique is used in Wilkinson power divider to achieve the desired bandwidth in corporate array. The antenna design is initially simulated in HFSS and then was converted to an AUTOCAD file for fabrication.

DECLARATION

We declare that this report entitled "Ultrawide Band (UWB) Monopole elliptical patch”is the result of our own work except as cited in the references. The report has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

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DEDICATION

To our Families and Teachers

ACKNOWLEDGEMENTS

First of all, we praise Allah Almighty, who gave us strength to undertake this project and to complete it in a timely and efficient manner.

We wish to express our gratitude to our supervisor; Asst Prof Fazal Ahmad, from the Faculty of Electrical Engineering, Military College of Signals, National University of Sciences and Technology, for his continuous support and supervision during the course of the project. His persistent guidance is certainly commendable.

Special thanks to Associate Professor Farooq Ahmed Bhatti from Faculty of Electrical Engineering, Military College of Signals, NUST, who has worked brilliantly in the field of Microwave Antennas and we received enough guidance through his practical experience.

Special thanks to all *the 'unsung heroes'* for supporting us in our entire working tenure. Their help on many occasions regarding the design of antenna and fabrication of our project made it possible to present it.

We would also like to acknowledge the struggle of our parents for our wellbeing and education. They have done enormous and endless efforts to make us standout. We would designate our success to them.

Last but not the least, we express our gratitude to lab engineers of RIMS NUST for their help in antenna measurements and results.

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CHAPTER NO. 1

INTRODUCTION

1.1 Brief Introduction

In this report, design and implementation of an Ultra WideBand (UWB) Monopole microwave antenna for integration with Earth Stations and Radar Platforms is presented. Proposed and simulated antenna system can efficiently operate at frequency range (1-30 GHz)theoretically. However the fabricated antennas are covering the bandwidth of 1.5-17.5 GHz. Three prototype antennas are designed and fabricated. Initially single element elliptical patch antenna is designed. In second phase two elliptical patches are used in series array and finally four elliptical patches are combined in corporate array in conjunction with Wilkinson Power combiner and divider. All the antennas cover the majority of the frequency band which is initially claimed. The main aim of the design of patch antenna at frequency range 1-30 GHz is to achieve maximum gain and minimum losses. HFSS and Agilent ADS software is used as a design tool. However the main focus is on the closer to the reality attribute of HFSS. The design of all the antennas (single patch, series array and corporate fed array) are finalized in HFSS and later on optimized for antenna efficiency and impedance matching over wide band. After the satisfactory results of the simulated design the antennas are fabricated and practically tested in lab using VNA (Vector Network Analyzer) and spectrum analyzer. The results are successful and in close approximation to the theoretical results. The reflection coefficient and resonant frequency of the antenna is tested with Vector

Network Analyzer. The motivation of this thesis is to practically implement a complete antenna structure capable of operating in Ultra Wideband.

1.2 Background

In past recent years major communications systems are using Ultra wideband (UWB) antennas in variety of applications. The spread spectrum and broadband of UWB are efficiently utilized in Radar systems. The UWB performance of antenna results from excitation by impulse or non-sinusoidal signals with rapidly time-varying performance. Recently, a new version of ultra wideband monocone antenna has been designed for UWB channel measurement, and the transient responses of a logarithmic periodic dipole and a Vivaldi antenna are presented for the characterization of a UWB antenna**.** In our project, we propose a new ultra wideband antenna (1 -30 GHz) for integration in Earth Stations operating in S-band, Ku-band and K-band.

1.3 UWB Antenna Approach

In order to design and develop the Ultra Wideband Antenna in depth study of antenna theory is required and practically following steps and approach is required to achieve the objective.

Analytical calculations of simple monopole circular patch, Software simulations in HFSS and optimization for UWB behavior and Fabrication of simulated design.

1.4 UWB Applications

Microwave band has been used in variety of application and communication devices. In future the depth of Microwave band can also be utilized for further advancement in the field of telecommunications. As these Ultra Wideband antennas cover the major portion of microwave band so these can be utilized in various application. The project will provide Antenna part of RF front end for microwave band i.e.

Integration with S-band and K-band Earth Station's front end, Integration with microwave Radar's front end, UWB (1-30 GHz) Monopole patch Antenna, UWB (1-15 GHz) Series Array and UWB Corporate Array.

Moreover these antennas can be further optimized and moulded in various applications and platforms as they cover huge frequency range but with specific research.

CHAPTER NO.2

DEVELOPMENT OF PROJECT

2.1 Review of Literature

This chapter states the background study, motivation and need of the product developed as a result of this research. The detailed objectives and the thesis outline are also presented to give an overview of the project.

2.1.1 Criteria for selection of Antenna

Different antenna structures for wireless communication have been proposed in the literature. These structures are motivated by their low profile, low cost, and easy fabrication. Other antennas have been used in wireless communications because of their wide-band characteristics and design simplicity. The first step in designing of the model is to select the type of antenna. The available options are:

Wire Antennas, Micro strip Antennas, Reflector Antennas, Traveling Waves Antennas and Aperture Antennas.

Our selection criteria is based on the following aspects

Wide Band, Omni Directional, More Compact profile, Less Cost and State of the Art Technology.

After much research and consideration, it was decided to use the micro strip technology for this UWB antenna as it has most of the features that fulfilled the requirements such as:

Used in mobile phones, Omni Directional Antenna, Lightweight and Compactness.

2.1.2 Patch Antenna

Patch antennas are often termed as micro strip antennas. These are the antennas which can be mounted on a flatter surface and usually have a comparatively low profile. It is composed of a metallic flat rectangular patch which is mounted over a larger metal sheet called a ground plane. The assembly is generally enclosed inside a plastic radome, which act as a shield for antenna structure and protect it from any damage. They are easy to fabricate and can be modified and customized easily as per requirements. They are the original type of micro strip antenna; the two metallic sheets together form a resonant piece of micro strip transmission line which has an approximate length of one-half wavelength of the radio waves. The radiation mechanism arises from discontinuities at each truncated edge of the micro strip transmission line. The radiation at the edges causes the antenna to act slightly larger electrically than its physical dimensions, so in order for the antenna to be resonant, a length of micro strip transmission line slightly shorter than one-half a wavelength at the frequency is used. A patch antenna is usually constructed on a dielectric substrate, using the same materials and lithography processes used to make printed circuit boards forming.

2.1.3 Advantages of Patch Antenna

The major advantage of patch antennas is the economy because they are inexpensive. They are easy to design and can be manufactured simply due to simple 2-dimensional physical geometry. The antenna's size is directly related to the wavelength of the resonant frequency so they are used at higher frequencies. Maximum directive gain which can be provided by a single patch antenna is around 6-9 dBi. The arrays of patches can be printed easily on a single (large) substrate using any of the available techniques. Patch arrays can offer much higher gains as compared to single patch with slightly higher cost. However matching and phase adjustment are required to be performed with printed micro strip feed structures. The quality of creating arrays of higher gain in a low-profile antenna is major reason that patch arrays are usually used in common airplanes and in various other military and civil applications.

Another advantage of patch antennas is that they can provide polarization diversity. Patch antennas can offer vertical, horizontal, right hand circular or left hand circular polarizations. This can be achieved by designing multiple feed points or it can be done by a single feed point with the help of asymmetric patch structures. Due to this unique property, patch antennas can be used indifferent form of communications links having multiple requirements.

2.1.4.Circular patch

Often employed micro strip antennas are designed with circular patch. The dimensions of circular patch are planned according to the antenna theory and resonant frequency.

These dimensions of the circular patch antennas are proportional to the dielectric strength of the substrate.

2.2 UWB ANTENNAS FOR MICROWAVE BAND

The UWB antenna should have certain properties so that it should be able to operate in various UWB applications. These properties are

Impedance matching for wideband, Low profile or compact profile and Omni directional radiation patterns.

Lot of techniques are in use for improvement in impedance matching for a wide frequency spectrum. Many, techniques can be used to enhance the bandwidth. One out of them which is most in common is adding a slim notch to the rectangular disk with the help of truncated grounds using asymmetric feeding mechanisms and trident-shaped feeding mechanism can be used. Planar monopole antennas are considered best for UWB applications.

2.2.1 Planar monopole antennas (PMAs)

Different planar monopole antennas are shown below

Square Monopole Antenna (SMA), Rectangular Monopole Antenna (RMA), Hexagonal Monopole Antenna (HMA) and Triangular Monopole Antenna (TMA).

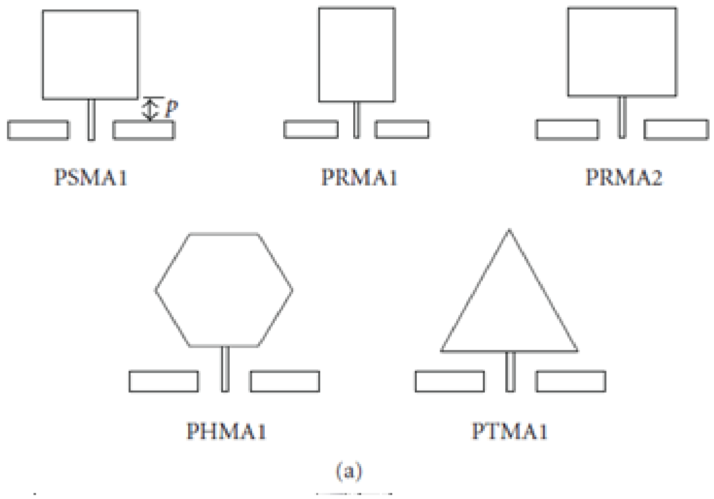


Figure 2.1 SMA, RMA, HMA, TMA

Circular Monopole Antenna (CMA) and Elliptical Monopole Antenna (EMA).

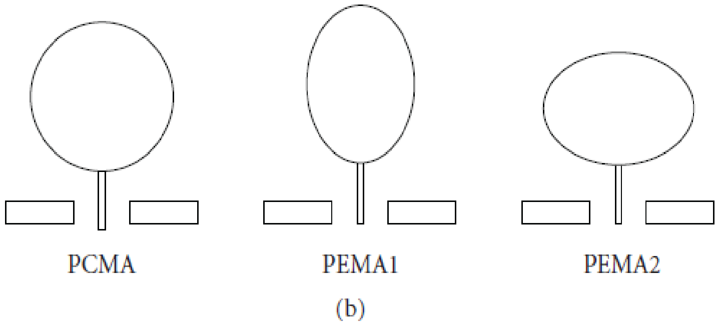


Figure 2.2 CMA, EMA

Hexagonal Monopole Antenna (HMA), Square Monopole Antenna (SMA) and Triangular Monopole Antenna (TMA).

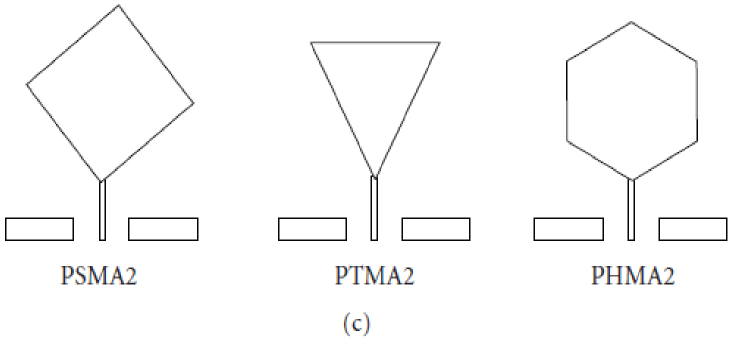


Figure 2.3 HMA, TMA, SMA

CHAPTER NO. 3

ANTENNA DESIGN

3.1 Design of Single Elliptical Planar Monopole Antenna (S-EPMA)

Below is the structure of an S-EPMA with a bandwidth of (1-30) GHz. Numerous plots of gain for different frequencies are shown in coming chapters. The reflection curves dictate the claimed bandwidth (1-30) GHz and the acceptable VSWR is 1-2 all over the bandwidth.

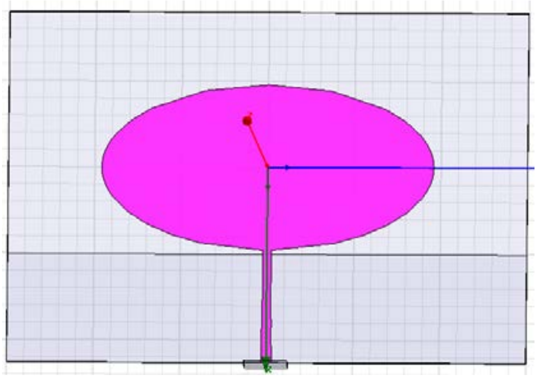


Figure 3.1S-EPMA

Figure 3.2S-EPMA Measurements

3.1.1 Design Specifications

The design specifications for the optimized dimensions are:

a. Bandwidth Optimization

i. Feed line width = 0.25 cm

b. Improved S11 Return Loss

i. Reported BW in research paper is (1--11) GHz but now achieved BW is (1-30 GHz)
ii. Substrate RT-Duroid with permittivity (2.2) can be used instead of FR4-substrate with permittivity (4.4).

c. Patch dimensions are optimized to achieve wide band impedance matching and improved gain.

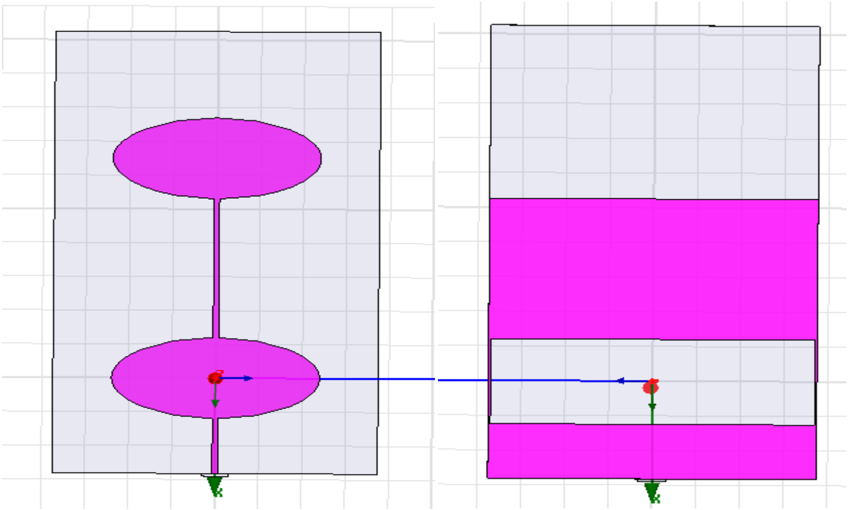
3.2Arrays Design

There are two ways to design the arrays of Planar Elliptical Monopole antennas

Series fed array (SFA) and Corporate fed array (CFA) using Wilkinson's UWB power divider.

3.2.1 Series Fed Array (SFA)

Below is the structure of a two-element array of the elliptical monopole antenna where each element is in series with the other. The S11 curve at -10 dB shows an achieved bandwidth of (1- 15 GHz). The VSWR is between 1 and 2 throughout the bandwidth. Plots of gain for different frequencies have been showed too.



Antenna array structure **Ground plane**

Figure 3.3SFA

3.2.2 Design Specifications

The dimensions of the two-element array are as shown:

Figure 3.4SFA Measurements

3.3 CorporateFed Array (CFA)

Parallel array is made using Wilkinson’s ultra wideband power combiner which has three ports as shown. The curves associated with all the three ports are shown.

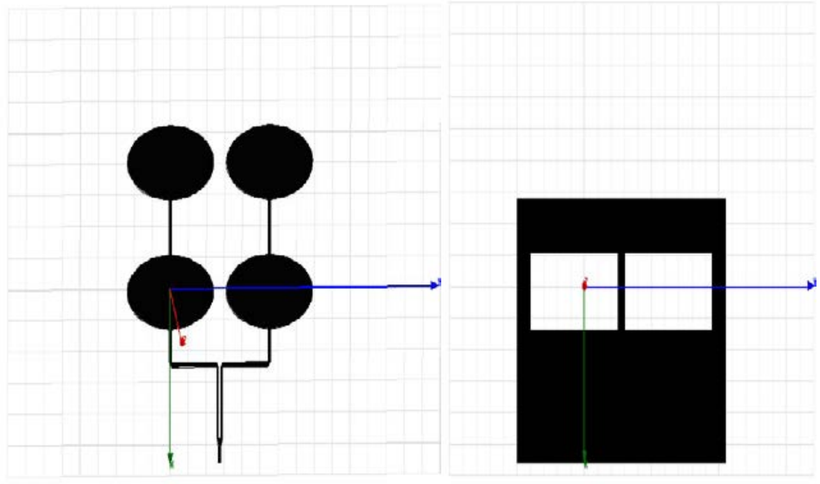


Figure 3.5HFSS Design of CFA

CHAPTER NO. 4

SIMULATION AND MEASURED RESULTS

In this chapter simulation results using software HFSS version 13 corresponding to simulated models in chapter no. 3 are discussed. Moreover measured results of simulated design are also shown. This chapter develops itself in a chronological manner starting from single element monopole to corporate monopole array involving integration of UWB Wilkinson's power combiner/divider.

4.1 Single element monopole Antenna

Following are the simulated and measured results of Single element monopole Antenna.

4.1.1 Simulated and Measured S11 curve

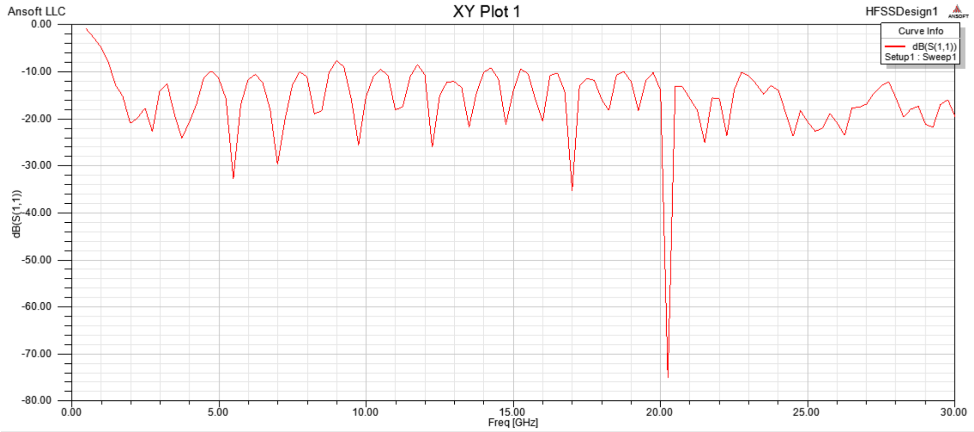


Figure 4.1 S11 Curve

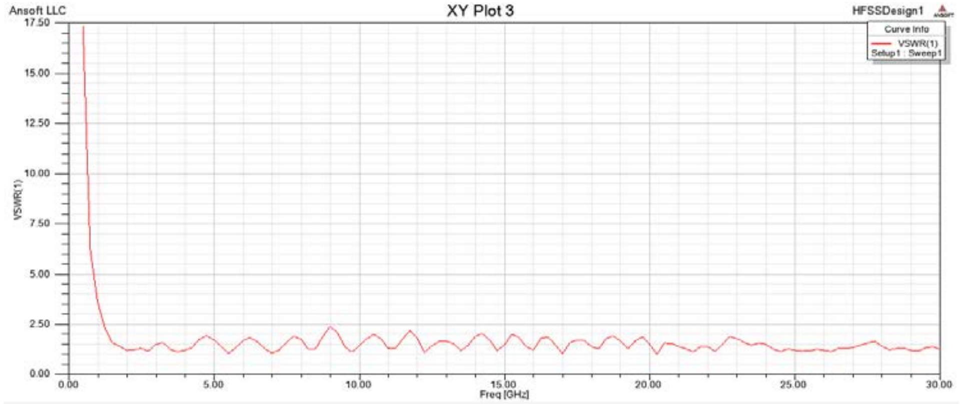


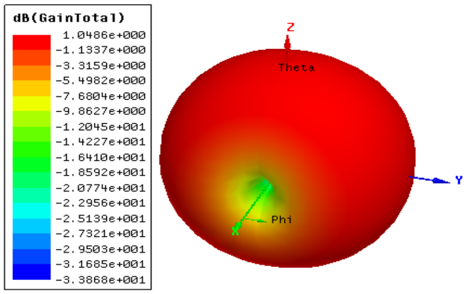
Figure 4.2 VSWR

4.1.2Simulated Gains at various frequencies

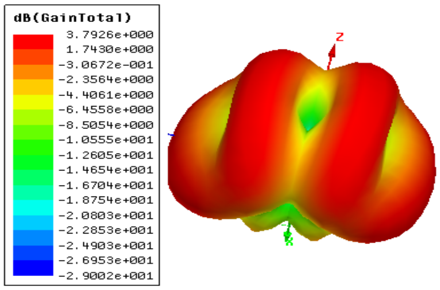
Simulated results at selected frequencies are shown

Gain (db)

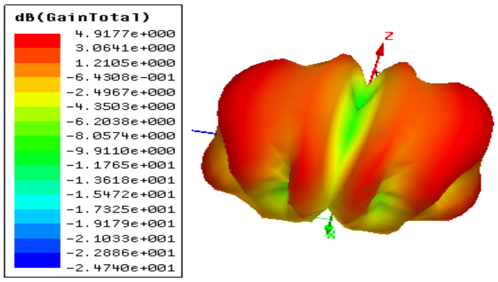
Frequency 1 GHz



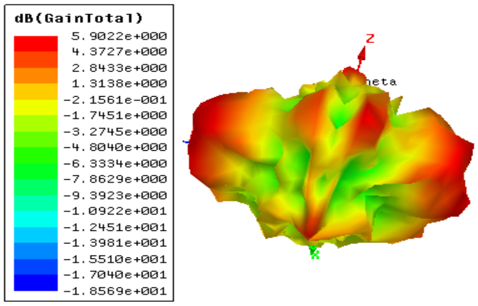
Frequency 3 GHz



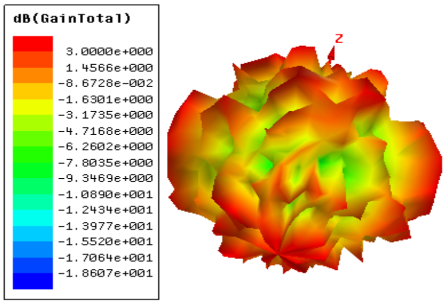
Frequency 5 GHz



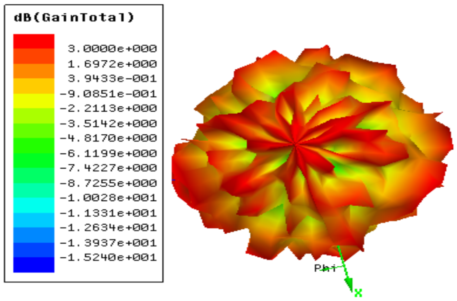
Frequency 10 GHz



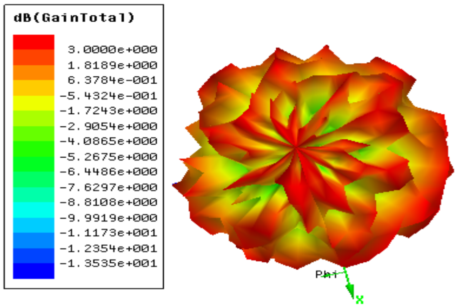
Frequency 15 GHz



Frequency 20 GHz



Frequency 25 GHz



Frequency 30 GH

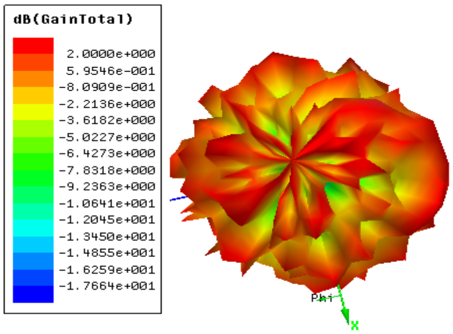
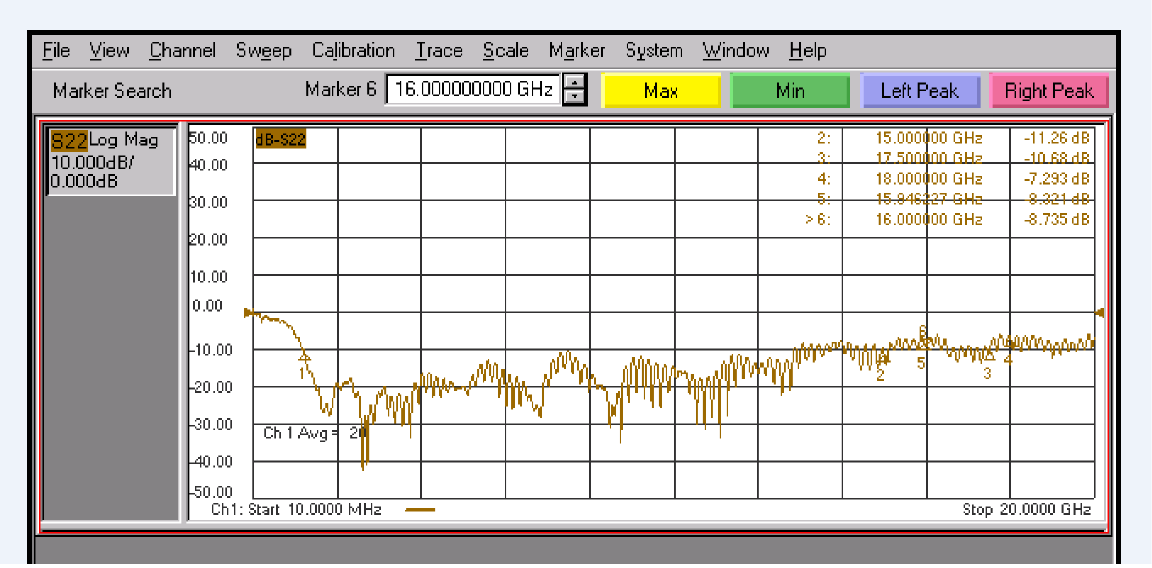


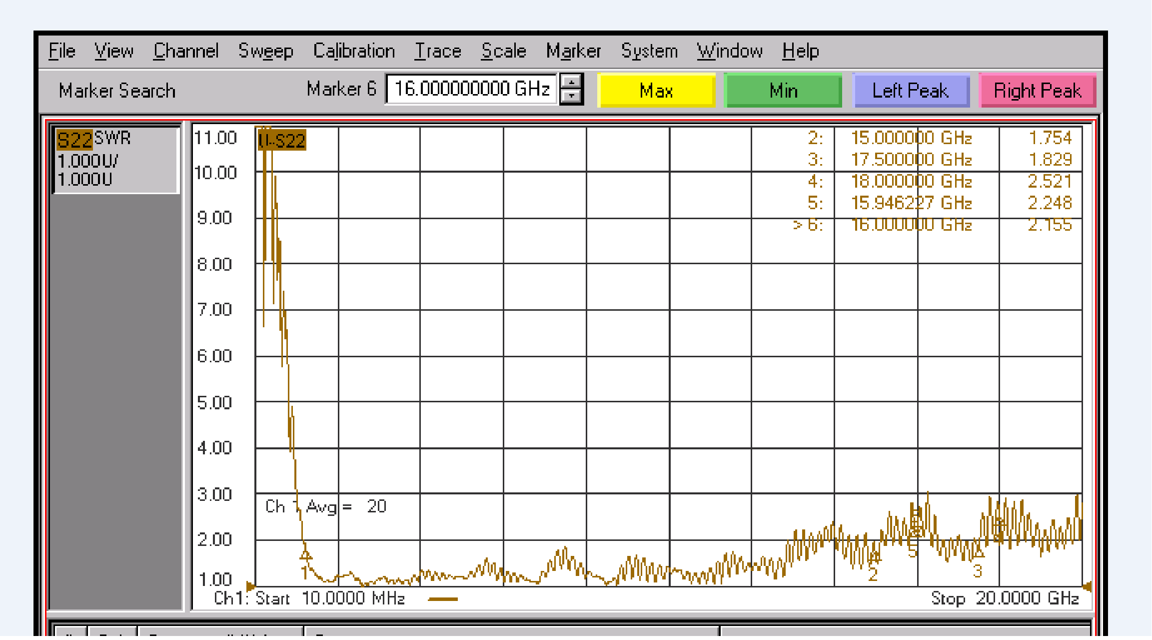
Figure 4.3 Simulated Gains at Various Frequencies

4.1.3 Measured Results through VNA



```
Marker 6  16.000000000 GHz
S22 Log Mag
10.000dB/
0.000dB
dB-S22
   2:   15.000000 GHz   -11.26 dB
   3:   17.500000 GHz   -10.68 dB
   4:   18.000000 GHz   -7.293 dB
   5:   15.946227 GHz   -8.321 dB
 > 6:   16.000000 GHz   -8.735 dB
Ch 1 Avg = 20
Ch1: Start 10.0000 MHz                Stop 20.0000 GHz
```

Figure 4.4 S11 curve



```
Marker 6  16.000000000 GHz
S22 SWR
1.000U/
1.000U
U-S22
   2:   15.000000 GHz   1.754
   3:   17.500000 GHz   1.829
   4:   18.000000 GHz   2.521
   5:   15.946227 GHz   2.248
 > 6:   16.000000 GHz   2.155
Ch 1 Avg = 20
Ch1: Start 10.0000 MHz                Stop 20.0000 GHz
```

Figure 4.5 VSWR

4.2 Series Array Monopole Antenna

Following are the simulated and measured results of series Array monopole Antenna.

4.2.1 Simulated and Measured S11 curve

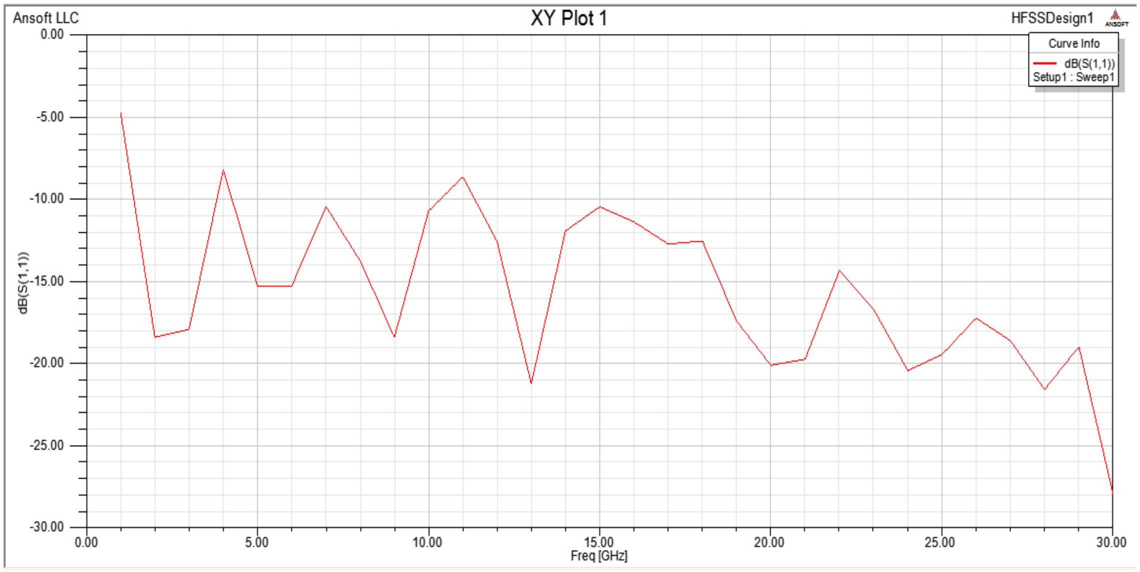


Figure 4.6S11 curve

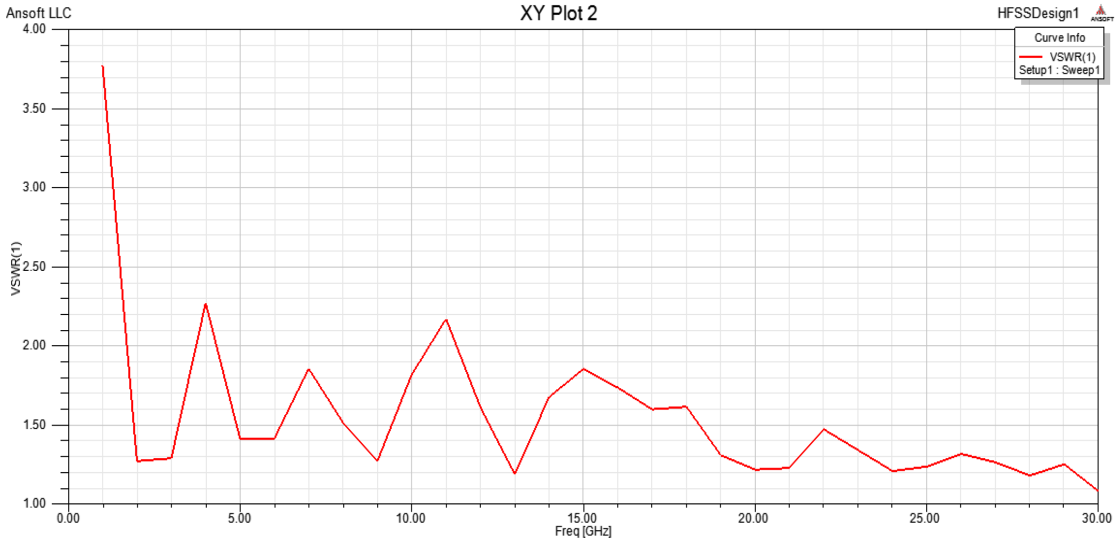
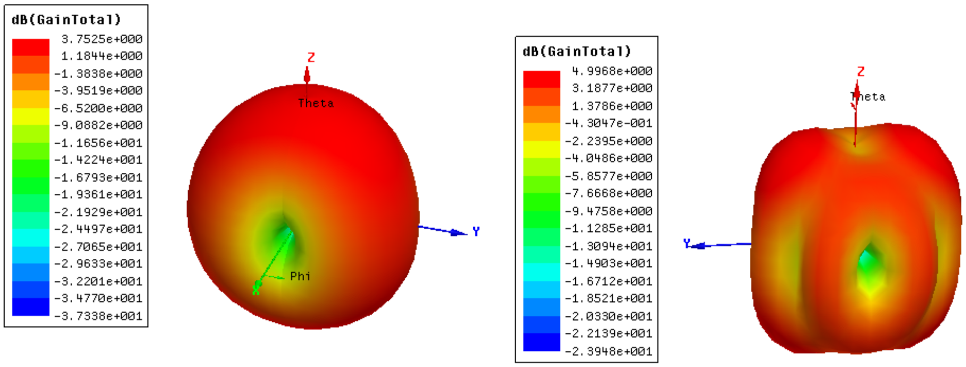


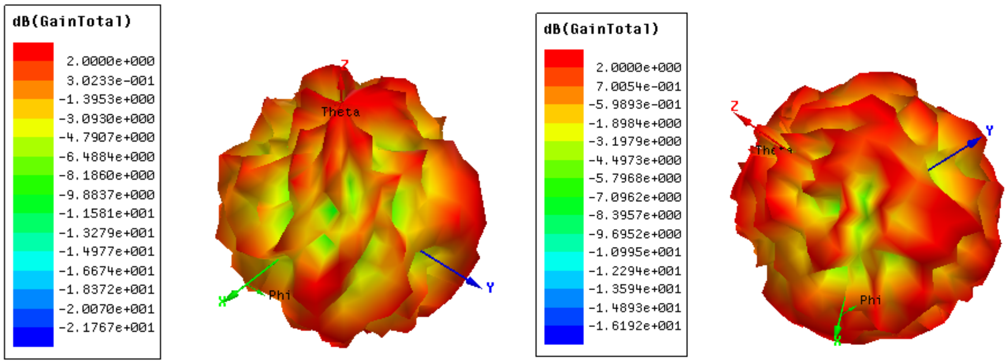
Figure 4.7 VSWR

4.2.2 Simulated Gain (db) at various frequencies

Simulated results at selected frequencies are shown


Frequency 1 GHz

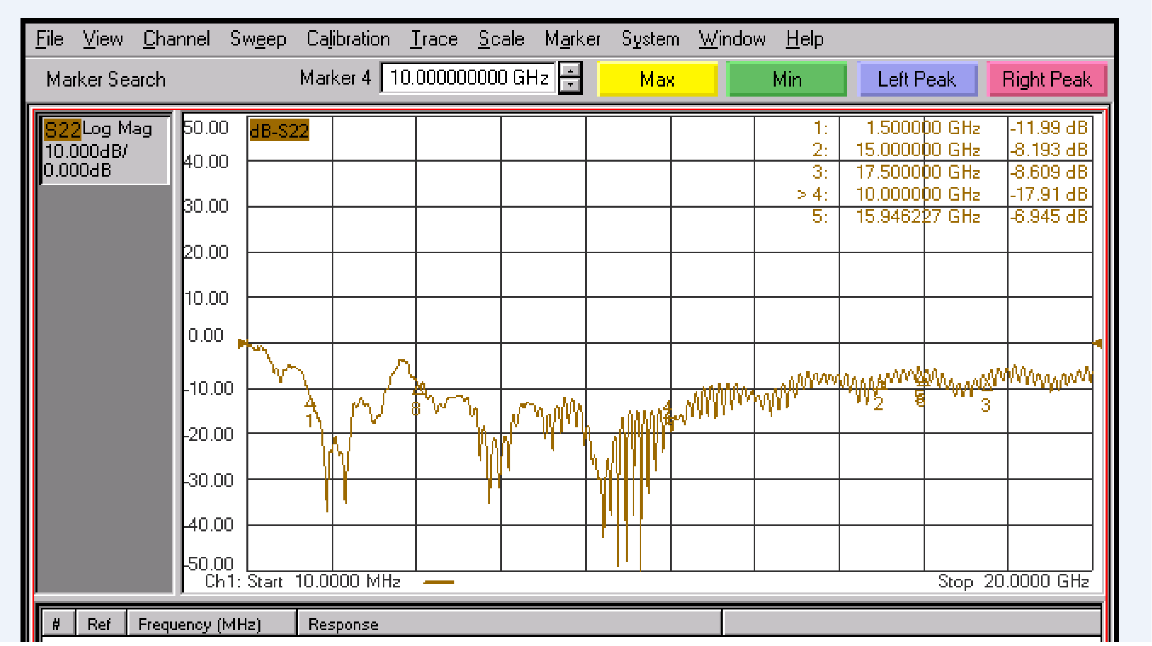
Frequency 2 GHz


Frequency 13 GHz

Frequency 30 GHz

Figure 4.8 Simulated Gains at Various Frequencies

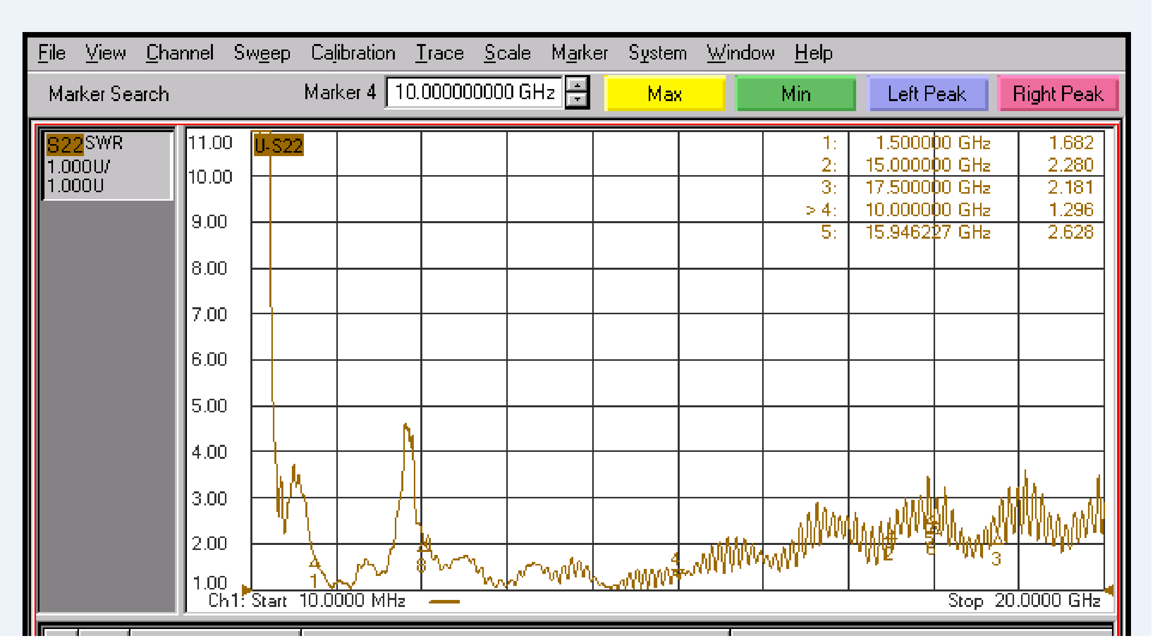
4.2.3 Measured Results through VNA



Marker 4 10.000000000 GHz

1:	1.500000 GHz	-11.99 dB
2:	15.000000 GHz	-8.193 dB
3:	17.500000 GHz	-8.609 dB
> 4:	10.000000 GHz	-17.91 dB
5:	15.946227 GHz	-6.945 dB

Figure 4.9 S 11 Curve



Marker 4 10.000000000 GHz

1:	1.500000 GHz	1.682
2:	15.000000 GHz	2.280
3:	17.500000 GHz	2.181
> 4:	10.000000 GHz	1.296
5:	15.946227 GHz	2.628

Figure 4.10 VSWR

4.3 Corporate Array Monopole Antenna

4.3.1 Simulated and Measured S11 curve

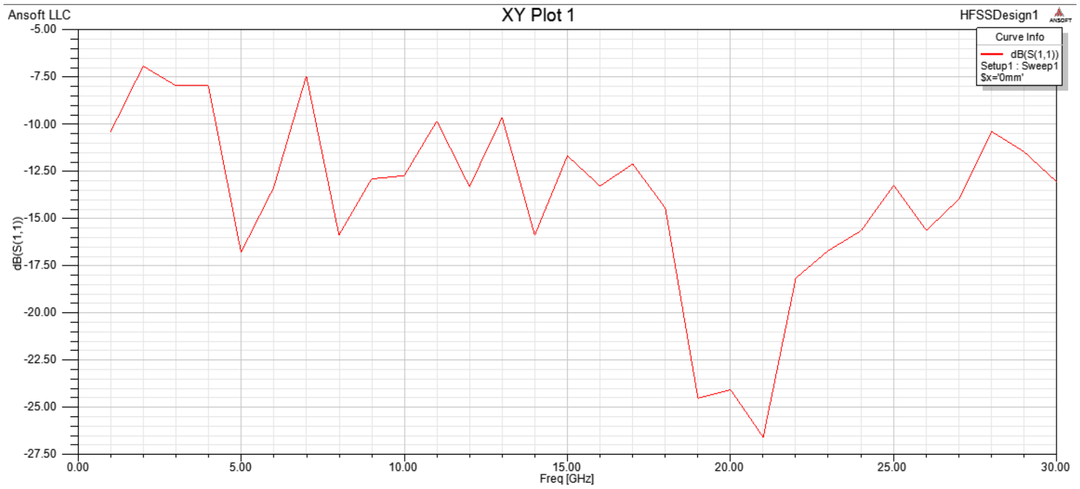


Figure4.11 S11 curve

4.3.2 Simulated Gain (db) at various frequencies

Simulated results at selected frequencies are shown

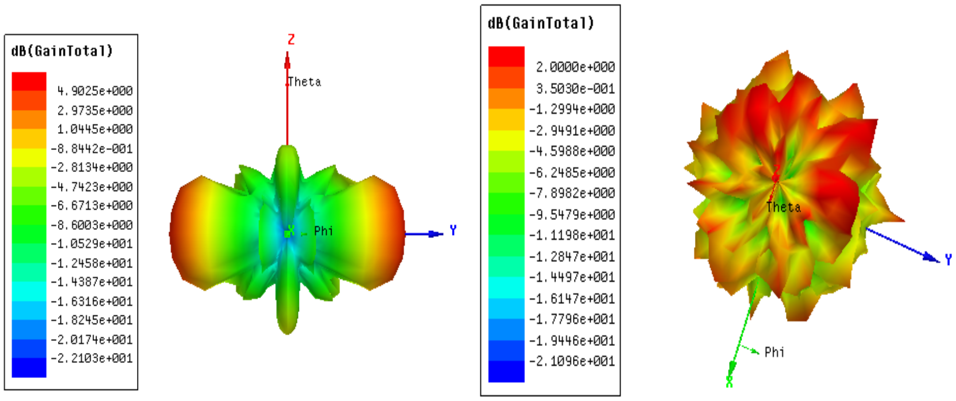
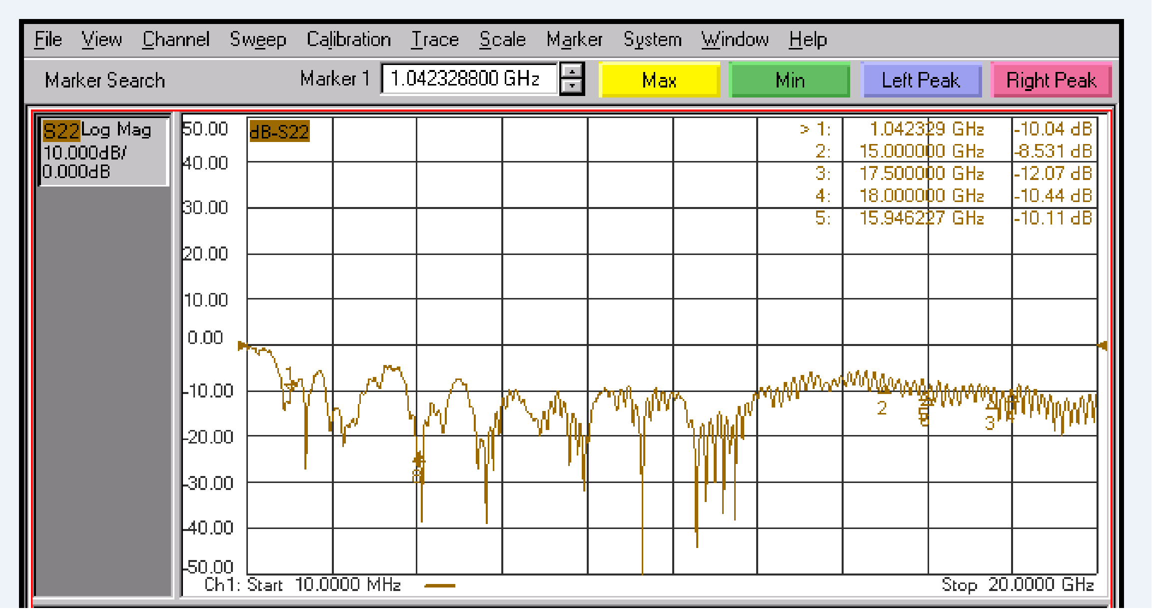

Frequency 1 GHz **Frequency 2 GHz**

Figure 4.12 Simulated Gains at Various Frequencies

4.3.3 Measured Results through VNA



Marker 1 1.042328800 GHz

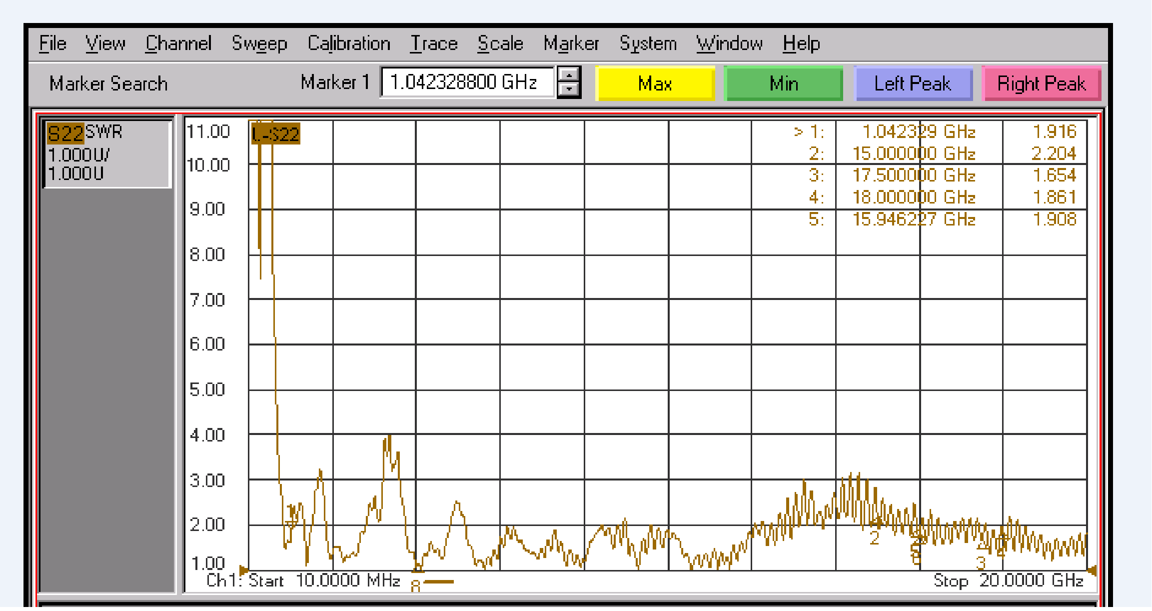
S22 Log Mag
10.000dB/
0.000dB

> 1:	1.042329 GHz	-10.04 dB
2:	15.000000 GHz	-8.531 dB
3:	17.500000 GHz	-12.07 dB
4:	18.000000 GHz	-10.44 dB
5:	15.946227 GHz	-10.11 dB

Ch1: Start 10.0000 MHz

Stop 20.0000 GHz

Figure 4.13 S11 Curve



Marker 1 1.042328800 GHz

S22 SWR
1.000U/
1.000U

> 1:	1.042329 GHz	1.916
2:	15.000000 GHz	2.204
3:	17.500000 GHz	1.654
4:	18.000000 GHz	1.861
5:	15.946227 GHz	1.908

Ch1: Start 10.0000 MHz

Stop 20.0000 GHz

Figure 4.14 VSWR

CHAPTER NO. 5

WILKINSON POWER DIVIDER

Wilkinson power divider is a specific class of power divider that can split an input signal in to two equal phase output signals. It can also combine two equal phase signals into a single signal in the opposite direction. In 1960, Ernest J. Wilkinson was the first scientist to publish about this divider. The divider was later on named after him.

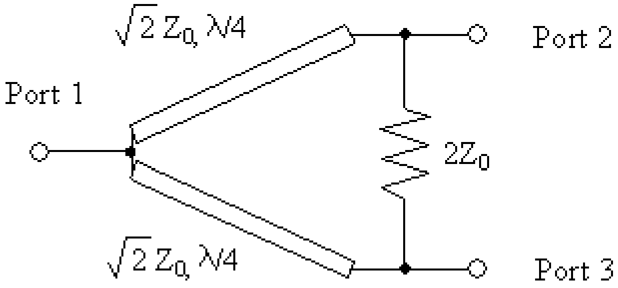


Figure 5.1 An Equal Divide Two port Wilkinson Power Divider

5.1 UWB Wilkinson Power Divider

5.1.1 HFSS Model

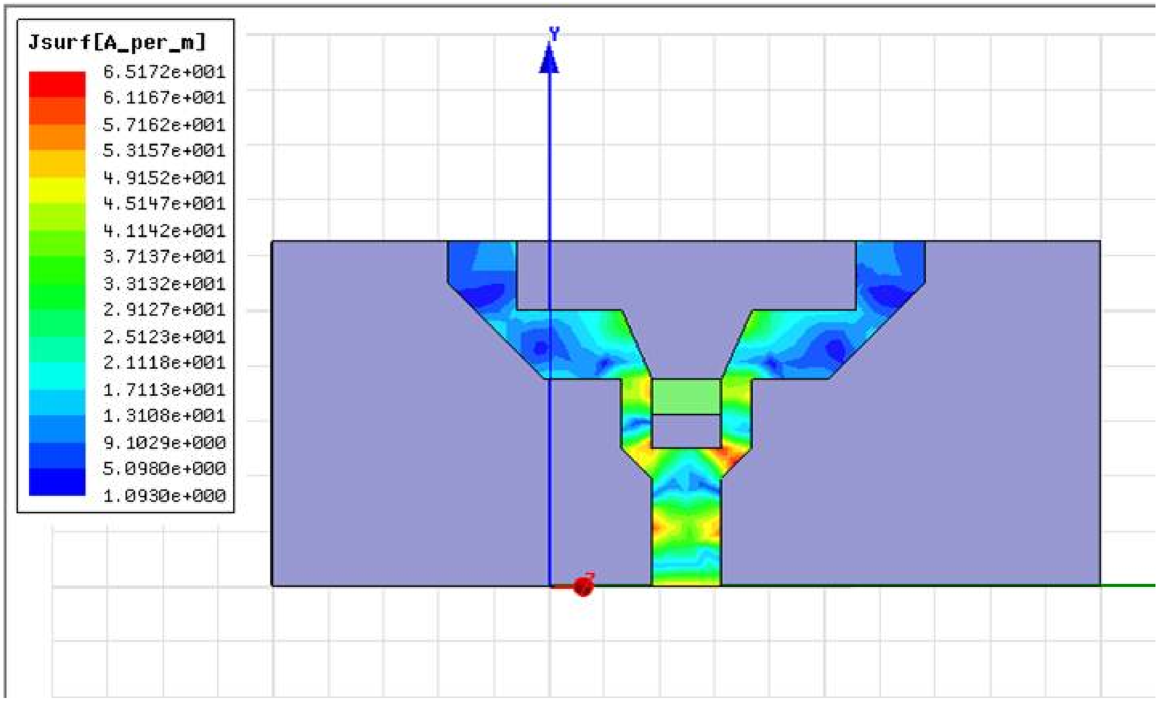


Figure 5.2 Wilkinson Power Divider Resonating from 1-15 GHz

5.1.2 Reflection Coefficient Curves

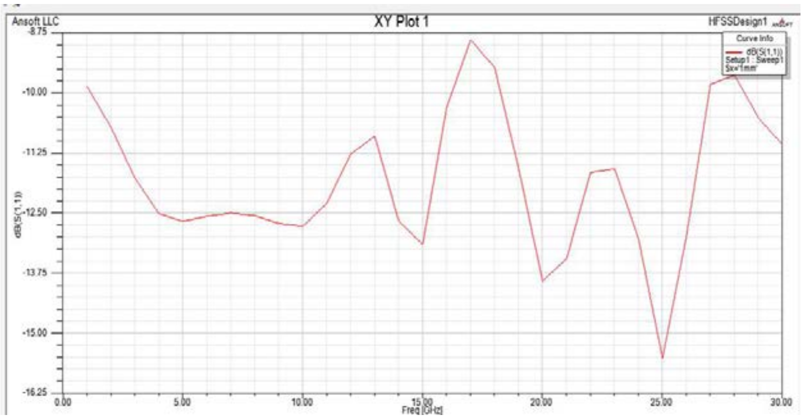


Figure 5.3 S11 Curve of Wilkinson Power Divider

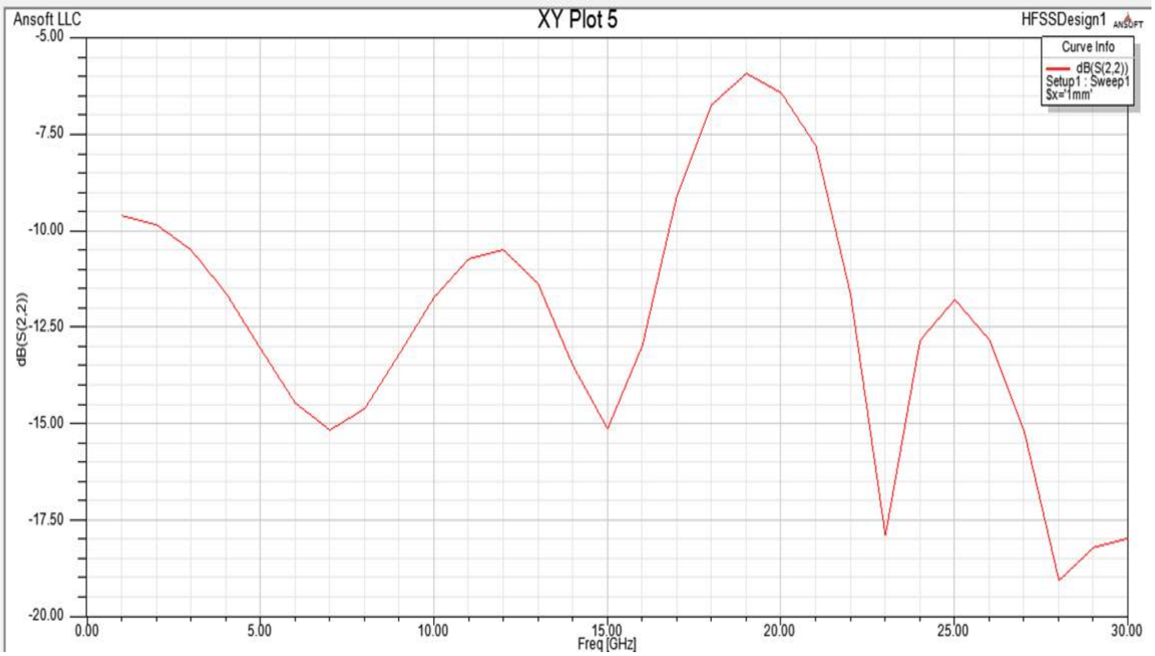


Figure 5.4 S22 Curve of Wilkinson Power Divider

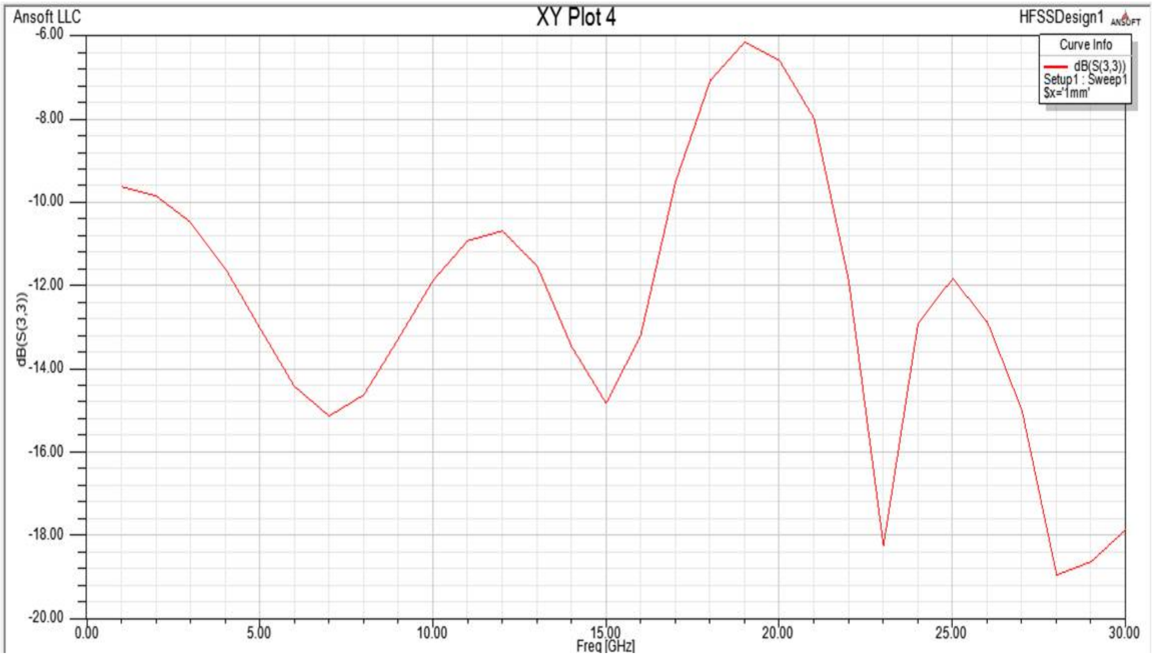


Figure 5.5 S33 Curve of Wilkinson Power Divider

5.1.3 Coupling Coefficients Curves

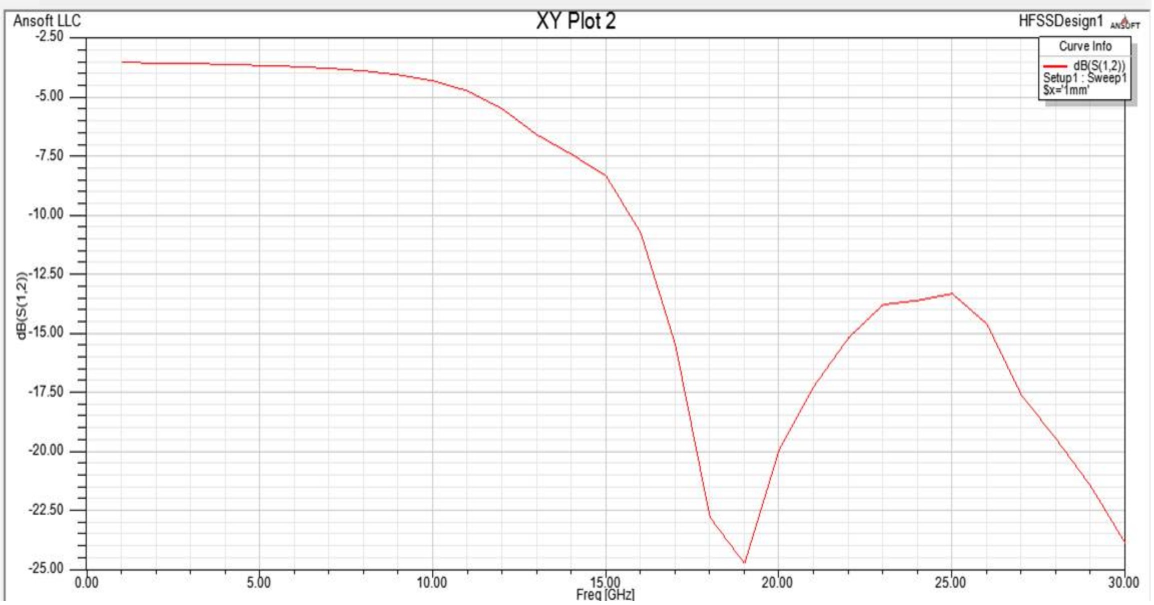


Figure 5.6 S12 Curve of Wilkinson Power Divider

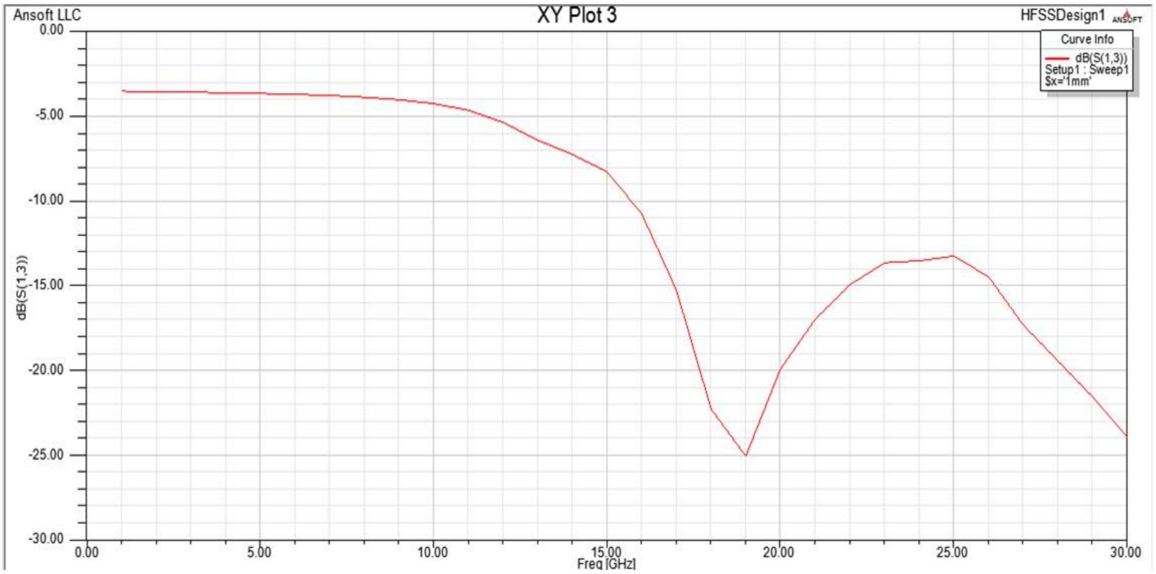


Figure 5.7 S13 Curve of Wilkinson Power Divider

CHAPTER NO.6

FUTURE PROSPECTS

Employment of UWB antenna technology is remarkably increasing as new and new communication devices are vastly being employed for commercial use. Proposed and fabricated UWB antenna is a viable solution for almost all of the communicational devices front ends which are currently operative from 1 GHz till 15 GHz (50% of Microwave band). To make current antenna design more attractive and adaptable, much research work is still needed to be done.

Future research work may include UWB antenna in different shapes and sizes with greater emphasis on miniaturization of antenna's surface area. Current fabricated antenna is more than one quarter foot in size, which makes it comparatively less well competitor than other frequency specific smart antennas. Moreover, applications which need directive flow of information and greater directivity are also not well supported by fabricated UWB monopole antenna. Gain is also another important factor which plays vital role in low earth orbit satellites and radar platforms which is not comprehensively addressed by Monopole antenna technology.

Monopole antenna technology might look very impressive in achieving greater band width in terms of reflections and positive gain but few inherent disadvantages comes along with it such as lesser magnitudes of gains and directivity which makes them lesser efficient radiators/receivers in terms of their capabilities to detect EM wave from a distance. Hence greater work is required to combat these inherent weaknesses of Monopole.

These problems might demand new ways and techniques to overcome them. Monopole UWB antenna technology might not be the solution every time. Hence new types of planar antennas must be explored which can offer same impedance matching capability as Monopole yet providing better gain, directivity and radiation efficiency in terms of distances. These new planar antenna technologies must also be more flexible in term of their sizes and shapes which shall make them a better competitor with to date frequency selective planar antennas.

Another important and vital aspect of UWB antenna technology is when they are being used as frequency selective receivers. There are such communication systems which while reception only desires that intended signal and EM radiation. Hence either changes in shapes or slots may be incorporated to reject undesired bands. Filters may also do the job of rejection instead of UWB antenna, but this will make the system complicated.

If such UWB antennas could be developed, they would have the capability to replace entire currently employed antennas in traditional microwave communication devices. Starting from cell phones, smart phones, iPods, TV, satellites till front ends of entire communicational devices might be integrated with such antennas. These antennas may also one day extend their purpose of usage and could be used in applications such as energy scavengers and harvesters.

CHAPTER NO. 7

CONCLUSION

UWB antenna technology is one of the promising field of electromagnetic and antenna theory that shall pay huge dividends in future of microwave communication. This aspect of research needs thorough attention by local microwave researchers as its entire work could be done indigenously in Pakistan.

Monopole antenna solution of UWB usage might not be the only viable solution, hence new techniques of planar antennas must be investigated and employed to make this concept practically workable with current devices.

Conclusions based on research work done in order to achieve better impedance matching and positive gain for making antenna ultra wide band are as follow:-

i. Achieving greater bandwidth towards lower frequencies greatly affects the size of antenna i.e. size of antenna increases as frequency decreases.

ii. Gain of lower most frequency is lowest in UWB antenna

iii. Omni directional patterns are achieved only

iv. Range of antenna tends to decrease

v. Corporate UWB antennas require equal UWB power combiners/ dividers

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