Final Thesis

by Wajhee Nasir

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Microstrip Patch Array Antenna For X-Band Applications

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Submitted to the Faculty of Electrical Engineering, Military College of Signals, National University of Sciences and Technology in fulfillment for the requirements of a B.E Degree in

Telecommunication Engineering

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ABSTRACT

Low cost microstrip array antennas having high gain using corporate feeding techniques and Taconic dielectric as a substrate are used for GHz frequency range applications. To achieve compact dimensions, optimum design parameters have been selected for single element. These design parameters also provide with the best possible characteristics such as radiation efficiency as well as high gain. The antenna designed would be 1x4 array. Optimum feeding technique will be decided on the basis of various simulated antenna parameters. The antenna which will be designed will provide better return loss at frequencies between 9.5 GHz to 11.5GHz. Since, the antenna has a resonance frequency around 10GHz, this antenna is suitable for applications such as military radars, satellite communication, etc, operating in the X-Band which according to IEEE which stretches from 8 GHz to 12 GHz.

CERTIFICATE

It is hereby certified that the contents and form of the project report entitled "**Microstrip Patch Array Antenna for X-Band Applications**" submitted By

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have been found satisfactory as per the requirement of the B.E. Degree in Electrical (Telecom) Engineering.

Supervisor:
Associate Professor
Engr Fazal Ahmed
MCS, NUST

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DECLARATION

We hereby declare that no content of work presented in this thesis submitted in support of another award of qualification or degree either in this institution or in anywhere else.

DEDICATED TO

Faculty for their help

And our parents for their support

ACKNOWLEDGEMENT

We thank Allah Almighty for giving us knowledge and strength to accomplish this massive task successfully.

We would like to thank our project supervisor, Assistant Professor Engr Fazal Ahmed without whose support and encouragement; it would not have been possible to complete this project. We also thank and appreciate to our colleague for helping in developing the project with their abilities.

Last but not the least, we are very thankful to our parents, who bore with us in times of difficulty and hardship. Without their consistent support and encouragement, we could not have accomplished our targets successfully.

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List of Abbreviations

CST	Computer Simulated Technology
RX	Receiver
TX	Transmitter
dB	Decibel
VSWR	Voltage Standing Wave Ratio
EDA	Electronic Design Automation
HF	High Frequency
PCB	Printed Circuit Board
HFSS	High Frequency Structure Simulator

Chapter 1

PROJECT DESCRIPTION

1. PROJECT DESCRIPTION

1.1 Introduction

1.1.1 Microstrip Antenna

It is an antenna which consists of a very thin metallic strip called patch which is placed on a ground plane where the thickness of the metallic strip is restricted by the value $t << \lambda 0$ and the height is restricted by values $0.0003\lambda 0 \leq h \leq .05\lambda 0$ [12-14]. The microstrip patch is so designed that its radiation pattern is maximum normal to the patch. For a rectangular patch, the length L of the element is usually of the values between $\lambda 0 /3 < L < \lambda 0 /2$.

1.1.2 Patch Antenna

It is a type of radio antenna having a low profile, which can be mounted on a flat surface. It consists of a flat rectangular sheet called patch of metal, mounted over a larger sheet of metal called a ground plane.

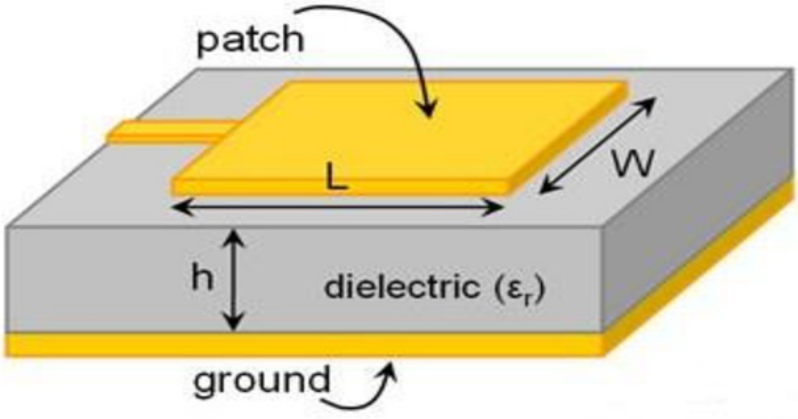

Figure 1 – Microstrip Patch Antenna

1.1.3 Array Antenna

It is basically a set or combination of two or more antennae to work together as a single antenna. The antennae signals are combined or processed in order to achieve improvement in the performance of antenna ,i.e., increase in gain.

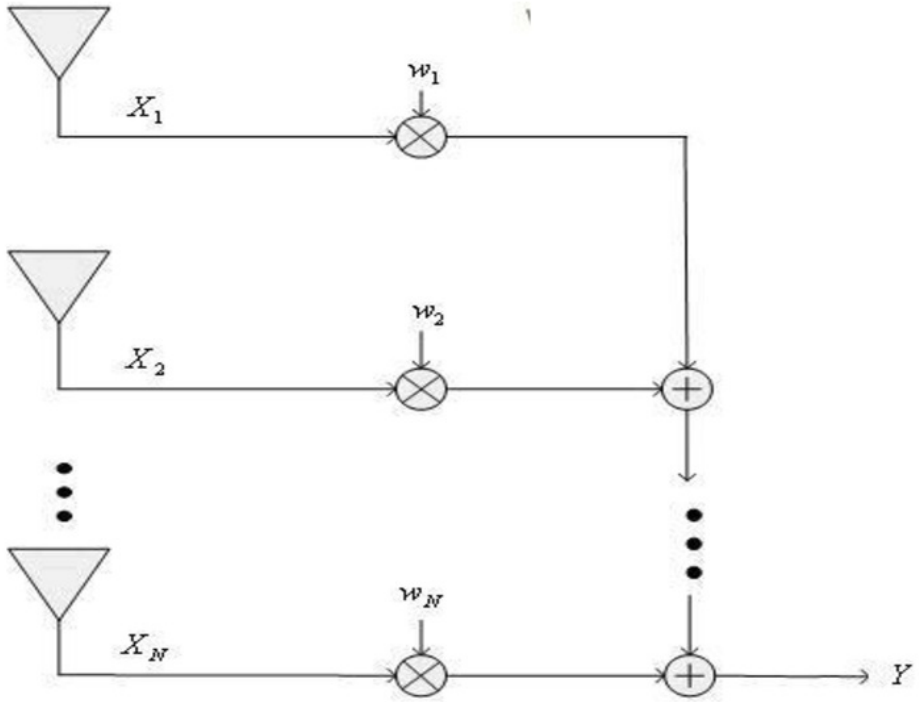

Figure 2 – Array Antenna

1.2 Background Study

1.2.1 Scope of Work

The scope basically involves the implementation of the knowledge of principles of antenna theory and software skills (HFSS and CST) to design a cost effective and light Microstrip patch array antenna for applications in the X-Band and will find its uses in satellite designing, medical applications and military systems. Figure below conceptualizes the model:

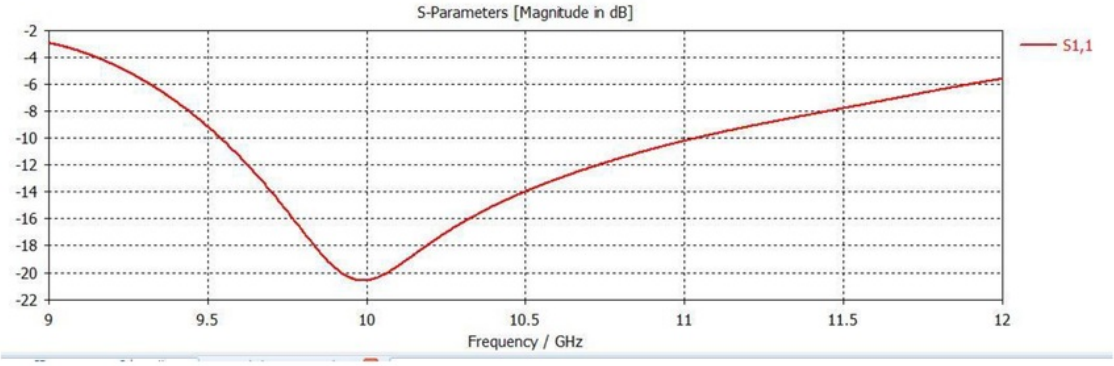

Figure 3 – Simulation of Antenna

1.2.2 CST (Computer Simulation Technology)

Computer Simulation Technology (CST) provides accurate 3D electromagnetic Electronic Design Automation (EDA) solutions for the mathematical (numerical) problems Maxwell Equations. It is the state of the art tool for the fast and accurate simulation of HF devices such as planar and multi layer structures, couplers, antennas and filters and are market leaders in Time Domain Simulations. It allows to completely test an antenna before using it on the actual device. We learnt regarding various functions of this software to use effectively for completion of our project.

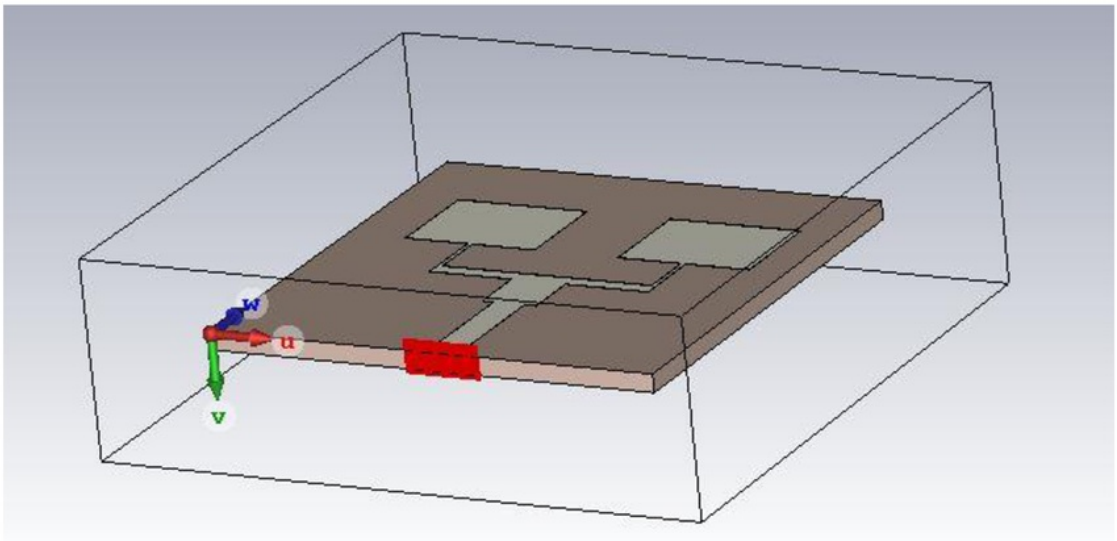

Figure 4 – Layout of CST Simulation of a 1x2 Array Antenna

1.3 Background

Wireless communication system of the modern era require high gain, light weight, cost effective and simply structured antennae to guarantee characteristics like reliability, mobility and high efficiency. Such requirements can be satisfied by Microstrip antennae. Microstrip antenna's are light weight, relatively easy to construct, low in cost and are conformable to the mounting surface. All of the advantages of printed circuit technology are provided by such antenna. Radars and satellites are some wireless communication related applications which use micrsostrip antennae due to the advantages they possess. A very low frequency bandwidth and lack of ability to operate at power levels which are of a higher order in waveguides are some of the limitations of microstrip antennas. Increasing the gain and bandwidth are therefore the challenges in designing microstrip antennas. Different array configurations are used to provide such characteristics as improved antenna efficiency, high gain and wide bandwidth. Among the elements of an array, the distribution of voltages is dependent upon the feeding network. This feeding network All induced voltages are accumulated to be fed into one point by the use of suitable feeding network. Configurations of corporate and series feeding arrays provide high efficiency through impedance matching of the highest possible degree. Corporate feed network can modify the power distribution among antenna elements. This feed can steer beam by introducing phase change. Antenna performance depends on the choice of design parameters (height , frequency and dielectric material, etc). It is very important. Substrates which are thick having dielectric of very low ranges offer optimum efficiency and bandwidth covering almost the entire band, but are having elements larger in size. Gain and high radiation efficiency in millimeter wave lengths is given by microstrip antenna containing uniaxial substrate with superconducting patch on them . Radiation efficiency and length of resonating microstrip antenna is reduced due to the width related discontinuities of such a micrsostrip patch. Various kinds of radar systems such as remote sensing radars, shuttle imaging radar, synthetic aperture radar (SAR) and other wireless communication systems operate in L, C and X bands. Microstrip antennae are the first option for high frequency bands such as X-band due to its light weight, robustness and low cost.

1.4 Problem Statement

To design and fabricate High Gain and Wide Band Microstrip Patch Array Antenna to find its usage for applications requiring a low cost, small in size and portable antenna with efficient connectivity. Integration of this antenna with such devices will enhance their capacity and working efficiency.

The project involves working on CST which will help in simulating the designing of antenna. Then fabrication of our final model of antenna and verify or testing our results of practical antenna with the results of CST.

The final product will be an antenna that operates in the X -band(8 GHz to 12 GHz) that finds its application in the satellite communication domain.

1.5 Proposed Application

The end product will be an optimized X-Band antenna with required band notch characteristics The designed and fabricated antenna will find its uses wireless applications like wireless monitors, camcorders and printers etc. In the modern era, seamless connectivity is the need of the hour. Therefore our antenna will try to provide this feature in a heterogeneous network. Pakistan Army is in dire need of acquiring indigenous and cost effective resources in the field of radars and satellite communication. This antenna will fill that void. Such antennae could be combined in array to design heterogeneous networks.

Chapter 2

SYSTEM DESIGN AND DEVELOPMENT

2. ANTENNA DESIGN AND FEATURES

The proposed system will have following features:

a. To cover entire X-band range i.e from 8 to 12 GHz

b. Low power

c. Enhanced bandwidth

d. Improved gain

e. Small size

f. Lesser Return Loss

2.1 Methodology

Initially we designed one element antenna and by varying its various parameters, we got better results. After that we converted this single element to array antenna by implementing second element as well. As the desired results were achieved we implemented two more elements in the array antenna. The final antenna shape was a 1x4 element microsrtip patch array antenna.. The Computer Simulation Technology (CST) was used to simulate and verify results of the proposed antennas.

2.2 DETAILED DESIGN

The antenna we have designed is a 1x4 array. The dimensions of a single element is 12.1 mm length and 9mm width. The dimensions of all the elements of the microstrip patch array antenna is 80 mm length and 40 mm width . The feeding technique used is commercial feeding technique. This specific feeding technique was selected due its

characteristics which provide low return loss as compared to proximity feeding technique or series feeding technique. To get the initial idea and concept of a microtrip patch array antenna, we followed a research paper, which implemented a microstrip patch antenna for some X-band frequencies. The proposed shape of the antenna in the research paper was a single element microstrip patch antenna.

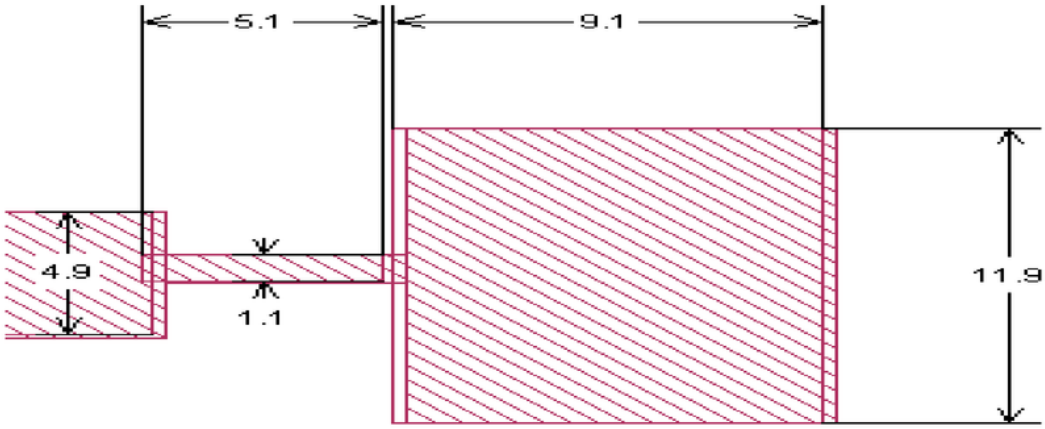

Figure 5 - Design in Research Paper

Above figure shows the designed antenna from the research paper.

Chapter 3

CST DESIGN AND RESULTS

3. CST DESIGN, HARDWARE AND RESULTS

After implementing the design on CST and optimizing the parameters we have achieved certain results which are discussed below.

3.1 Substrate Selection

The use of a good substrate in this microstrip patch array antenna design is a science in itself. Thin boards with high dielectric constants are desirable in microwave circuits because they reduce unwanted crosstalk, higher order modes and surface waves, yield smaller circuit sizes (therefore increasing design efficiency), and prevent radiation losses. On the other hand, a lower dielectric constant of around 2.2 with a thicker substrate is preferred for the patch antenna to achieve high gain, larger bandwidth and overall greater efficiency. Before any thought was given to what substrate properties will suit the needs of this application, it is already apparent that at high frequencies, a substrate with measurable and consistent parameters is necessary in order to establish any kind of benchmark. FR-4, possibly the most popular substrate using in the electronics industry today, typically has a permittivity of 4.5 with a certain variance, and comes in various thicknesses, the FR4 epoxy glass substrates are most efficient for most PCB applications. The material has a very low cost and mechanical properties are also excellent, making it an ideal choice for a wide range of electronic component applications. As more and more microwave systems are being developed which are aimed at consumer markets, a considerable interest is developing in minimizing the cost of these systems.

Since it is easily available in market and is cheap, it stood out as the best choice to use it for implementing our design. After conducting the study of different designs from the various IEEE research papers we decided FR4 to be our substrate of choice to implement our design.

3.2 CST design

Since we have selected very simple designed which is easy to fabricate. Firstly we have made our design on CST software and achieved our desired results.

CST design of the antenna is shown below

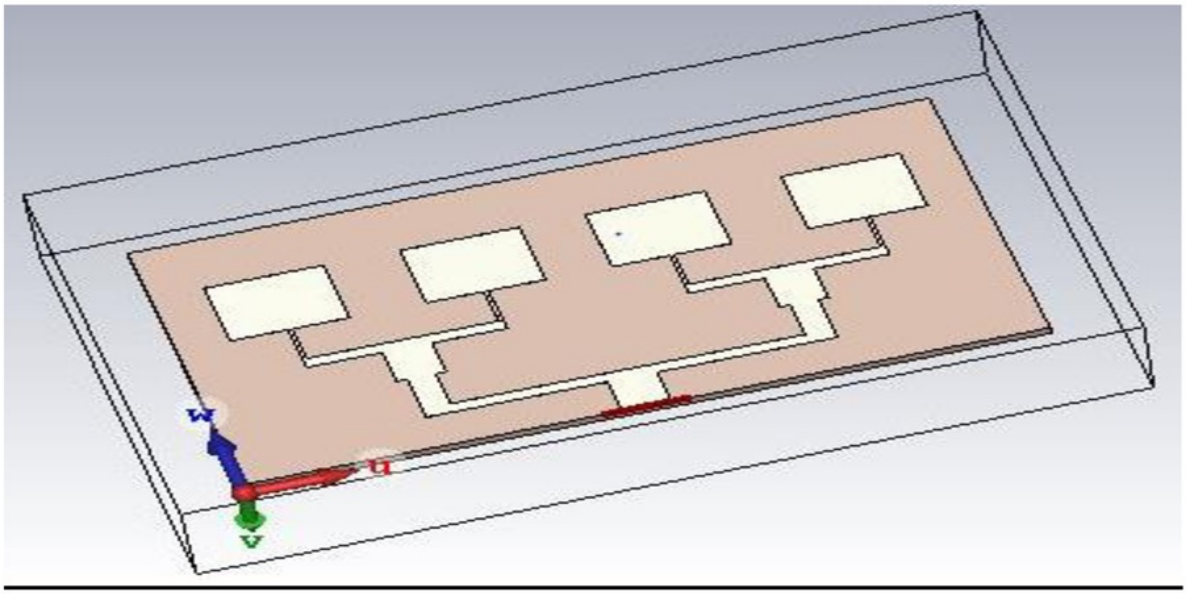

Figure 6 - CST Design

3.3 RESULTS

To achieve certain results, we had to optimize the dimensions as per our requirement of the project. Simulated results are as shown

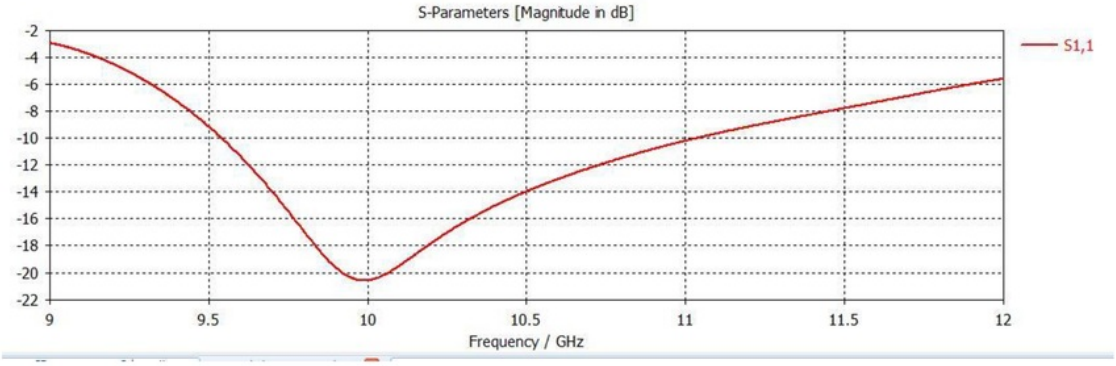

Figure 7 - S(1,1) Parameters of Antenna

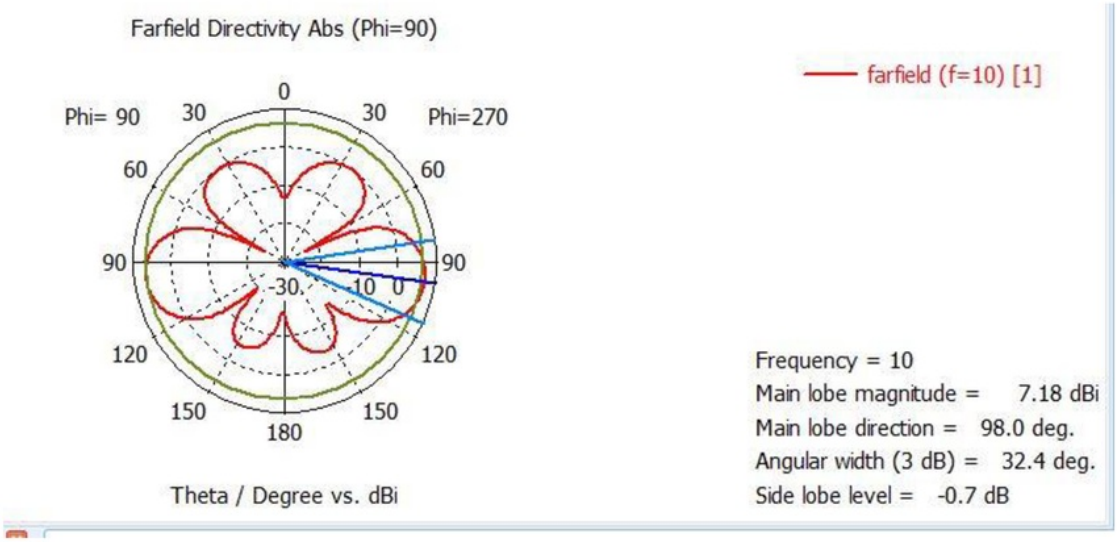

Figure 8 - Far Field Directivity of Antenna

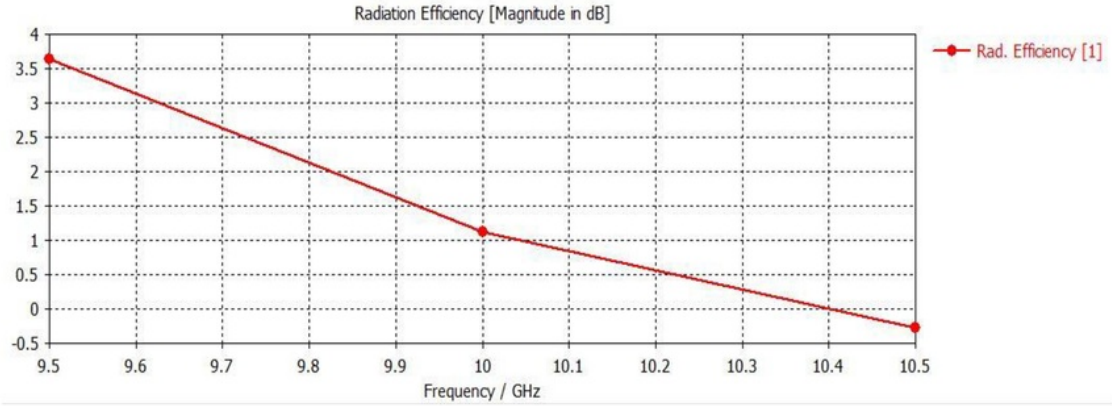

Figure 9 - Radiation Efficiency

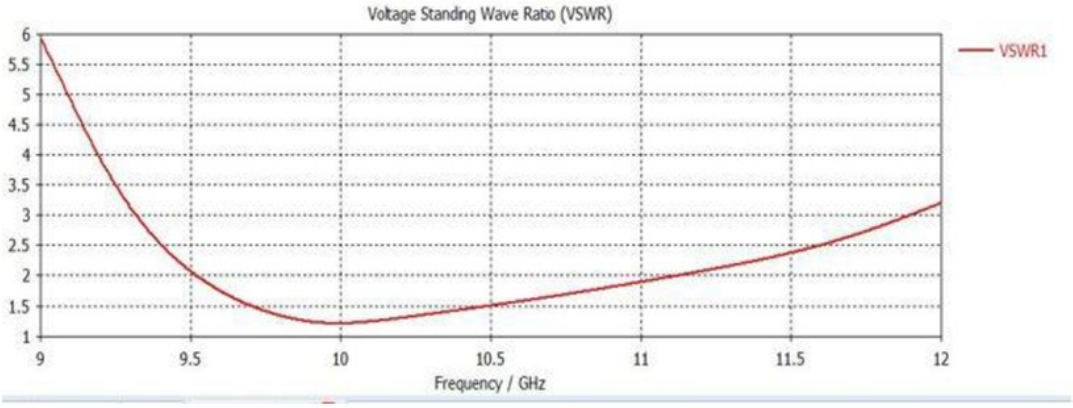

Figure 10 - VSWR

Chapter 4

HARDWARE INTEGRATION, FABRICATION AND RESULTS

4.1 HARDWARE IMPLEMENTATION

After the simulated results were achieved, the antenna was fabricated and tested for compliance for results in RF lab MCS as shown below:-

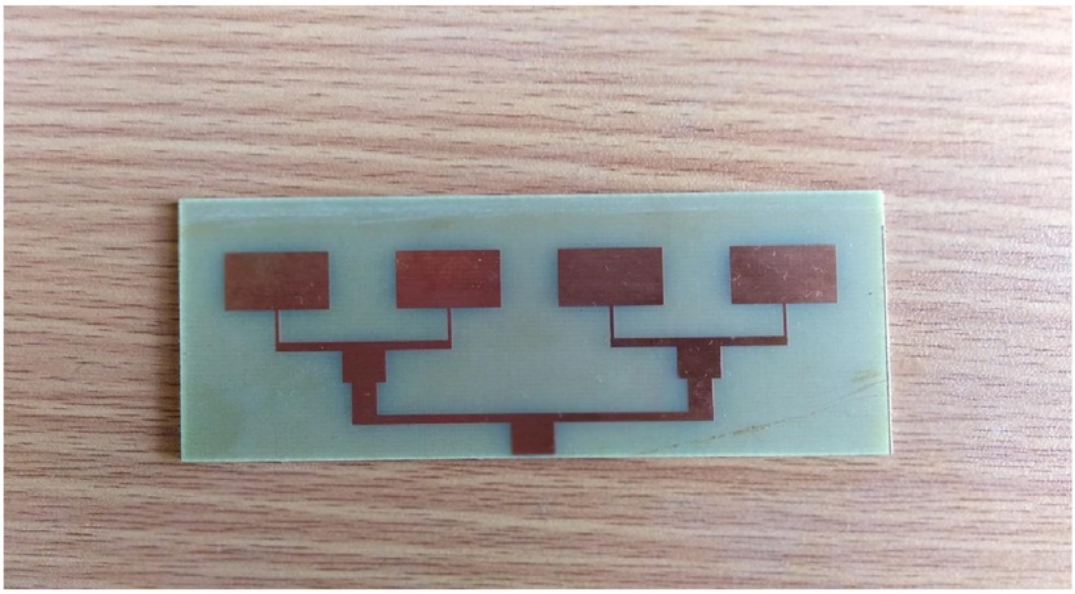

Figure 11 - Antenna Front side

All fabricated antennas showed acceptable results which were very close to the simulated results.

First the antenna was simulated and fabricated using FR4. The actual results were close to the

simulated results. The final antenna design was fabricated in at the NIE (National Institute of Electronics).

Measured results are meet the desired requirements of our design and are very close to the simulated results.

Chapter 5

FUTURE PROSPECTS AND CONCLUSION

5.1 FUTURE PROSPECTS

Since antenna is covering the entire X band as its frequency starts from 8 GHz to 12 GHz. So, further improvements can be implemented to increase its bandwidth. As we have used FR-4 Substrate which is easily available in the market for the implementation of our design, it is a lossy material and do not provide better gain as compared to the other substrates, so the design can be implemented using other substrates which will enhance gain. By applying different more accurate techniques available in the literature, size of the antenna can be considerably reduced.

5.2 CONCLUSIONS

For this project a wideband microstrip patch array antenna was proposed, designed, simulated, constructed and tested. The antenna has very high application for the devices using X band as radars, satellites, motion detectors and automatic traffic signals. Since array antenna uses multiple antennas there is a greater requirement of isolation between antenna elements, which we have achieved in our project by applying different tested techniques available in the literature.

Since wide band array has vast applications in upcoming future technologies like modern radars, satellite communication systems, GPS, WiMAX systems, military radars etc, considerable work can be done by increasing the no of elements in the antenna and especially reducing the size so that it should be compatible with handheld and portable devices.

Chapter 6

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CHAPTER 7

ANNEXURE

Microstrip Patch Array Antenna For X-Band Applications

Extended Title: Design and development of the High Gain and Wide Band Microstrip Patch Array Antenna.
Brief Description of The Project / Thesis with Salient Specs: Modern wireless communication system requires light weigth, low profile, simple structure and light weight antennas to assure mobility, high efficiency and reliability, characteristics. Such requirements are satisfied by Microstrip patch array antenna. The key features of such an antenna are light weight, low cost and relative ease of construction. All advantages of PCB technology are provided by this antenna.
Scope of Work : The project basically involves the design of hardware architecture of microstrip patch array wideband antenna by reducing the size and increasing the operating band. The final design will be tested and practically implemented for X band. The project will be completed by June 2017.
Academic Objectives :

The project will involve:

- Understanding and use of CST Software
- Antenna Theory

Applications / Objectives :

The main goal of this project is to create microstrip patch array antenna which can be used for any portable indoor/ outdoor device which require greater bandwidth.

The antenna can be used for

- Radars
- Satellite
- Portable communication devices

Material Resources Required :

PCB for fabrication of antenna

No of Students Required :4

Special Skills Required :

CST Software

Final Thesis

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