Wideband MIMO Antenna for Mobile Phones

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ABSTRACT

The aim of Project “Wideband MIMO Antenna for Mobile Phones” is to make a dual port planar multiple-input multiple-output (MIMO) antenna with wide bandwidth. This MIMO antenna have achieved a wide bandwidth from 0.8 GHz to 3.5 GHz, fully covering the 2G bands of GSM900/GSMI800/GSMI900, 3G bands of TD-SCDMAIWCDMA/CDMA2000 and 4G (LTE) bands whereas the rest of antennas does not support all(2G,3G,4G) at once. Its Reference point is -6dB, which is much better than most of antennas. Besides, the envelope correlation coefficient and mean effective gain are also studied. The planar structure and good diversity performance make the MIMO antenna very suitable for mobile terminals like smart phones.

CERTIFICATE

It is hereby certified that the contents and form of the project report entitled" **Wideband MIMO Antenna for Mobile Phones"** submitted By 1) Captain WaqasJamshed2) Captain Abid Islam 3) Captain Rana Muhammad AliRahman4) Captain AnjumIqbal Khan have been found satisfactory as per the requirement of the B.E. Degree in Electrical (Telecom) Engineering.

Supervisor:
Associate Professor
Dr. Farooq Ahmed Bhatti
MCS, NUST

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DECLARATION

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

DEDICATED TO

Almighty Allah,

Faculty for their help

And our parents for their support

ACKNOWLEDGEMENT

Nothing happens without the will of Allah Almighty. We thank Allah Almighty for giving us knowledge and strength to accomplish this task successfully.

We would like to thank our project supervisor, Associate ProfessorDr. Farooq Ahmed Bhatti without whose support and encouragement; it would not have been possible to complete this project.

We alsothank and appreciate to our colleague for helping in developing the project and people who have willingly helped us 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

MIMO	:Multiple-Input Multiple-Output
GSM	:Global System for Mobile Communication
HFSS	:High Frequency Simulation Software
LTE	:Long Term Evolution
3G	:Third Generation
RX	:Receiver
WLAN	:Wireless Local Area Network
TX	:Transmitter
db	:Decibel
VNA	:Vector Network Analyzer
VSWR	:Voltage Standing Wave Ratio
ADS	: Advance System Design

Chapter 1

PROJECT DESCRIPTION

1. PROJECT DESCRIPTION

1.1 Background Study

With the rapid development of wireless communication technology, there is an increasing demand for high data rates and high reliability, which can hardly be satisfied by traditional communication technology. Recently, MULTIPLE-INPUT–MULTIPLE-OUTPUT (MIMO) technology has attracted much attention for its advantages of reducing multipath fading and increasing transmission capacity and reliability.

MIMO wireless systems, characterized by multiple antenna elements at the transmitter and receiver, have demonstrated the potential for increased capacity in rich multipath environments. Such systems operate by exploiting the spatial properties of the multipath channel, thereby offering a new dimension which can be used to enable enhanced communication performance.

While coding and signal processing are key elements to successful implementation of a MIMO system, the propagation channel and antenna design represent major parameters that ultimately impact system performance. As a result, considerable research has been devoted recently to these two areas. For example, assessing the potential of MIMO systems requires a new level of understanding concerning multipath channel characteristics. Furthermore, while we have extensive information concerning the behavior of antenna diversity in multipath channels, recent activity surrounding MIMO communications has exposed new issues related to the impact of antenna properties and array configuration on system performance.

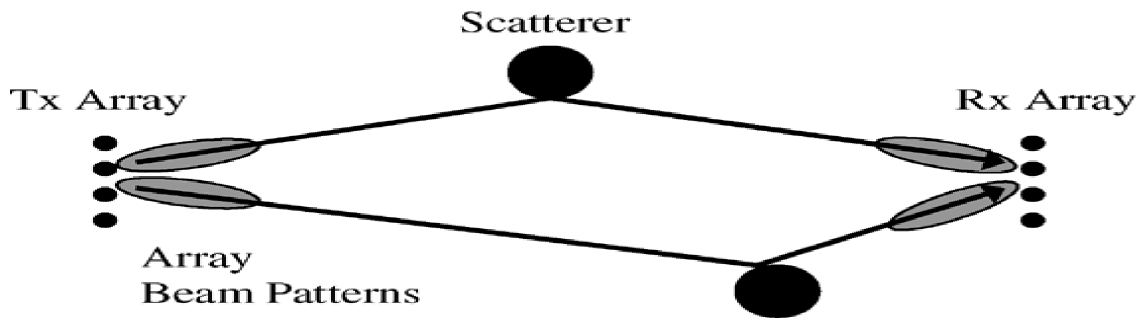


Figure 1 - Simple multipath propagation environment showing two paths between transmit and receive.

1.2. Problem Statement

To Design and fabricate a compact MIMO antenna covering all bands of 2G,3G and 4G (.8-3)GHz with enhanced gain.

The project involves working on HFSS 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 HFSS.

The final product will be an antenna that is operating in range of 0.8 GHz to 3 GHz which in future can be practically used in Smart Phones.

1.3. Proposed Application

In practical applications, multipath fading is a big challenge because signals transmitted from different transmission paths have different amplitudes and phases and they are likely to counteract each other at the receiver.This problem can be easily solved by using MIMO technology and multiple antennas in one system. Plenty of MIMO antennas designed for different communication systems and applications have been presented.

1.3.1 MIMO

MIMO (multiple input multiple output) is an antenna technology for wireless communication in which multiple antennas are used at both the source (transmitter) and the destination (receiver). The antennas at each end of the communications circuit are combined to minimize errors and optimize data speed. This principle can be used in a point-to-point multipath channel. For example, consider the scenario depicted in Fig. 1 which shows two propagation paths between a transmitter and receiver. If the arrays can resolve the two paths, the system can encode a unique data stream on each propagation path, resulting in an increase in communication capacity without an increase in required bandwidth. As typical wireless channels consist of many different closely spaced (in angle) paths, resolution of individual multi paths is often not possible.

Therefore, MIMO implementations must use more advanced array signal processing to exploit the channel spatial resources. Before discussing these concepts in more detail, however, we first define a model for the MIMO communication system to facilitate the presentation.

1.3.2 Why MIMO

MIMO has become an essential element of wireless communication standardsincluding IEEE 802.11n (Wi-Fi), IEEE802.11ac (Wi-Fi), HSPA+ (3G), WiMAX (4G), and Long Term Evolution (4G).

All wireless technologies face the challenges of signal fading, multi-path, increasing interference and limited spectrum. MIMO (multiple-input-multiple-output) technology exploits multi-path to provide higher data throughput, and simultaneous increase in range and reliability all without consuming extra radio frequency. It solves two of the toughest problems facing any wireless technology today, speed and range.

MIMO technology has also possible applications in digital television (DTV), wireless local area networks (WLANs), metropolitan area networks (MANs), and mobile communications.

1.3.3 MIMO role in this Project

Several MIMO antennas designed for 4G application are reported. These 4G MIMO are designed for wireless routers and 3G/4G indoor application. Neither of them is suitable for mobile phones because of their large sizes. A handset antenna based on ceramic material is proposed which presents a quad-band MIMO antenna with a modified PIFA structure. However, both of them adopt stereo structures and have significant heights, which make them less competitive with those antennas having planar structures as the mobile terminals and smart phones getting thinner and thinner. And some MIMO antennas with planar structures are designed for mobile terminals, but they don't have enough bandwidth to cover the bands of 2G/3G/4G mobile communication systems.

In this project, a dual-port wideband MIMO antenna for mobile phones is proposed. The proposed MIMO antenna element has a monopole operating around center frequencies and an SIR stub extending from the ground to generate lower resonant frequencies and broaden the bandwidth. Then a dual-port MIMO antenna is formed by symmetrically arranging two antenna elements on the substrate. In order to decrease the coupling between the antenna elements, a slot is etched on the ground and a neutralization line is connected with the two antenna elements. The simulated bandwidth of the proposed MIMO antenna is from 0.8 GHz to 3 GHz, covering the 2G/3G/4G mobile communication bands which are currently in use in Pakistan. The isolation, total efficiency, peak realized gain, envelope correlation coefficient and mean effective gain are also presented.

1.4 Methodology

The design of the MIMO antenna begins by choosing wide band antenna and adjusting its bandwidth according to our proposed project by applying appropriate technique to achieve isolation between the antenna elements.

The substrate adopted here is FR4 with relative permittivity of 4.4, dielectric Loss tangent of 0.02 and thickness of 0.8 mm. The goal of our design is to obtain a wideband to cover the 2G/3G/4G bands.

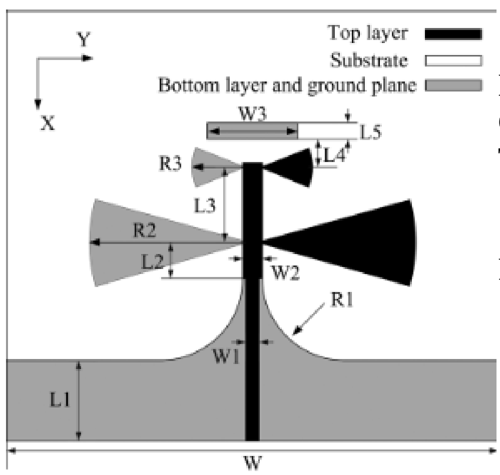
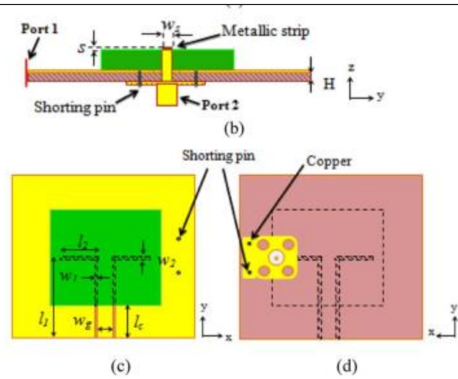
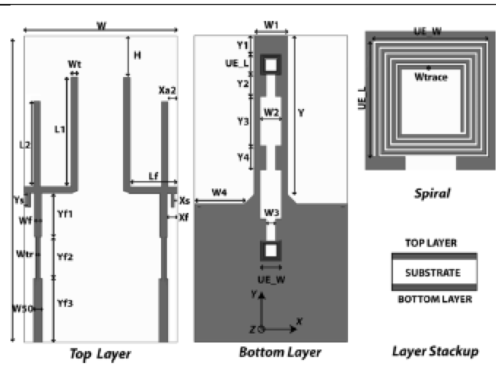
The High Frequency Structure Simulation (HFSS) software was used to simulate the proposed antennas.

Chapter 2

LITERATURE REVIEW

2. Different Existing Antennas with Deficiencies

Table 1 - Already existing antennas

<table>
<tr><td>a</td><td>
</td><td>Size: 26 x 60 x 1.6 mm^3
Substrate : FR4 (4.4) (0.02)
Band : WLAN 2.4 GHz and 5 GHz
Type : Dual band
S11: <-10 dB
S21: <-30 dB
Peak Gain: 4.5 dBi</td></tr>
<tr><td>b</td><td>
</td><td>Size : 70 x 70 x 1.6
Substrate: FR4 (4.4)(0.02)
Band : LTE 4G(2.09- 3.38)GHz for por1
(2.40- 3.09)GHz for por2
Type:
Single BandS11: <-10dB for (2.09-3.38)GHz
S22: <-10dB for (2.40-3.09)GHz
S21: <-20dB for (2-3.4)GHz
S12: <-20dB for   (2-3.4) GHz
Peak Gain: 4.5dBi at 2.6GHz</td></tr>
<tr><td>c</td><td>
</td><td>Size : 50 x 100 x 1.56
Substrate: FR4 (4.4)(0.02)
Band : LTE 4G (803- 823)MHz
(2.340- 2.9)GHz
Type: Dual Band
S11: <-10dB
S22: <-10dB
S21: <-17dB
S12: <-17dB
Peak Gain: - 4dBi for lower band
2.9dBi for upper band</td></tr>
</table>

2.1 Deficiencies

2.1.1 Deficiencies in system (a)

a. Dual Band not Wide Band
b. Covers only WLAN no 3G 4G Band
c. Complex Design

2.1.2 Deficiencies in system (b)

a. Single Band
b. Covers only 4G Band
c. Element 1 and Element 2 have different bands
d. Large Size
e. Complex Structure

2.1.3 Deficiencies in system (c)

a. Large Size
b. 4G Band
c. Dual Band
d. Low Gain
e. Complex Structure

Chapter 3

SYSTEM DESIGN AND DEVELOPMENT

3. ANTENNA DESIGN AND FEATURES

The proposed system will have following features which address deficiencies in existing antennas:

a. Compact Size

b. Novel Design

c. Covers 2G, 3G and 4G Bands (also Wi-Fi)

d. Wide Band

e. Improved Gain

f. Improved Isolation between antenna elements

g. Simple Structure

h. Easy to Fabricate

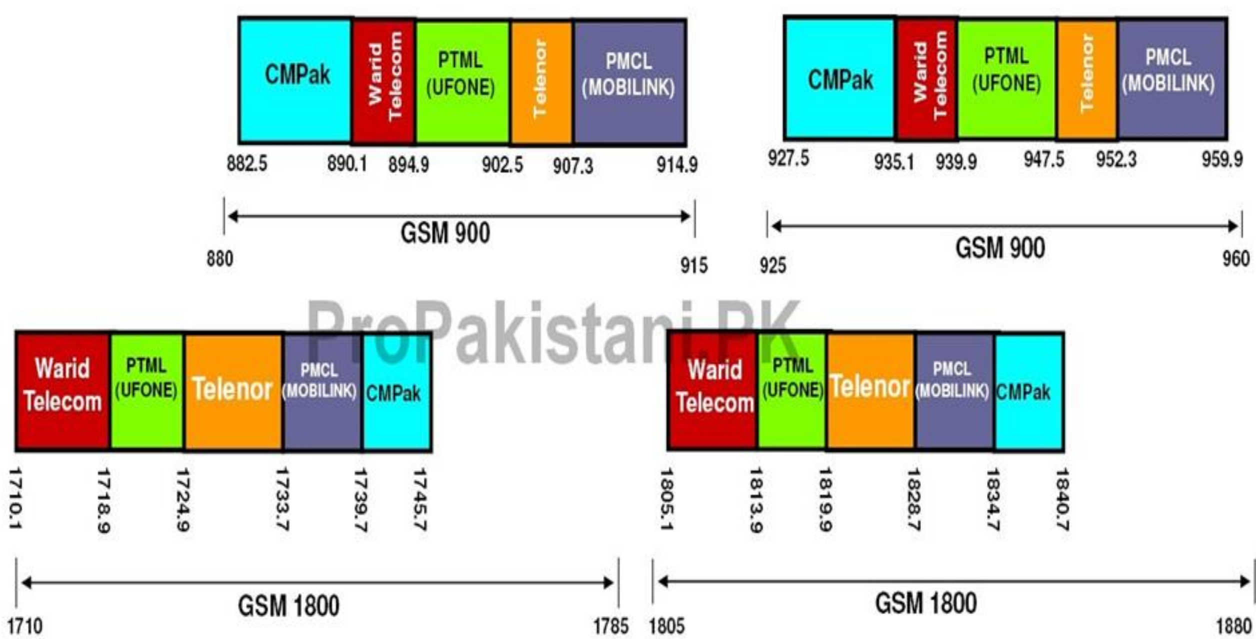


Figure 2 - GSM bands used in Pakistan

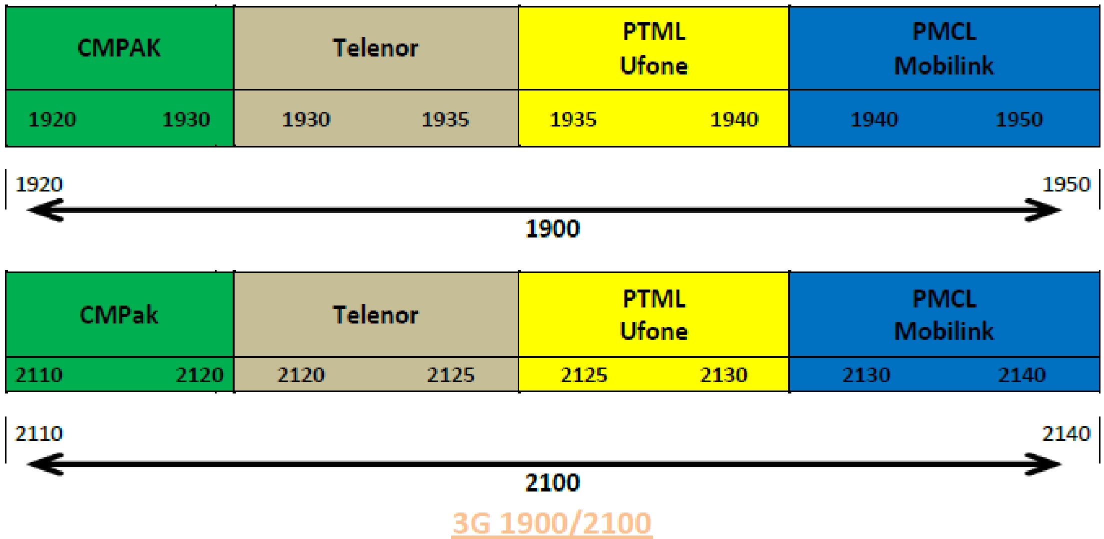


Figure 3– 3G band used in Pakistan

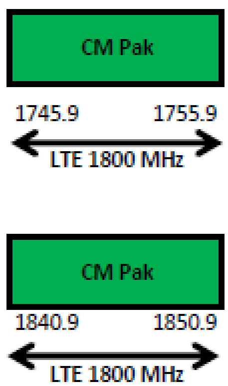


Figure 4- LTE Band Used in Pakistan

3.1 DETAILED DESIGN

At this stage our team moved on from the literature review and hardware selection phases to the implementation phase; although we already encountered some bottle necks and setbacks. Nonetheless, we will explain our design strategy, problem analysis and their overall pertinence to achieving our end goal. Keeping above features in view we have selected a design shown below

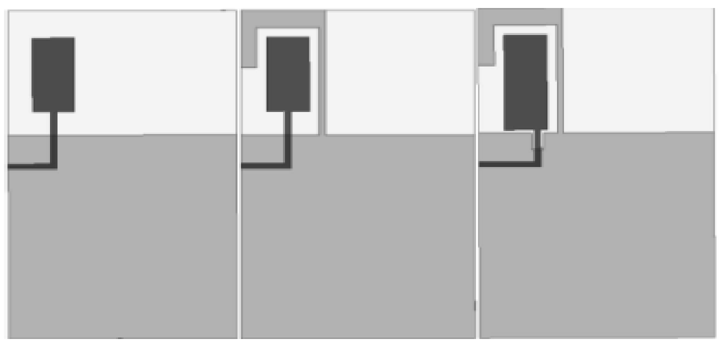


Figure 5- Suggested Design

Above figure shows the design steps of the MIMO antenna element. Firstly, a monopole with proper length and width is designed to operate around 1.8 GHz. The monopole is fed by a 50 ohm feeding strip. The simulated S parameter shows that the monopole has a wide bandwidth of -6 dB from 1.2 GHz to 2.38 GHz. Then an SIR stub extending from the ground is introduced to generate lower resonant frequencies and broaden the bandwidth. The SIR stub is coupling fed by monopole and the bandwidth is broadened from 0.84GHz to 2.68 GHz. In order to obtain better impedance matching, a rectangle part opposite the feeding line is cut from the ground and the parameters are also optimized, as shown in Fig. (2).

The final selected shape is shown below and dimensions are listed in the table with HFSS design.

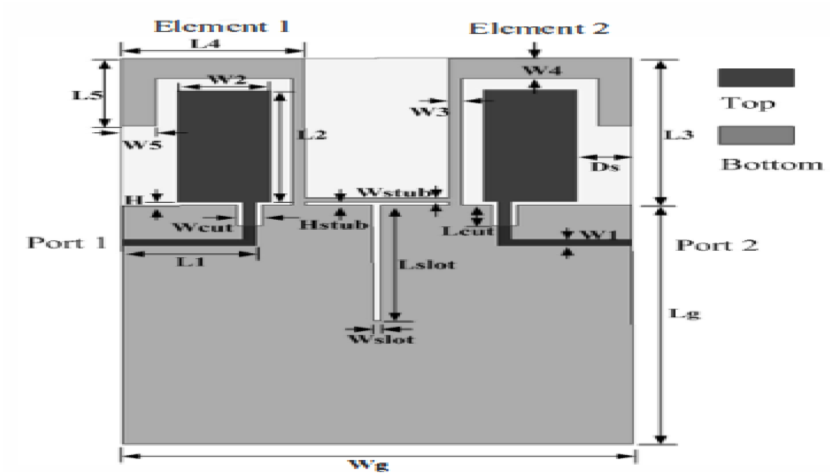


Figure 6- Final Selected Shape

Chapter 4

HFSS DESIGN AND RESULTS

4. HFSS DESIGN, HARDWARE AND RESULTS

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

4.1 Substrate Selection

The use of a good substrate in this microwave strip 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 thicknessesFR4 epoxy glass substrates are the material of choice for most PCBapplications. The material is very low cost and has excellent mechanical properties, making it ideal for a wide range of electronic component applications. As more and more microwave systems aimed at consumer markets are developed, there is a considerable interest in minimizing the cost of these systems.

Since it is cheap and easily available in the market, it became the best choice for us to use it for our design implementation. After studying different designs from the different research papers of IEEE we decided to implement our design using FR4 with 1mm thickness.

4.2 HFSS design

Since we have selected very simple designed which is easy to fabricate. Firstly we have made our design on HFSS software and achieved our desired results. Optimized parameters of the antenna are shown below

Parameter	l1	l2	l3	l4	l5
Value(mm)	15	31.5	41	23	17
Parameter	w1	w2	w3	w4	w5
Value(mm)	1	13	1.5	9	4.1
Parameter	Lcut	H	Hstub	Lslot	Lg
Value(mm)	5	0.1	0.5	30	56
Parameter	Wcut	Ds	Wstub	Wslot	Wg
Value(mm)	3	6.5	1.5	2	60

Table 2 Optimized Parameters

And HFSS design of the antenna is shown below

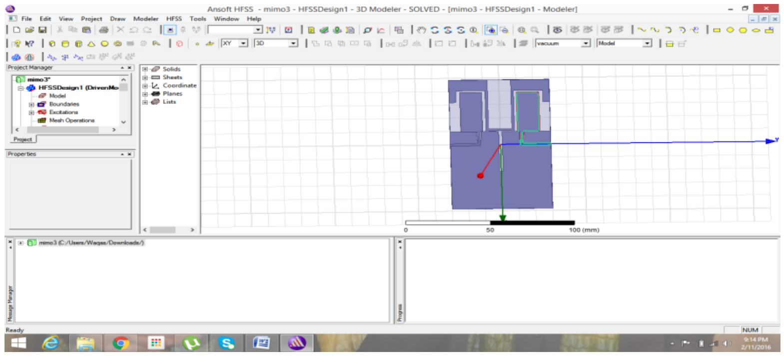


Figure 7- HFSS Design

4.3 RESULTS

After optimizing the dimension we have achieved certain results as per our requirement of the project. Since the size of the antenna is very small we have faced a lot of difficulty in achieving lower band. As we are working on MIMO there was a great challenge to achieve isolation between two elements which is shown in S(1,2). Gain of antenna was a great challenge because of the FR4 substrate limitation. Simulated results are as shown

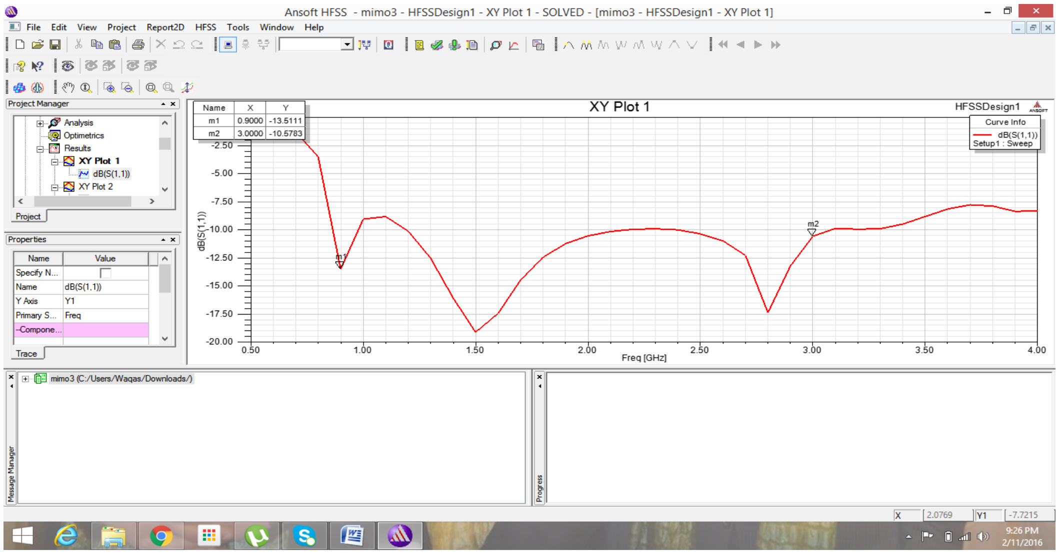


Figure 8 S(1,1) Parameters

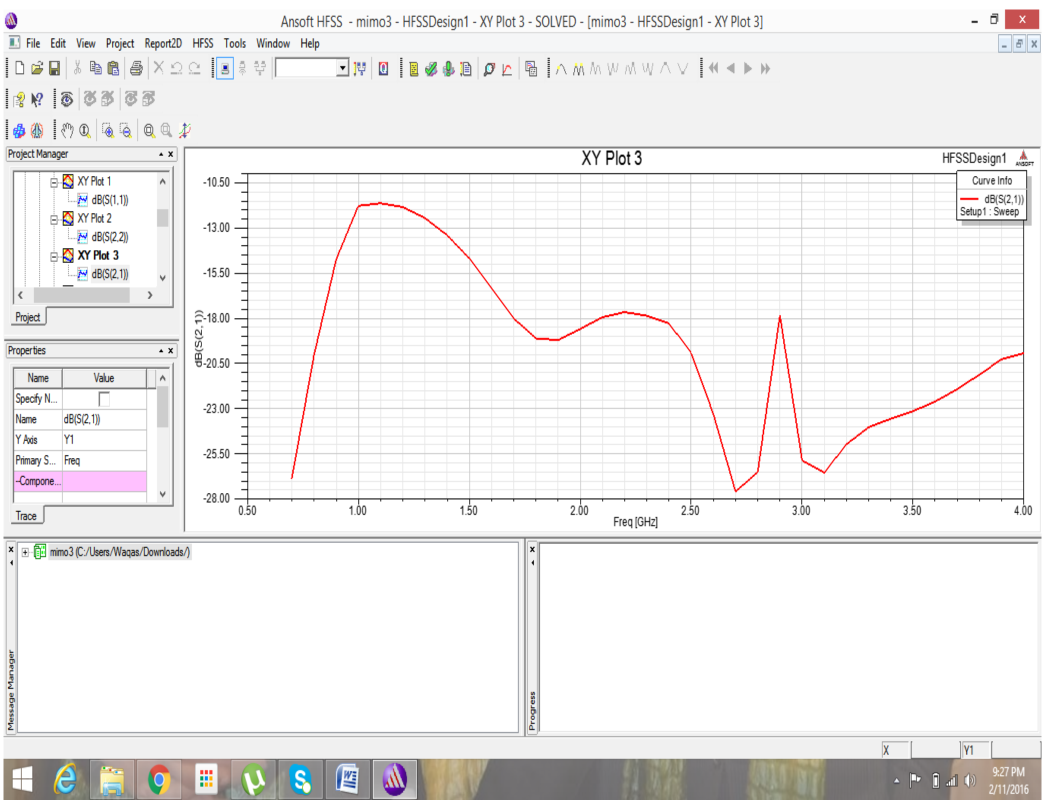


Figure 9 S(2,1) Parameters

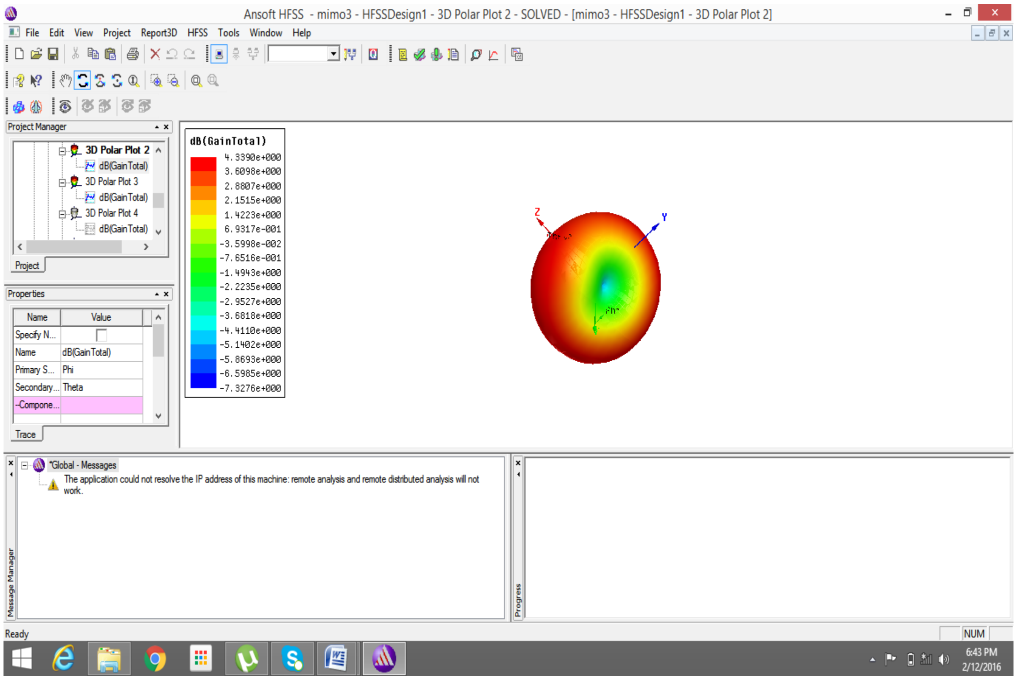


Figure 10- Gain at 0 .9 GHz

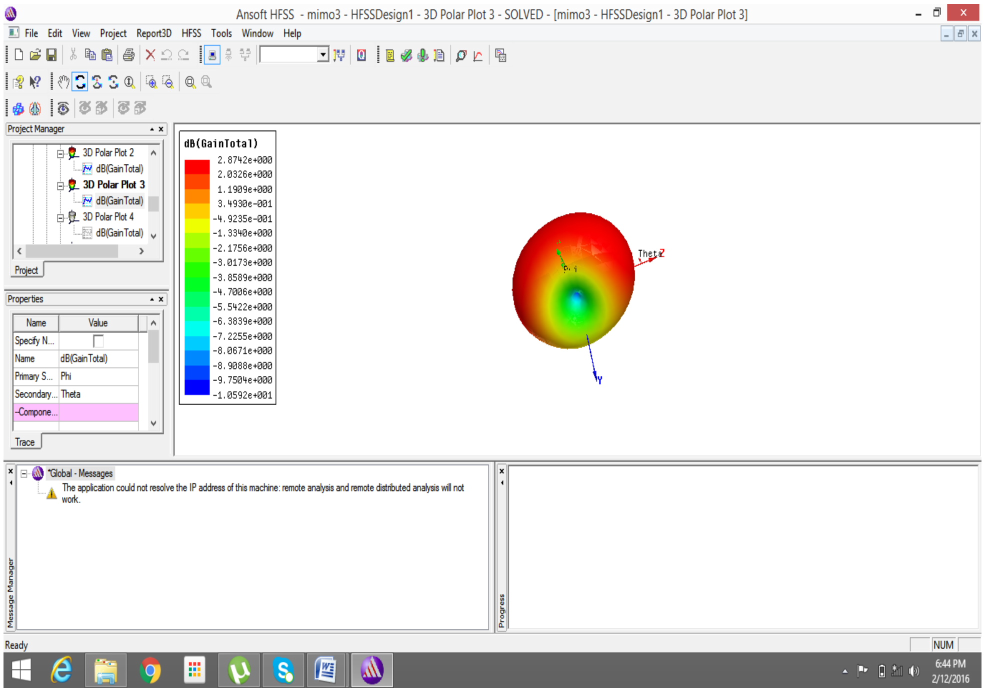


Figure 11-Gain at center frequency 1.8GHz

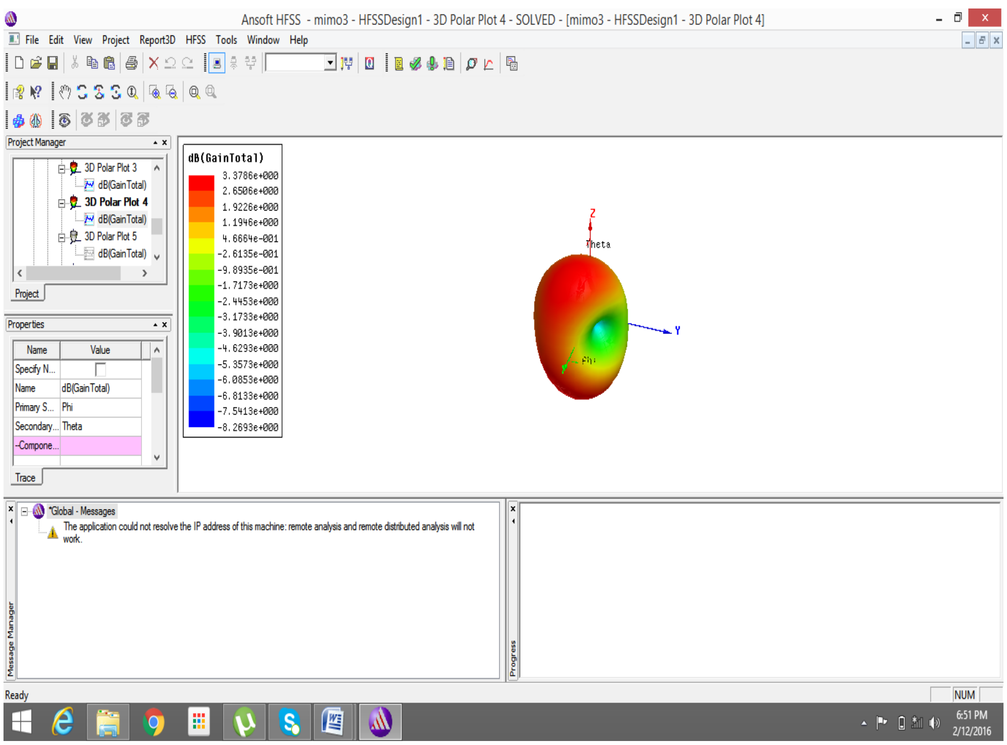


Figure 12- Gain at 2.1GHz

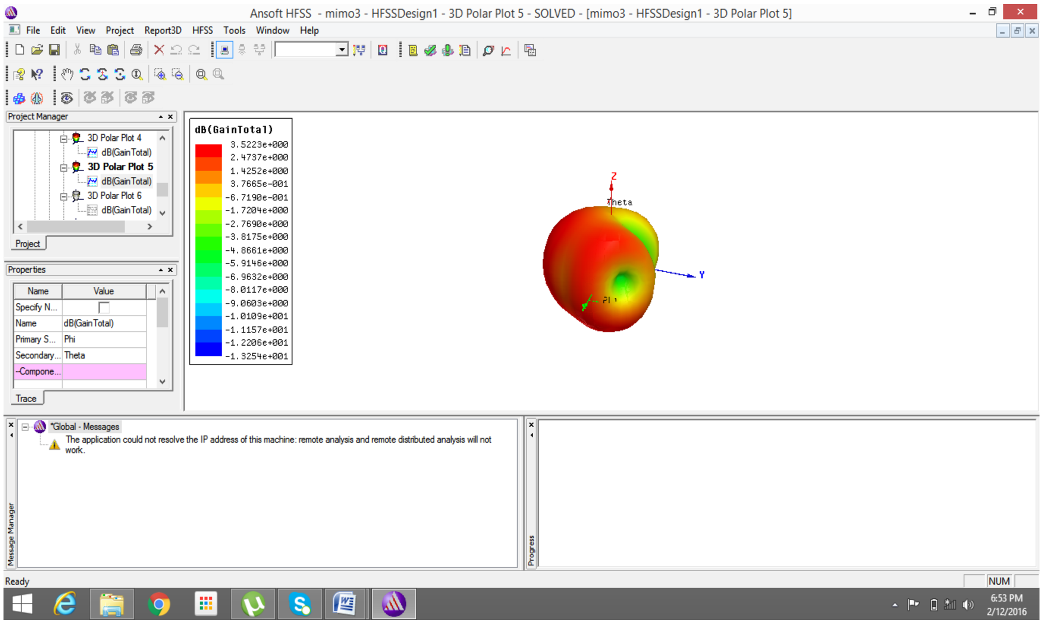


Figure 13 - Gain at 2.7GHz

Chapter 5

HARDWARE INTEGRATION, FABRICATION AND RESULTS

5.1 HARDWARE IMPLEMENTATION

After achieving the simulated results antenna was fabricated in RF lab MCS and tested in the same lab as shown below:-

Figure 14 Bottom side using FR4

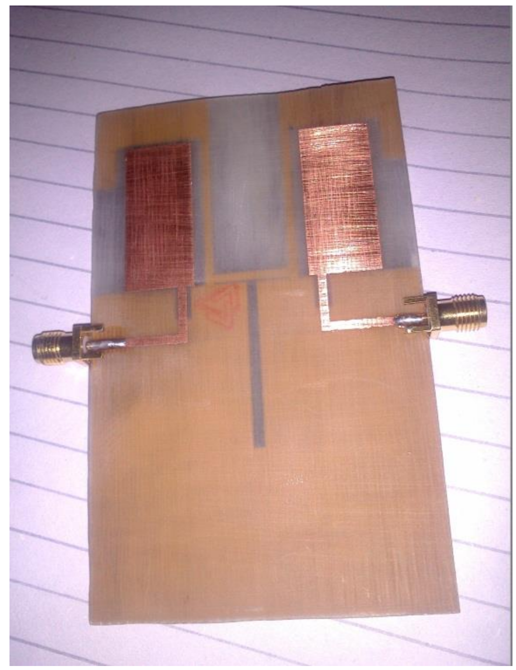


Figure 15 TOP side using FR4

All fabricated antennas showed acceptable results which were very close to the simulated results. First the antenna was simulated and fabricated using FR4 with .8mm thickness. The actual results were close to the simulated results but did not matched 100% of the simulated results. Then new substrate tectonic was selected and all the parameters were optimized keeping the same design. The antenna was fabricated in RF MCS lab All the results were achieved as per the simulated results except the lower band i-e .8GHz to .95 GHz. Final antenna design we got fabricated from the NIE and the substrate FR4 with

.8mm thickness was not available. Then we simulated the antenna design on FR4 1mm thickness and got it fabricated from the NIE(National Institute of Electronics).

Figure 16- Bottom side using FR4

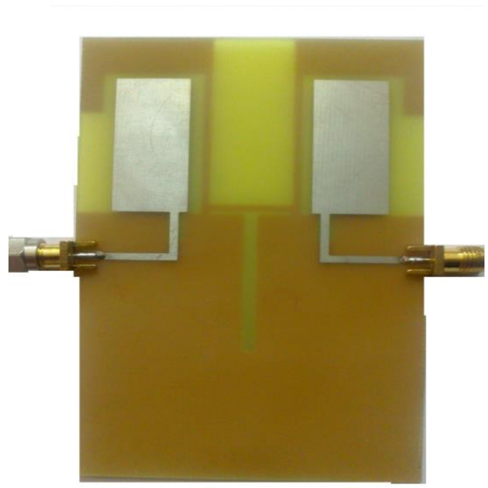


Figure 17- Top side using FR4

Some initial testing results in MCS showed acceptable match with simulated which are demonstrated in a short video clip. However antenna was tested in the RF and Microwave lab at NIE. Measured results are very close to the simulated results and meet the requirement of our design. After that measured and simulated results were ploted using MATLAB as shown below

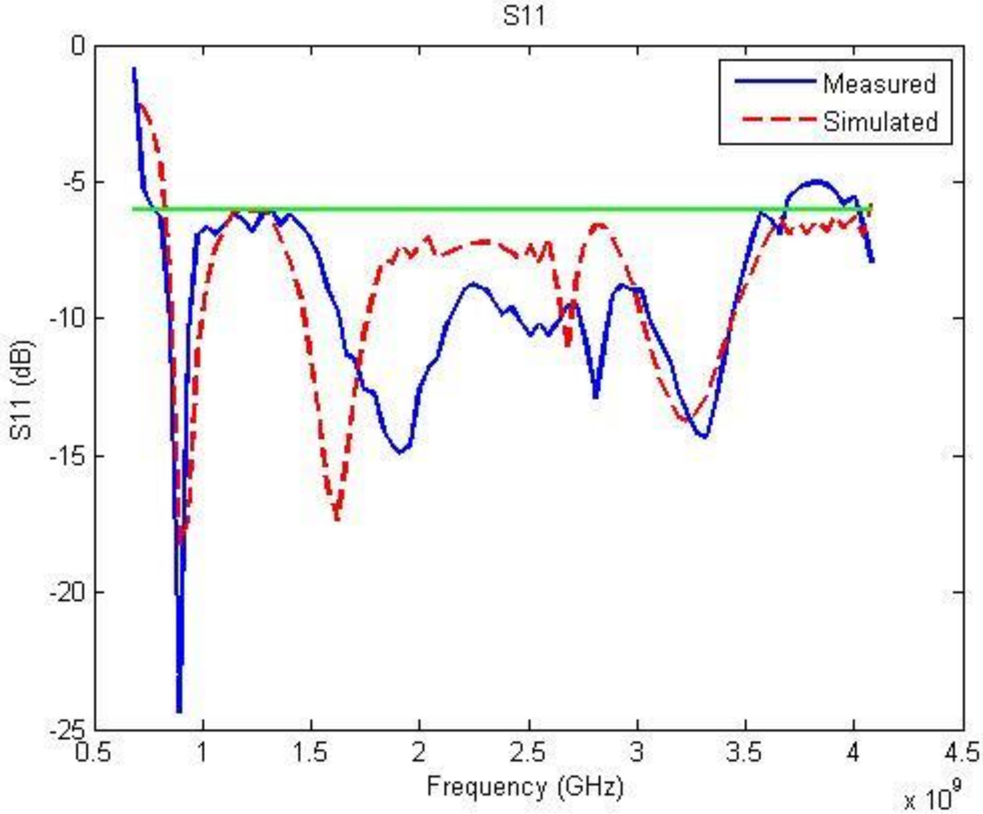


Figure 18 Measured and Simulated S11

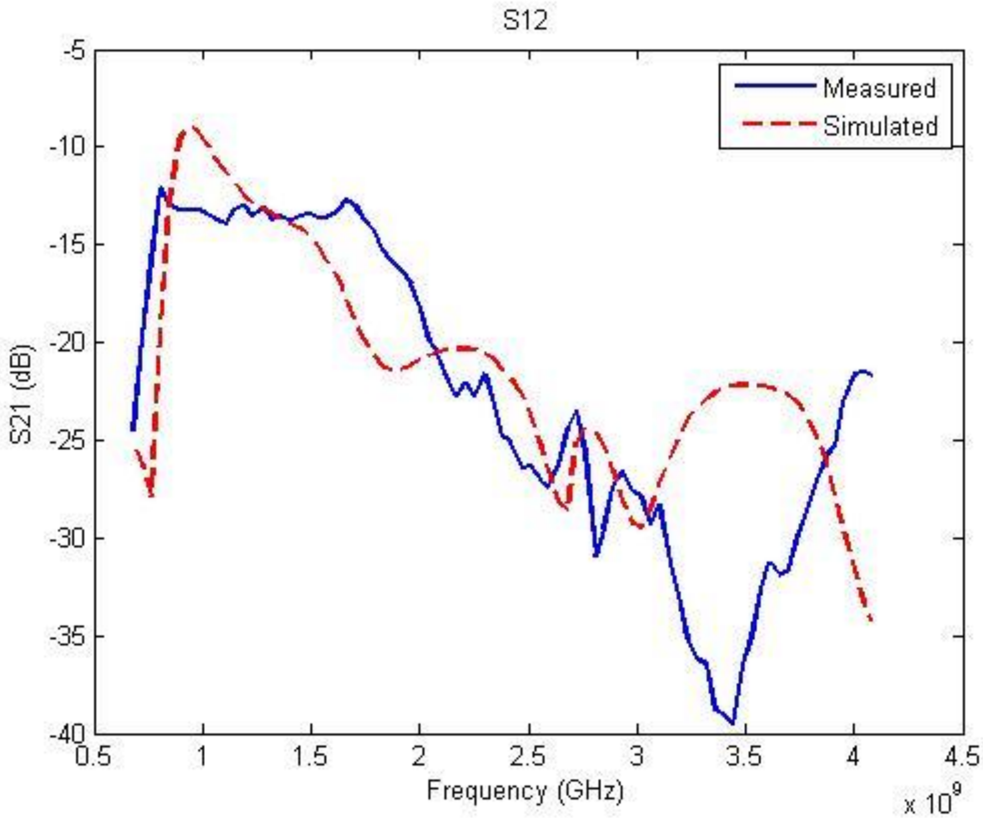


Figure 19 Measured and Simulated S12

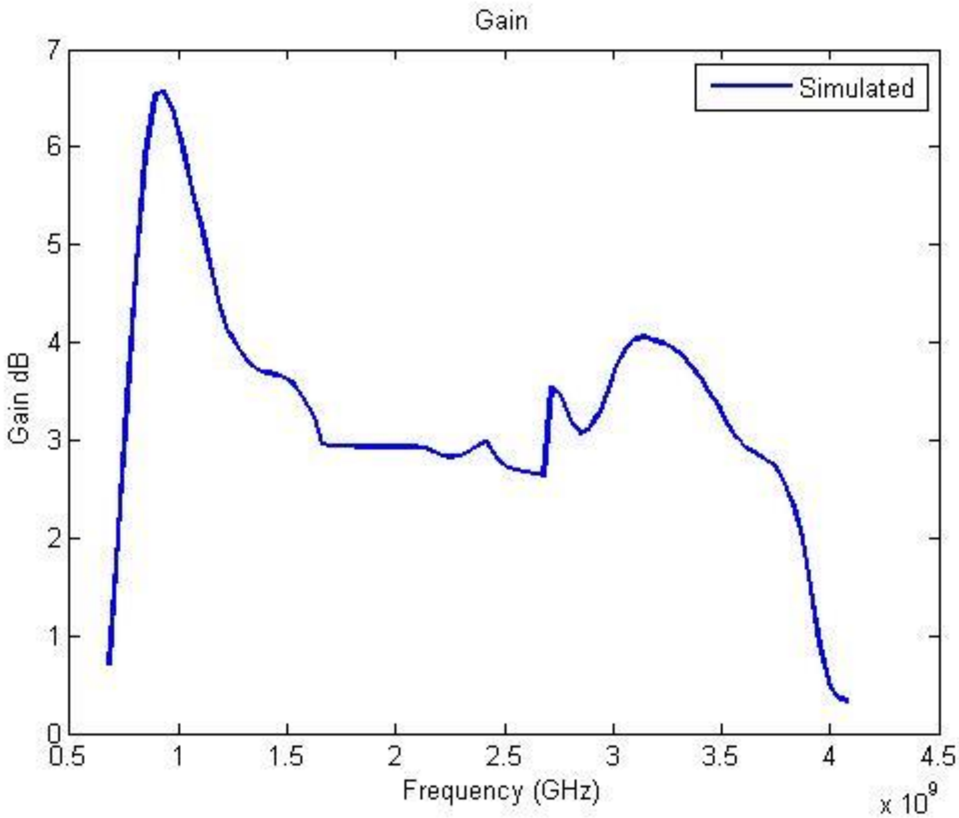


Figure 20 GAIN

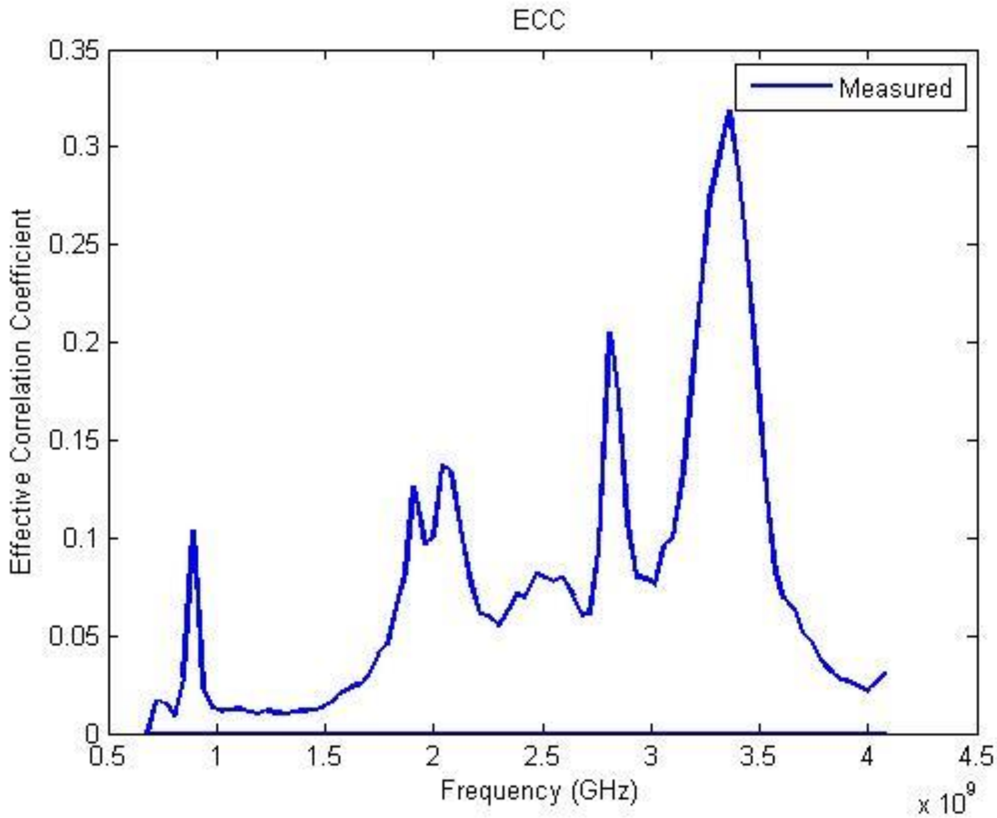


Figure 21 ECC

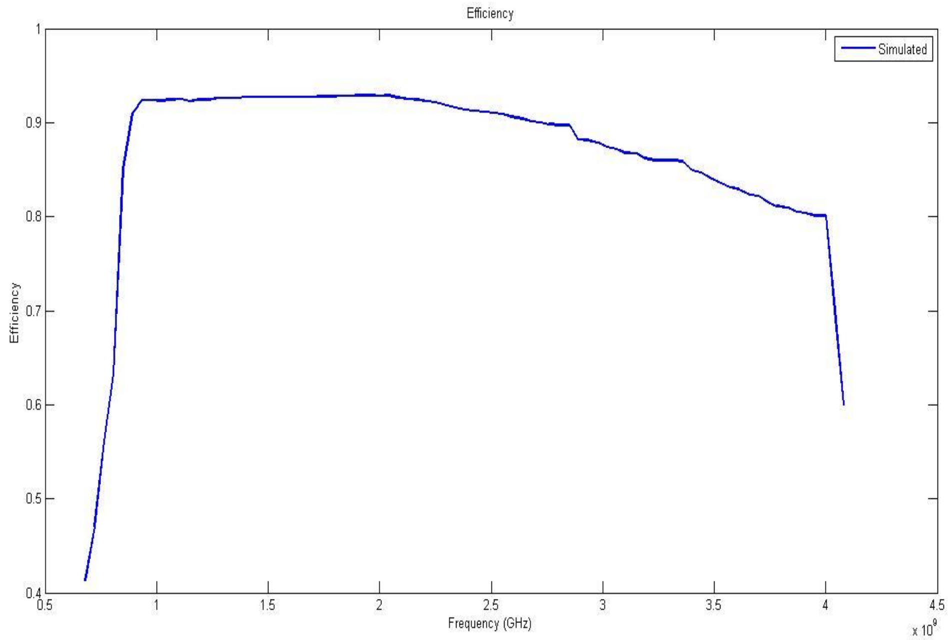


Figure 22 EFFICIENCY

Chapter 6

FUTURE WORK AND CONCLUSION

6.1 FUTURE WORK

Since antenna is covering all the 2G/3G/4G bands currently used in Pakistan, but the 4G bands which are allocated for future use are not completely covered by this MIMO antenna. 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.

6.2 CONCLUSIONS

In this project a MIMO antenna for wide band was proposed, designed, simulated, constructed and tested. The antenna has very high application for the smart phone currently used in Pakistan.

Since MIMO technology 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 MIMO has vast applications in upcoming future technologies like 5G, 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 the mobile phone

Chapter 7

REFERENCES

References

a. W. C. Zheng, L. Zhang, Q. X. Li, and Y. Leng, "Dual-Band DualPolarizedCompact Bowtie Antenna Array for Anti-InterferenceMIMO WLAN," iEEE Trans. Antennas Propag., vol. 62, no. I, pp.237-246, Jan. 20 14.

b. S. F. Roslan, M. R. Kamarudin, M. Khalily, and M. H. Jamaluddin,"An MIMO Rectangular Dielectric Resonator Antenna for 4GApplications," IEEE Antennas Wireless Propag. Lett., vol. 13, pp.32 1-324,2014.

c. C. X. Mao and Q. X. Chu, "Compact Coradiator UWB-MIMO Antenna With Dual Polarization," iEEE Trans. Antennas Propag.,vol. 62, no. 9, pp. 4474-4479, Sep. 2014.

d. K. L.WongandM. T. Chen, “Small-size LTE/WWAN printed loop antenna with an inductively coupled branch strip for bandwidth enhancement in the tablet computer,” IEEE Trans. Antennas Propag., vol. 61, no. 12, pp. 6144–6151, Dec. 2013.

e. M. S. Sharawi, A. B. Numan, M. U. Khan, and D. N. A1oi, "ADual-Element Dual-Band MIMO Antenna System with EnhancedIsolation for Mobile Terminals," IEEE Antennas Wireless Propag.Lett., vol. II, pp. 1006-1009,2012.

f. M. A. Jensen, 1. W. Wallace, "A review of antennas and propagation for MIMO wireless communications," iEEETrans.AntennasPropag., vol. 52, no. II, pp. 2810 2824, Nov. 2004 .

ANNEXURE

Wide Band MIMO Antenna For Mobile Phones

Extended Title: Design and development of the wide band Multiple-Input-Multiple-Output antenna for the mobile phone.
Brief Description of The Project / Thesis with Salient Specs: With the rapid development of wireless communication technology, there is an increasing demand for high date rates and high reliability, which can hardly be satisfied by traditional communication technology. Recently, multiple-input-multiple-output (MIMO) technology has attracted much attention for its advantages of reducing multipath fading and increasing transmission capacity and reliability. Due to the advantages of the MIMO technology, it is considered as the key technology in the 4G (LTE) and future wireless communication. However, it is a fact that the 4G communication is rapidly popularizing in the worldwide while the 2G/3G communication systems are still in use currently. Therefore, MIMO antennas with wide bandwidth which can cover all the bands of 2G/3G/4G are pretty good candidates for mobile phones
Scope of Work : The project basically involves the design of hardware architecture of MIMO wideband antenna by reducing the size and increasing the operating band. The final design will be tested and practically implemented for 2G,3G and 4G band. The project will be completed by Jun 2016.
Academic Objectives :

The project will involve:

- Understanding and use of HFSS
- Understanding and use of ADS
- Understanding and use of circuit CAM

Application / End Goal Objectives :

The main goal of this project is to create MIMO antenna which can be used for mobile phones.

The antenna can be used for

- 2G
- 3G
- 4G

Previous Work Done on The Subject :

Following patent exist on the subject :

- M. A. Jensen, 1. W. Wallace, "A review of antennas and propagation for MIMO wireless communications," iEEE Trans.Antennas Propag., vol. 52, no. II, pp. 2810 2824, Nov. 2004 ..
- C. X. Mao and Q. X. Chu, "Compact Coradiator UWB-MIMO Antenna With Dual Polarization," iEEE Trans. Antennas Propag.,vol. 62, no. 9, pp. 4474-4479, Sep. 2014..
- Y. J. Ren, "Ceramic Based Small LTE MIMO Handset Antenna,"iEEE Trans. Antennas Propag., vol. 6 1, no. 2, pp. 934-938, Feb.20 13.

Material Resources Required :

PCB for fabrication of antenna

No of Students Required :4
Special Skills Required : HFSS Software ADS software