COMPACT QUASI SELF COMPLIMENTARY 2/4-PORT MIMO ANTENNA FOR WIRELESS APPLICATIONS.

A Thesis submitted in partial fulfillment of the requirement for the Award of Degree of

MASTER OF ENGINEERING

In Electronics and Communication Engineering

Submitted by

RAJAT SHARMA

ROLL NO: 801761013

Under Supervision of

DR. GEETIKA DUA and DR. HARI SHANKAR SINGH

(LECTURER) (ASSISTANT PROFESSOR)

THAPAR INSTITUTE
OF ENGINEERING & TECHNOLOGY
(Deemed to be University)

ELECTRONICS AND COMMUNICATION ENGINEERING DEPARTMENT

THAPAR INSTITUTE OF ENGINEERING & TECHNOLOGY

(A DEEMED TO BE UNIVERSITY), PATIALA, PUNJAB

JULY, 2019

DECLARATION

I, **RAJAT SHARMA** hereby declare that work presented in this thesis entitled **"COMPACT QUASI SELF COMPLIMENTARY 2/4-PORT MIMO ANTENNA FOR WIRELESS APPLICATIONS."** in partial fulfilment of the requirement for the award of degree of **Master of Engineering** submitted at **Electronics and Communication Engineering Department,** Thapar Institute of Engineering & Technology (Deemed to be University), Patiala is an authentic record of work carried out under supervision of **Dr. Geetika Dua (Lecturer, ECED , Thapar Institute of Engineering & Technology, Patiala) and Dr. Hari Shankar Singh (Assistant Professor, ECED, Thapar Institute of Engineering and Technology, Patiala.)** .

Date……August 5, 2019

Rajat Sharma

801761013

Dr. Geetika Dua

Electronics and Communication Engineering Department

Thapar Institute of Engineering and Technology, Patiala

147004

Dr. Hari Shankar Singh

Electronics and Communication Engineering Department

Thapar Institute of Engineering and Technology, Patiala

147004

ACKNOWLEDGEMENT

Words are frequently less to uncovers one profound respects. With an understanding that work like this can never be a result of single individual. I am very thankful to all those who helped me to complete this work of thesis.

This work would not have been possible without the consolation and capable direction of **Dr. Geetika Dua** and **Dr. Hari Shankar Singh** for their important help. Their eagerness and good faith made this experience both fulfilling and agreeable. The greater part of honourable thoughts and arrangements in this work are consequence of our various dialogs. I am appreciative to **Dr. Amit Mishra**, Coordinator of course and **Dr. Alpana Aggrawal**, Head of the department, Electronics and Communication Engineering.

To wrap up things, I might want to express gratitude towards GOD for every single great deed.

(Rajat Sharma)

ABSTRACT

Over the most recent couple of decades, the developing interest for high information rates in remote correspondence has constrained antenna designers to search for an innovation that can give high information rates. Multiple input multiple output (MIMO) is technology, where multiple antenna are used at both transmitting and receiving terminals. In such systems, multiple independent channels are created, which increases the data rate significantly, without any requirement of bandwidth or transmitting power. In this thesis, designs are presented which relies on self-complementary structures. The feeding of designs are done by microstrip line. The antennas consists of two radiators present on the substrate. As the geometry is compact quasi self-complimentary, therefore ground and patch (radiators) are present on the same height. The two radiators are fed by using two quasi self-complimentary feedlines. In this, the fully recommended HFSS procedure is followed. Substrate of particular dimensions are taken and patch is also designed on the substrate. The dimensions of various elements of substrate are varied on the basis of simulations. The designs are analysed and its parametric optimizations are done on HFSS software. The final results are fabricated. The goal of this work is to improve the performance of Multiple input multiple output system (MIMO) antenna system in terms of radiation efficiency and isolation between the antenna elements

CONTENTS

LIST OF FIGURES

LIST OF SYMBOLS AND ABBREVIATIONS

UWB	*Ultrawideband*
FCC	*Federal Communication Commission*
MIMO	*Multiple Input Multiple Output*
MMR	*Multimode Resonator*
SCA	*Self Complimentary Antenna*
QSCA	*Quasi Self-Complimentary Antenna*
SNR	*Signal to noise ratio*
CSI	*Channel Symbol Interference*
SDMA	*Space Division Multiple Access*
MISO	*Multiple Input Single Output*
SIMO	*Single Input Multiple Output*
HFSS	*High Frequency Structure Simulator*
SISO	*Single Input Single Output*
UWB-MIMO	*Ultrawidebnd Multiple Input Multiple Output*
HPBW	*Half Power Beam Width*
FNBW	*Full Null Beam Width*
Umax	*Maximum Radiation Intensity*
U0	*Radiation Intensity of Isotropic*
Rl	*Inductance Resistance*
Rr	*Radiation Resistance*
L	*Inductance*
C	*Capacitance*
Za	*Antenna Impedance*
Ra	*Antenna Resistance*
Xa	*Antenna Reactance*
LOS	*Line of Sight*
WLAN	*Wireless Local Area Network*

CHAPTER 1

THEORY OF MICROSTRIP ANTENNA

1.1 INTRODUCTION TO MICROSTRIP PATCH ANTENNA

Microstrip antennas were become very popular in 1970. Today there are different uses of microstrip receiving wires in the field of government and commercial applications. Dielectric substrate with radiating patch is used for its fabrication. The feedlines are inscribed on the one side and ground plane on the other side. The patch is constructed by using conducting material. Copper and gold are used for its construction. Microstrip patch comes in different shapes like square, rectangle, circular and round Microstrip antenna are low profile. The applications of it in the field of high performance aircraft, spacecraft's, satellites etc. It is shown in Figure 1.1

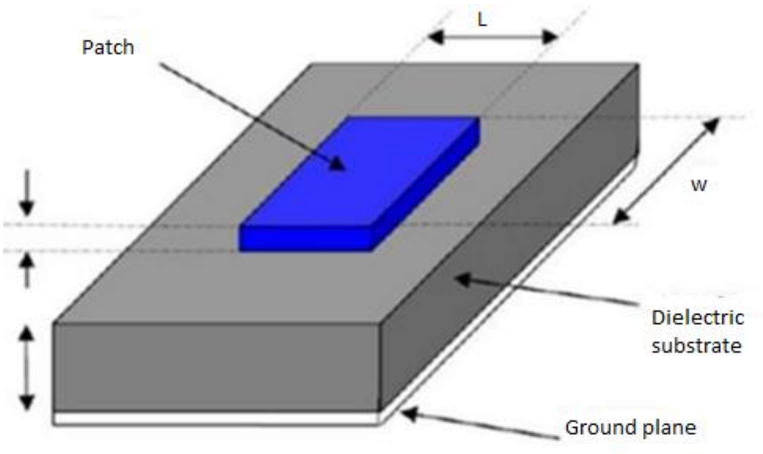


Figure 1.1 Schematic of Microstrip Patch Antenna [1]

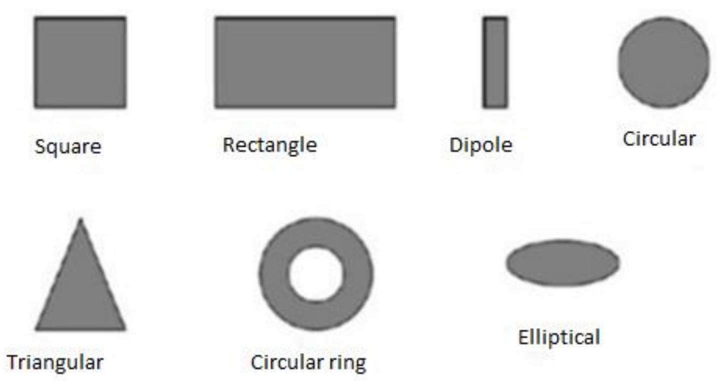


Figure 1.2 Configurations of Microstrip Patch antenna [2]

1.2 FEEDING TECHNIQUES

Feeding the microstrip patch antenna also assumes a significant job for its legitimate working. Transferring the power is very important in feeding techniques. In this there is transportation of power between microstrip line and radiating patch by using electromagnetic field coupling.

There are four important techniques to feed the microstrip patch antenna.

1.2.1 Microstrip Line Feed

In this method, a strip assumes a significant job. It is legitimately connected to the microstrip patch. The size of the conducting strip is minimized whereas the size of the patch is larger. Also, this type of feeding technique is very important. It's designing and fabrication is simple. Demonstrating of this kind of sustaining method is basic and simple to coordinate. It is also easy to utilize. However, there is one disadvantage of this feeding technique. When thickness of the substrate becomes more, then its surface wave radiation also increases. It is clearly appeared in Figure 1.3

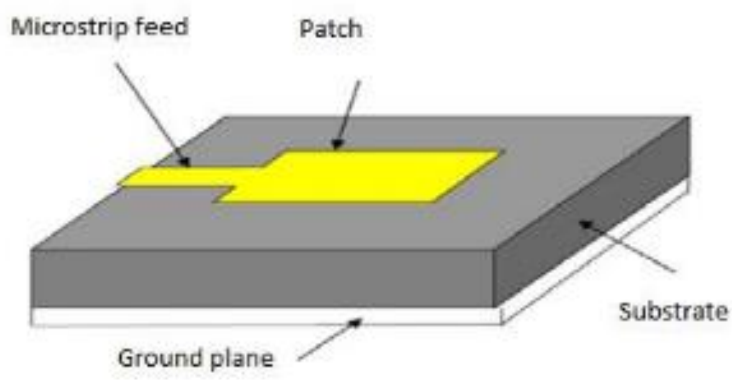


Figure 1.3 Schematic of Microstrip Line Feed [3]

1.2.2 Coaxial Probe Feed

In coaxial feed technique, there is a connection between outer side of the conducter to the ground plane and inner side of the conductor to the patch. Microstrip patch antenna utilizes this type of feeding technique for feeding purpose. Its Fabrication is also easy. This feeding technique also have low radiation effect. But in this feeding technique, there is a requirement to improve the bandwidth. By increasing the bandwidth, the micrsostrip line feed and coaxial effected by the radiation effect and matching problem. The placement of feed will be at proper position to have a proper impedance matching. It is shown in Figure 1.4.

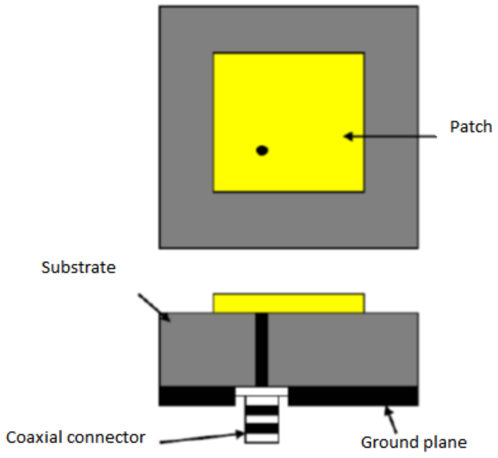


Figure1.4 Schematic of Coaxial Probe feed [4]

1.2.3 Aperture Coupled Feeding

In this technique, there is a partition between microstrip line and coupling with the help of ground plane. The area of coupling opening is underneath the patch. Due to which, it results in lower polarisation. Placement of the aperture plays a very crucial role for the detection of coupling. Radiation effect can also be reduced in this technique. Additionaly, in this kind of technique, a transmitting patch component is scratched on the upper portion of the substrate. The design of this coupling strategy is with the end goal that coupling opening is situated beneath the patch which aides in low cross polarisation. The bandwidth output in this type is about 21%. In this, the arrangement allows the independent optimization of the feeding mechanism. It is appeared in Figure 1.5

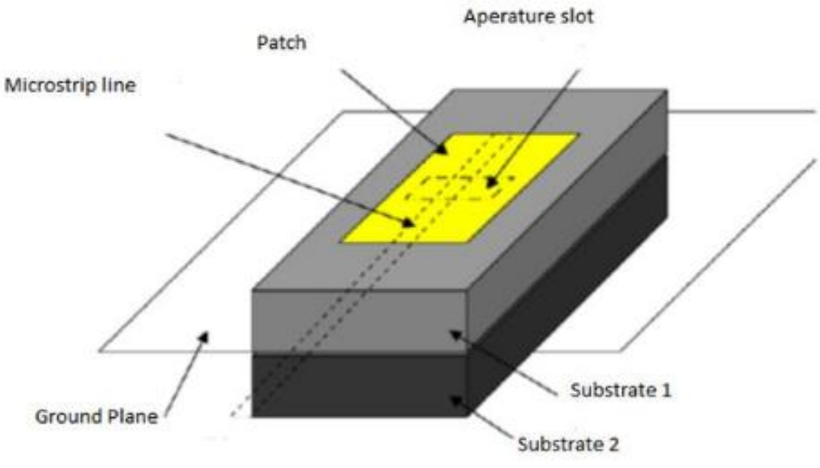


Figure1.5 Schematic of Aperture coupled Technique [5]

1.2.4 Proximity Coupled Technique

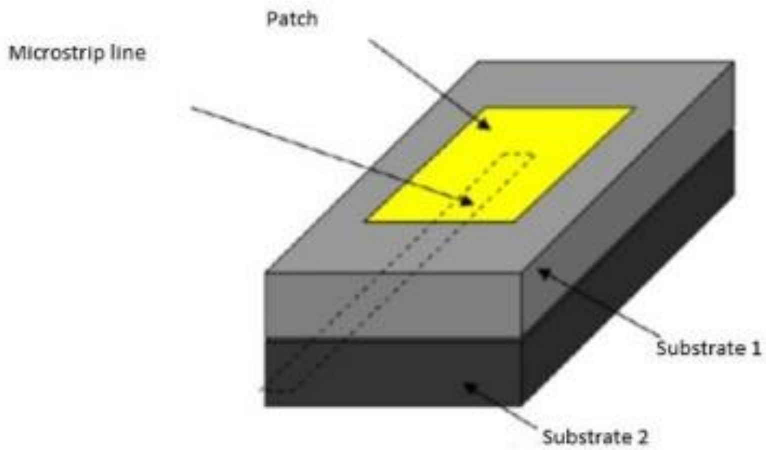


Figure 1.6 Schematic of Proximity coupled Technique [6]

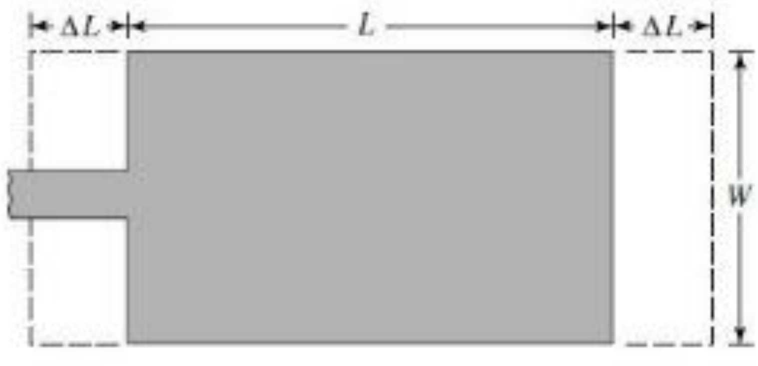
This encouraging strategy is also known electromagnetic coupling technique. In this configuration of feeding technique, the location of feedline is between the two substrates and location of radiating patch is present on the upper portion of the substrate. This feeding technique is very beneficial. It also had an advantage of increasing the bandwidth. The bandwidth of this technique is about 13%. It is appeared in Figure 1.6

Table 1.1 Comparison between different feeding techniques.

Feed type/Property	**Microstrip line feed technique**	**Coaxial feed technique**	**Aperture coupled technique**	**Proximity Coupled technique**
Spurious feed radiation	High	High	Lesser	Minimum
Reliability performance	Superior	Poor because to soldering	Superior	Superior
Ease of fabrication	Simple	Soldering and drilling needed	Alignment is required	Alignment is required
Impedance matching performance	Simple	Simple	Simple	Simple
Bandwidth	2-4%	2-4.5%	2-4.5%	13%

1.3 MICROSTRIP MODEL ANALYSIS

1.3.1 Transmission Line Model



.

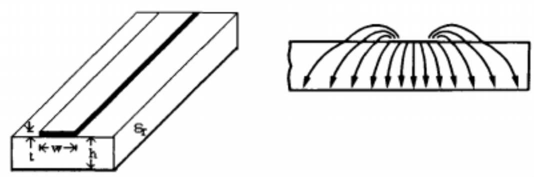


Fig 1.7 Microstrip line and its electric field lines [7]

It is another type of technique which is used for the analysis of microstrip model. Its complete analysis is performed in the derivation written below. Low-impedance Z_p represents the antenna impedance, transmission line of length L, separated by two slots at x=0, L and another two slots at y=0, W with fringing field which is distributed upto a distance ΔL and ΔW respectively

Traverse electric magnetic mode (TEM) is not supported by this model.

$$\frac{\Delta L}{h} = 0.412\ (\epsilon_r + 0.3\ )\left(\frac{w}{h} + 0.264\right) \qquad (1\text{-}1)$$

$$\epsilon_{eff} = \frac{\epsilon_r+1}{2} + \frac{\epsilon_r-1}{2}\left[1 + \frac{12h}{w}\right]^{-1/2} \qquad (1\text{-}2)$$

Where ϵ_r = Effective dielectric constant

h = Height of dielectric substrate.

W = width of patch.

In order to maintain the proper impedance matching, the length of the patch should be less than W. It can be also well maintained by lowering the wavelength.

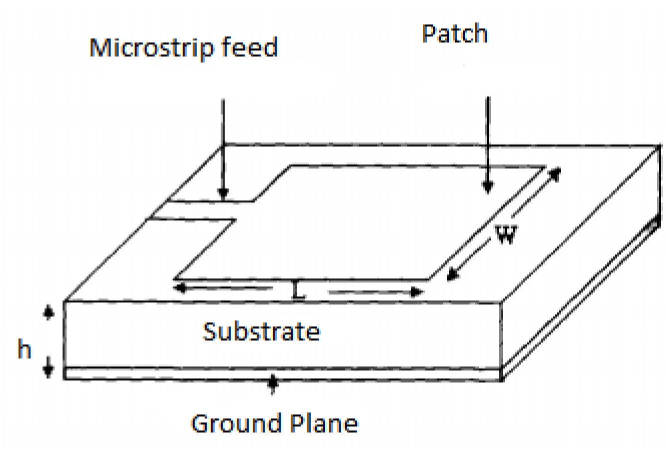


Figure 1.8 Schematic of Microstrip patch antenna.

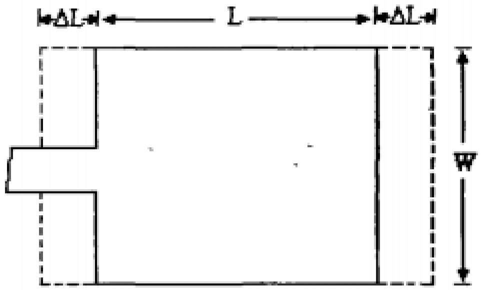


Figure1.9 Schematic of Effective length of rectangular microstrip antenna [8]

$$L_{eff} = L + 2\Delta L \quad (1\text{-}3)$$

Also the resonant frequency is given by

W is the width of the patch and it is given by the relation

$$W = \frac{1}{2f_r\sqrt{\mu_0\epsilon_0}}\sqrt{\frac{2}{\epsilon_r+1}} \quad (1\text{-}4)$$

Its actual length is given by the relation

$$L = 1/2f_r\sqrt{\epsilon_{eff}} - \sqrt{\mu_0}\epsilon_0 - 2\Delta \quad (1\text{-}5)$$

Conductance

Y is the equal admittance.

The equivalent admittance is given by the relation

$$Y1 = G1 + jB1$$

Where $$G1 = \frac{W}{120\lambda_0}[1 - \frac{1}{24}(k_0h)^2] \quad (1\text{-}6)$$

$$B1 = \frac{W}{120\lambda_0}[1 - 0.636\ln(K_0\, h) \tag{1-7}$$

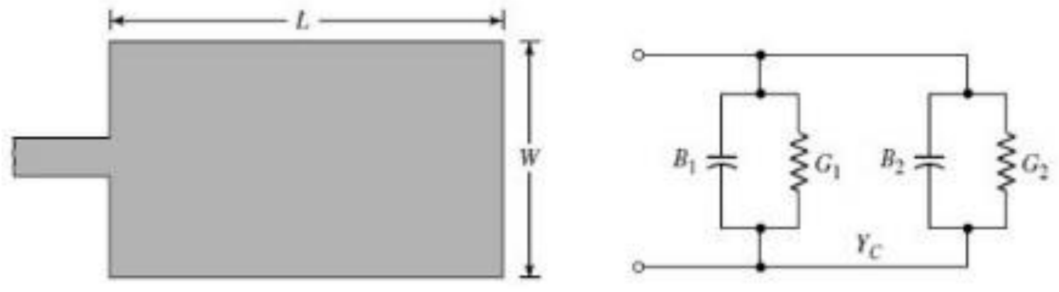


Figure 1.10 Schematic of rectangular microstrip patch and its transmission 1ine model [9]

But slot 2 is identical to slot 1

Therefore $Y2 = Y1, \quad G2 = G1, \quad B2 = B1$

But, conductance is defined as

$$G1 = \frac{2P_{rad}}{|V_0|}$$

The radiated power is given as

$$P_{rad} = \frac{|V_0|^2}{2\pi n_0}\int_0^{\pi}\left[\frac{\sin\left(\frac{k0\, w}{2}\right)}{\cos\theta}\right]\sin 2\,\theta d\theta$$

Finally, $$G1 = \frac{I_1}{120\pi^2} \tag{1-8}$$

1.3.2 Cavity Model

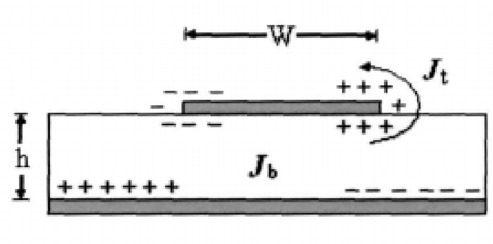


Figure 1.11 Charge distribution on the microstrip patch

The use of transmission line model is not so difficult. The cavity model can easily be improved as compare to transmission line model. The configuration of cavity model is such that the dielectric substrate is bounded by magnetic wall along the edge.

The dissemination of the charge is managed by two component. One of the component is attractive and other component is repulsive. Microstrip antenna consists of impedance function which have complex poles. As a result, the imaginary part of these poles have power lost by the radiation. At any frequency *f* near the radiation, the quality factor is given by

$$Q = \frac{2\pi f(average\ total\ energy)}{average\ power\ dissipated} = 1/\delta_{eff}$$

Hence, $\delta_{f=\frac{1}{Q_r}}$

Q_t is total antenna quality factor and it is given by

$$\frac{1}{Q_t} = \frac{1}{Q_d} + \frac{1}{Q_c} + \frac{1}{Q_r} \quad (1\text{-}9)$$

Q_d represent the quality factor and is given by

$$Q_d = \frac{w_r \omega_t}{P_d} = \frac{1}{\tan \delta} \quad (1\text{-}10)$$

$\omega_r =$ Angular resonance frequency

$w_t =$ Total energy stored in the patch

$$Q_c = \frac{w_r \omega_r}{P_c} = \frac{h}{\Delta} \quad (1\text{-}11)$$

Where P_c is the conductor loss

h is the height of the substrate.

Q_c is the quality factor.

$$\Delta_{eff} = \tan \delta + \frac{\Delta}{h} + \frac{P_r}{\omega_r w_t} \quad (1\text{-}12)$$

1.4 ADVANTAGES AND LIMITATIONS OF MICROSTRIP PATCH ANTENNA

There are many advantages of micro strip patch antenna.

- Low weight and low volume.
- Smaller in size.
- East to fabricate
- Low cost
- Dual frequency operations.
- Support dual polarisation types i.e. Linear and Circular.

There are disadvantages of Microstrip antennas which are listed below.

- Narrow data transfer capacity.
- Low gain and efficiency.

- It have higher cross Polarisation.
- It have lower power handling capability.
- Low impedance bandwidth.

1.5 APPLICATIONS

There are various applications of microstrip patch antenna in different fields.

- Remote sensing purpose.
- Useful for Environmental instrumentation.
- Provides very useful applications in the field of satellite communications.
- Biomedical radiator.
- Satellite navigation receivers.
- Applications like mobile and satellite communications.
- Useful for GPS.
- WiMAX.
- Applications like Radar communications.
- Telemedicine applications.

1.6 TYPES OF ANTENNAS

1.6.1 Dipole Antenna

Dipole antenna may be defined as the simplest type of antenna which is composed of conducting wire rod that is half to the length of maximum wavelength. The configuration of dipole antenna is such that the wire rod is split in the middle and there is separation between two sections by an insulator.

There are three types of dipole antenna

- Idea1 half- wavelength dipole
- Folded dipo1e
- Hertzian dipo1e

1.6.2 Monopole antenna

It may be defined as the antenna having straight rod shaped conductor with the locality of conductor prependicularly over a conducting surface called ground plane. The configuration and designing of monopole antenna is easy as compare to other antennas. It is also known as resonant antenna. The fuction of rod is to behave as an open resonator for radio waves. Therefore, the main function of the antenna is to determine the length of the radio waves [10].

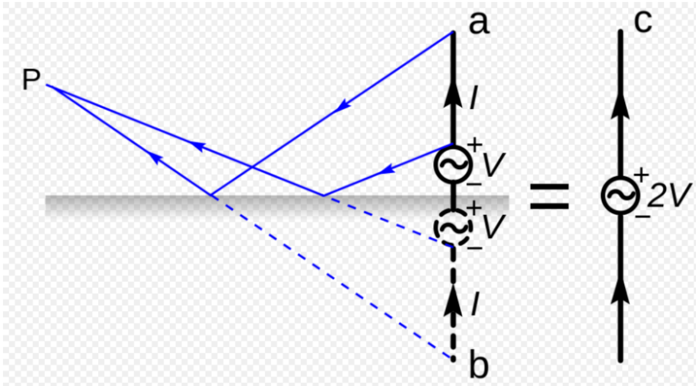


Figure 1.12 Schematic of monopole antenna showing the same radiation pattern over the ground plane [10]

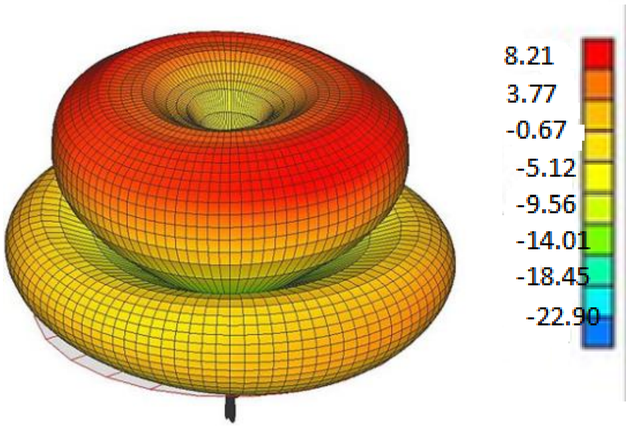


Figure 1.13 Schematic of radiation Pattern of ¾ Wavelength Monopole Antenna [10]

The radiation pattern of this type is omnidirectional. The amount of power transmission by the antenna is equally distributed in all the directions. Also, the power transmitted by the antenna varies with elevation angle.

1.6.3 PIFA (Planar inverted F antenna)

Antenna designers are looking for innovative methods to improve the decreasing efficiency of antenna. To fullfill this demand of researchers, PIFA antenna was introduced. In this antenna, the shortening of the pin at the feed takes place which introduces parallel inductance to the antenna impedance. This antenna is resonant at quarter wavelength and also have SAR properties. Its low profile and an omnidirectional pattern makes it famous in the market. Shorting the pin plays a very crucial role to maintain the resonancy of the antenna. This antenna is also very useful for communication purposes.The use of PIFA antenna has increased in the mobile phone market [11].

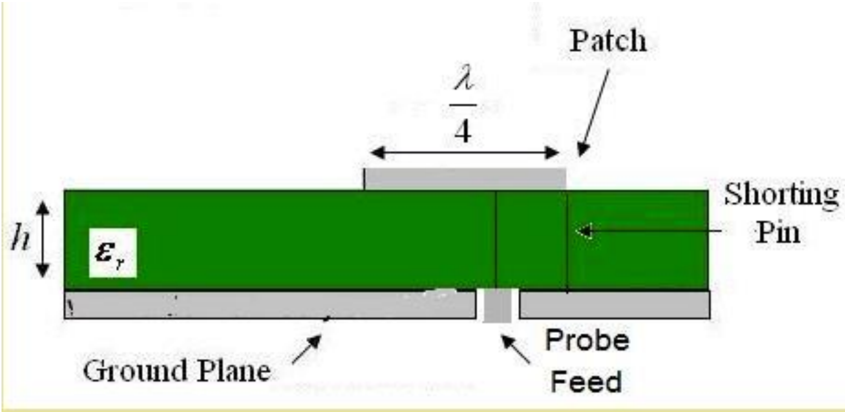


Figure 1.14 PIFA antenna [11]

CHAPTER- 2

UWB MIMO ANTENNA

2.1 UWB TECHNOLOGY

2.1.1 UWB

Ultra-wideband (UWB) plays a crucial role in present wireless technology. The applications of UWB technology are target sensor data collection and applications like tracking [12].UWB technology is used to transmit information spread over larger bandwidth. It is more attractive for researchers in the field of wireless applications [13-16]. Larger impedance bandwidth, compact size and low profile are the major challenges for UWB antenna. UWB was also known as pulse radio but FCC currently defines UWB as an antenna transmission. There is a difference between conventional radio transmission and UWB. Transmission of information by altering the phase and power level of the sinusoidal are the two important point regarding the UWB. The important thing regarding the UWB technology is its capability to calculate the time of flight of the transmission at different frequencies [17].

2.1.2 Beamwidth

Beamwidth is the angular partition between two indentical points which are on the opposite side of a pattern maximum. There are two types of beam width.

- Halfpower beam width
- Full null beam width

HPBW is the angular separation having magnitude of the radiation pattern declined by 50% from the peak of the main beam. Mathematically,

$$HPBW = \frac{70\lambda}{D} \tag{2-1}$$

Where λ is the wavelength .

D is the diameter.

The unit of HPBW is radian or degrees.

FNBW is the angular separation between the first nulls of a pattern.

Mathematically, $FNBW = 2HPBW$

$$FNBW = \frac{140\lambda}{D} \tag{2-2}$$

Where λ is the wavelength.

D is the diameter.

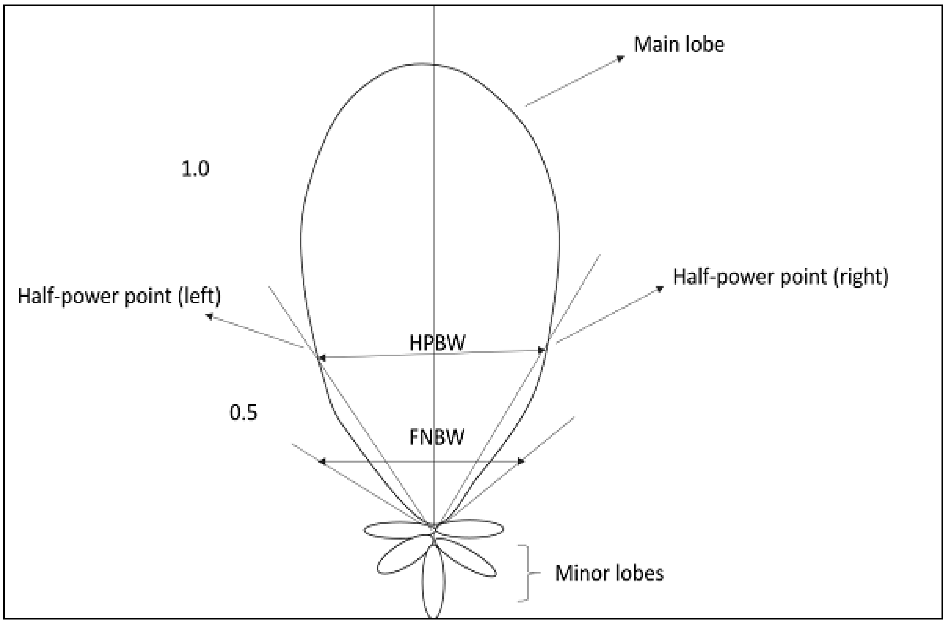


Figure2.1 Half power points on the major lobe.

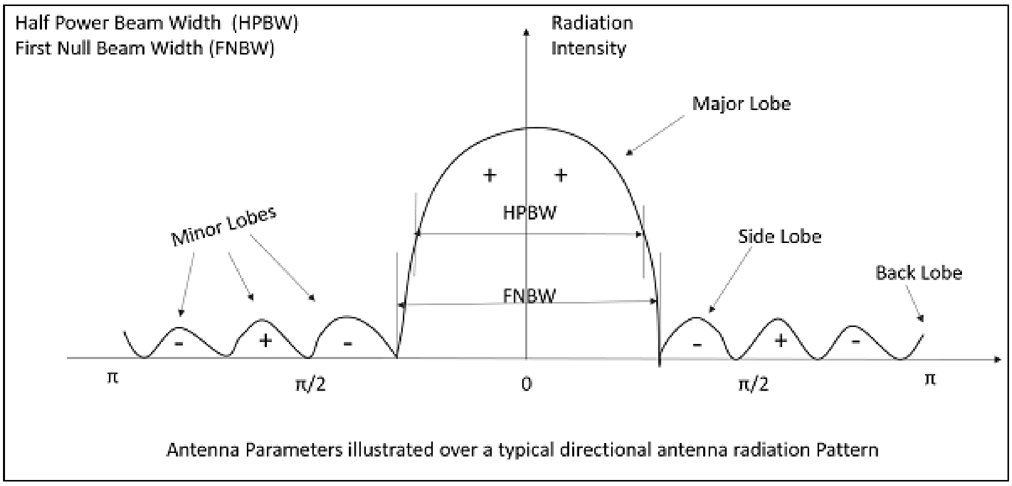


Figure2.2 HPBW and FNBW along with major and minor lobes

2.1.3 Applications of UWB

Applications of UWB Technology are as follows

- Radar Imaging.

- Short distance Communication.
- Precision locating.
- Tracking.
- High speed LAN/WAN.
- Altimeter (Aviation).
- Intrusion detection.
- Geolocation.
- Military applications.

There are various characteristics of UWB system like low average power and high resolution.

2.2 MIMO TECHNOLOGY

2.2.1 Basic building block

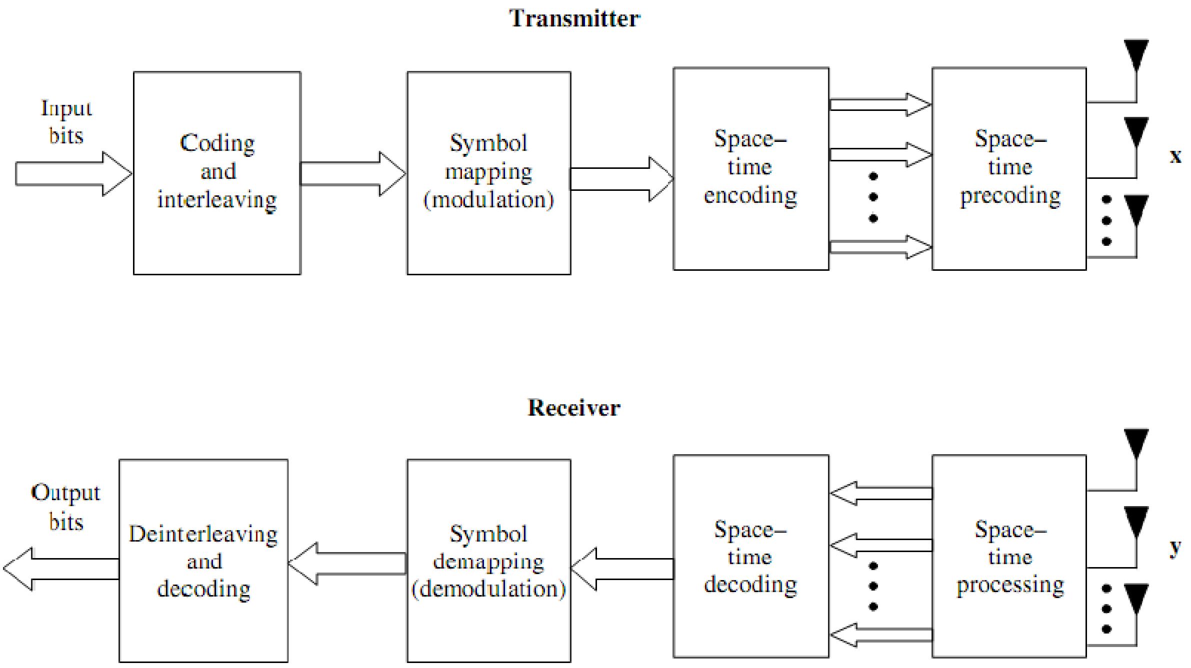


Figure 2.3 Basic building block

In the above basic building block of MIMO technology, the input bits are transmitted. These transmitted bits will undergo through coding and interleaving part. Then, space time coding and precoding process were performed. After that in receiver part, the transmitted bits are passed through space time coding and performs the reverse action of the transmitter. Finally, the output bits are collected at the output of receiver.

2.2.2 Channel Modelling

The MIMO channel model is described by using the matrix written below

$$y = Hx + n \tag{2-3}$$

Where y is the received signal vector.

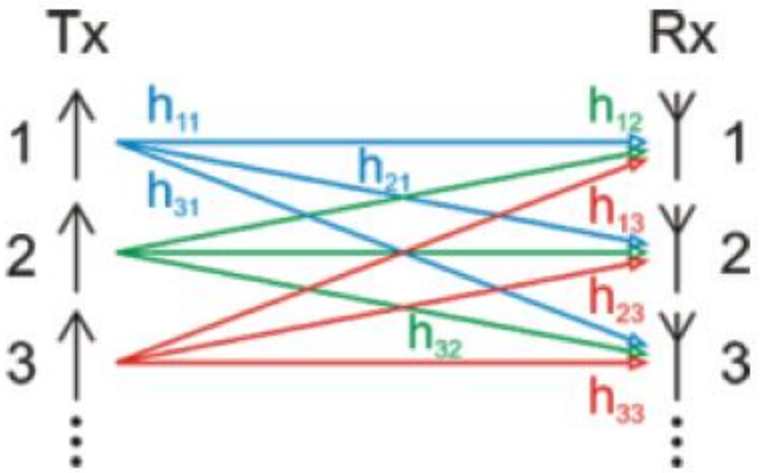


Figure. 2.4 MIMO Channel model [18]

The better explanation of MIMO channel model is given by the following method

$$H = \begin{bmatrix} H_{1,1} & H_{1,2} & \cdots & H_{1,M_T} \\ H_{2,1} & H_{2,2} & \cdots & H_{2,M_T} \\ \vdots & \vdots & \ddots & \vdots \\ H_{M_R,1} & H_{M_R,2} & \cdots & H_{M_R,M_T} \end{bmatrix},$$

2.2.3 Multiplexing

Multiplexing may be defined as the process of merging the multiple signals into one signal. Analog multiplexing is the analog merging of signals whereas digital multiplexing is the digital merging of signals. The idea of multiplexing was first discovered in telephony. The process of multiplexing takes place in a very efficient way. It splits the communication channel into different logical channels.

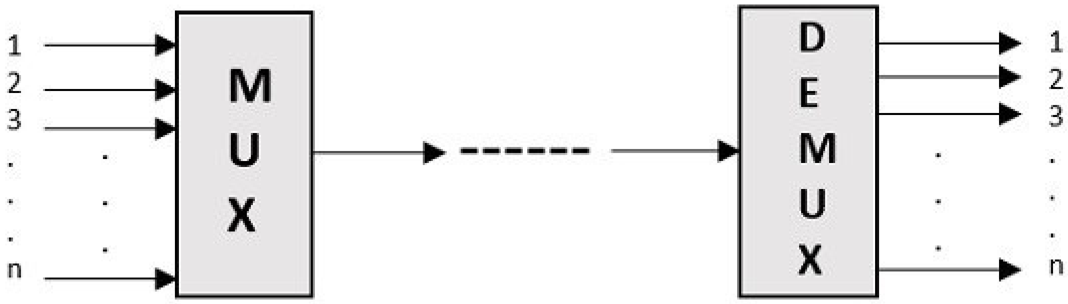


Figure2.4 Multiplexing [19]

2.2.3.1 Spatial Multiplexing

In Spatial multiplexing, each spatial channel carries independent information. In this, there is transmission of signals from each transmission antenna such that data rate increases without any change in frequency band [20].

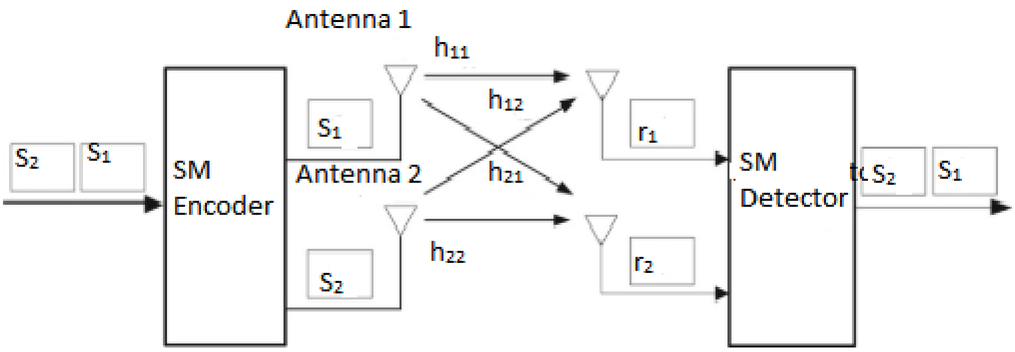


Figure 2.5 Spatial Multiplexing [20]

2.2.3.2 Polarisation Multiplexing

Polarisation multiplexing might be characterised as the multiplexing strategy for multiplexing the signals which are conveyed along on electromagnetic waves, which allows two channels of information to be transmitted on the same carrier frequency. The important application of multiplexing is satellite televisions downlinks to double the bandwidth in satellite dishes. It is also used in fiber optic communication [21].

2.2.3.3 Frequency Multiplexing

In frequency multiplexing, there is merging of different signals into one medium by transmitting signals in different frequency ranges. In order to avoid the overlapping, there is suitable frequency gap between two adjacent signals. In this, the frequency spectrum is divided into logic channels. This type of multiplexing is used in radio and TV transmission.

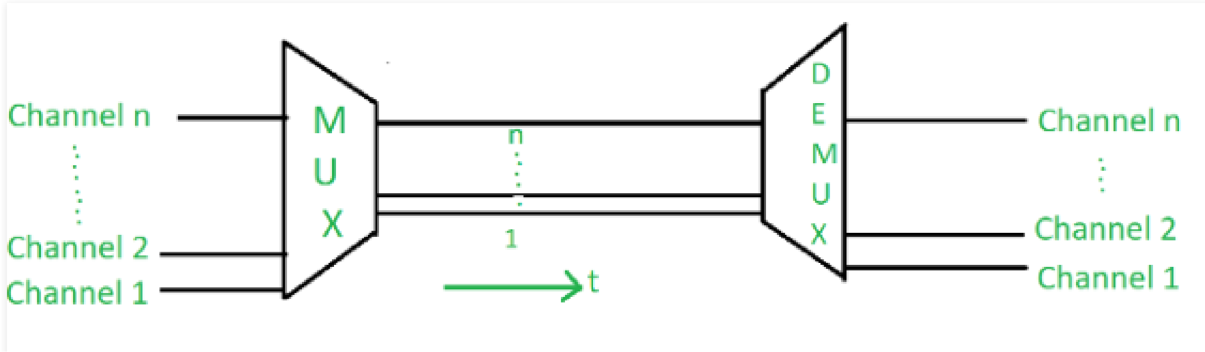


Figure 2.6 Frequency Multiplexing

2.2.3.4 Time Multiplexing

Time multiplexing is a digital technology which make use of time instead of frequency to separate the data streams. In this, there is sequence of bits or bytes which are coming out from each input stream, one after the other and in such a way that they are connected with the receiver. The operation of signals differs in both the multiplexing techniques. The fundamental difference between frequency multiplexing and time multiplexing is that in frequency multiplexing every one of the signal work at the same time with various frequencies while in time division multiplexing every one of the signal work with same frequency with different occasion [22].

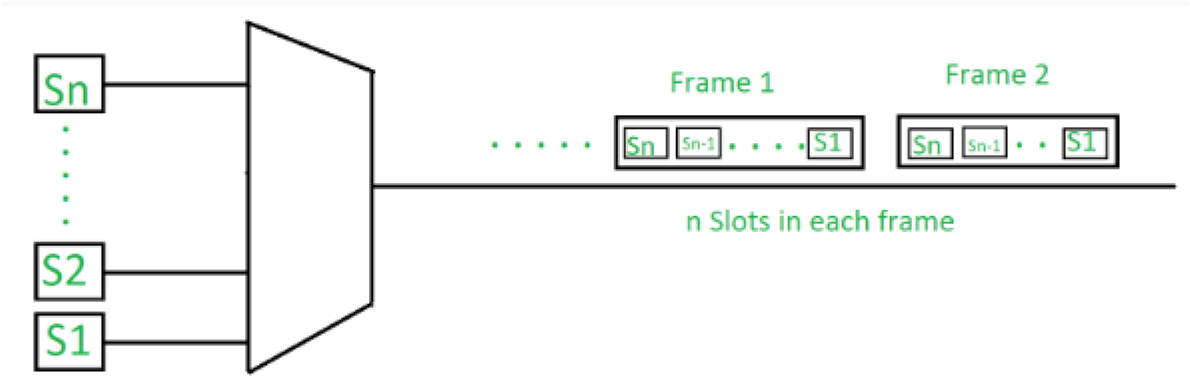


Figure 2.7 Time Multiplexing [22]

2.2.4 MIMO Parameters

2.2.4.1 Envelope Correlation coefficient (ECC)

Envelope correlation coefficient gives us the information regarding the independency of the radiation pattern of the two antennas. Also, the two antennas has zero correlation when both of the antennas are horizontally and vertically polarised respectively. Mathematically,

$$\rho_e = \frac{|\iint \overline{F_1 F_2 \, d\Omega}|}{\iint |F_1|^2 \, d\Omega . \iint |F_2|^2 \, d\Omega} \quad (2\text{-}4)$$

2.2.4.2 Mean Effective Gain (MEG)

MEG is the normal power gotten by the antenna under test P_r to the normal power gotten by the reference reception apparatus in the similar domain, P_{ref} [23]

$$G = \frac{P_r}{P_{ref}} \tag{2-5}$$

2.3 UWB MIMO SYSTEM

UWB-MIMO is the most important technology used in wireless applications now a days. UWB-MIMO innovation is presently turned into the most significant innovation because of the high information rate and short range communication. It is one of the best technology considered for short range communication because of the conditions imposed on power transmitted. UWB-MIMO is now become one of the challenging technology because of the compulsion that generally encounter to achieve wideband. MIMO has the potential to promote the overall antenna performance. There are new challenges like mutual coupling reduction in the UWB MIMO system. In UWB-MIMO, there are multiple antennas installed on the transmitter and receiver in order to achieve better communication as compared to other communication techniques.

There are various advantages of UWB-MIMO like high data interference immunity and to use low power. Multipath fading can also be reduced in UWB-MIMO technology. It is considered as the one of the best technology to improve channel capacity.

UWB-MIMO technology has unique characteristics that makes it different from other wireless technologies.

- In UWB-MIMO system, there is not any requirement of modulation and demodulation of carrier, which means it does not requires components like filters, mixers and amplifiers etc. which reduces its cost.
- It has tremendous capability to give higher data rate which can be up to hundered of Mbps which makes it different from other communication techniques.
- It is clear from the above information that UWB-MIMO is a very impressive technology for data transmission, which makes it different from other communication technology.
- This technology has very lesser detection and interception due to lower power density levels.
- It has lesser cost as compare to other wireless technology, which makes it popular in wireless communication standards.

In radio framework, MIMO is utilized to expand the limit of antenna by installation of multiple antennas on the transmitter and receiver terminals. MIMO is the most important part of communication industry now. It is also become the very important element of various communication standard like IEEE 802.11n (Wi-Fi), HSPA+ (3G) and WiMAX (4G) etc. At one time, numerous radio wires were installed on the transmitter and receiver terminals. But, in modern world, MIMO means to send more than one radio signals from the transmitter to receiver respectively. In 1970, Branderwurg and Wyner [24] has given an idea of the MIMO antenna. In mid 1980s, Jack took this research further at Bell Laboratories [25]. After this, the research was further taken to improve multiuser system operated over mutually crossed coupled linear network. Improving the performance of cellular radio network is the major challenge. Directional or smart antennas are utilized by the Space division multiple access (SDMA) for communication purpose. In past we utilize numerous reception apparatuses on the transmitter and receiver to improve the performance of cell framework. But with the latest trends in technology, there is transmission of more than one signals. Antenna plays a very vital role for wireless communication. Now a days, different arrays of antenna plays a very important role for interference reduction when more than one propagation occurs. UWB MIMO with high isolation is a major challenge. Also UWB antenna is designed with 5.8GHz band notched having a fear of interference. This antenna also helps in avoiding possible interference with 5.8 in growing technology. This antenna has various applications like cancer detection, radar imaging etc. UWB communication has also the probability to suffer from multipath fading. MIMO innovation is utilized to give multiplexing gain and variety increase to improve the limit and connection quality improvement. Precoding in general is assumed to be the **s**patial processing which occurs at the transmitter. The concept of the beam forcing is such that the equal signals is being transmitted from each of the transmitter such that the power of the antenna is enhanced at the receiver. In order to increase the gain, beamforcing is very beneficial. This process can be done by adding the signals emitted from the different antennas. In Spatial multiplexing, there is requirement of MIMO antennas. This process takes place in such a way that a high rate signal is splitted into 1ower rate streams. Also there will be a transmission of signals from different transmitter antenna. It is considered as the best technique to increase the channel capacity at higher signal to noise ratio (SNR). At transmitter, spatial multiplexing may be used without the presence of channel symbol interference (CSI). In case, if CSI is available then it can be mixed up with precoding. There is one more advantage of spatial multiplexing is that it can also be used for parallel transmission to more than one receivers, which also called as space division multiple access (SDMA).Diversity Coding is another type of coding technique. It is coding technique which is utilized when there is not any presence of CSI. In this type of coding technique, the signal is being transmitted from the coding antennas [26].

There are different forms of MIMO antenna, which can be written as follows.

SISO/SIMO/MISO are special cases of MIMO.

- Mu1tiple input and single output (MISO) is a situation when receiver has a single receiving wire.
- Single input multiple output (SIMO) is an antenna type when transmitter is having a single antenna.

- Single input single output (SISO) is a system which does not have transmitter and receiver antenna.

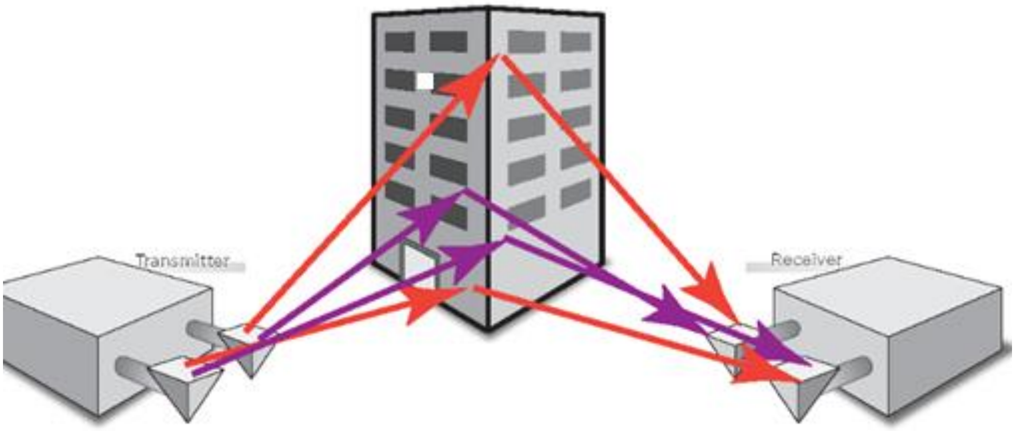


Fig 2.8 Schematic of MIMO exploits multipath propagation to multiply link capacity [27]

Fig 2.9 MIMO antenna type [28]

There are many challenges in designing of MIMO technology. In order to have a proper communication, channel bandwidth and high data rate must be at higher priority. Now a days the main field of researchers is to enhance channel capacity, bandwidth and gain. Also there is greater opportunity for the researchers to develop novel antenna techniques. Radiation pattern diversity has proven to be the one of the best technology to reduce correlation coefficient. Mutual coupling reduction is the important challenge in MIMO antenna design. If mutual coupling is reduced, then the communication between antenna elements will be improved. The main challenge is to maintain low mutual coupling. In Shannon capacity theorem, $C = B \log(1+S/N)$, where C is the channel capacity, B is the bandwidth and S/N is the signal to noise ratio. From the above expression it is clear that by enhancing the bandwidth and S/N ratio, the channel capacity can be improved.

But it is tough to have a compact size antenna elements to have low mutual coupling. An electromagnetic bandgap structure is presented to enhance the isolation between elements of antenna. The design of the MIMO antenna is also a challenge due to increasing no of frequency bands. Induction of MIMO technology in wireless communication indicates that antenna researchers must consider the co-existence of more than one antennas on the transmitter and receiver terminals. Also the need of high data rate and low mutual coupling are the primary issues while designing a MIMO antenna. Now a days, all the wireless technologies are using MIMO instead if SISO and MISO. In MIMO, the multiple no of antennas are installed on the transmitter and receiver to maintain proper communication. Because of the evolution of MIMO antennas, it has attracted much of the attention of the researchers towards wireless technology. Capacity, bandwidth and gain are the some of the characteristics of MIMO technology [29].

CHAPTER 3

LITERATURE REVIEW

Kinami *et al.* 1998, [30] presents a printed bow –tie antenna which is very useful for UWB applications. According to FCC, the UWB band approved is 3.1GHz to 10.6GHz. Also the return loss should be less than 10Db.

Agrawall *et al.* 1998[31] presents a wideband planar monopole antenna. One of the main function of this antenna is to increase the impedance bandwidth. There are various configurations are introduced like square, elliptical and rectangle.

Chen *et al.* 1998, [32] presents a small UWB microstrip fed monopole antenna. In order to boost the impedance bandwidth, a small slit is used. All the simulations regarding this antenna are performed in HFSS. The size of the antenna is 16*20 mm and provides an UWB from 2.6 to 27 GHz.

Aman and Chen 2003, [33] presents a wideband monopole antenna. Its simulation can easily be performed in HFSS. Bandwidth of impedance of this antenna is demonstrated by proper simulations.

Bahadori and Sami 2004, [34] presents an elliptical card UWB antenna. Its design is such a way that it is having a radiating element and ground p1ane. This feeding mechanism of this antenna in such a way that a noble feeding mechanism is used to feed the antenna. This antenna is adjusted to have band rejection with wireless local area network (5.1 to 5.8 GHz). Overall satisfactory performance can be achieved by using this antenna

Abdollahband and Mostafa 2005[35] presents a UWB monopole antenna in which chatacteristics like band notch are presented. The designing of this type of antenna in such a way that resonance are excited up to 123 percent. And this antenna is fabricated to achieve band notched characteristics.

Liang *et. al* 2005[36] presents a round plate monopole antenna for UWB applications. This antenna is mainly designed on the FR4 substrate. The feeding of this type of antenna is done by the 50ohm microstrip line. The antenna is structured so that that it gives a 10DB return loss. Also with the acceptance of UWB in the USA, it provides a greater field for the research area. Frequency domain characteristics plays a very crucial role to decide the performance of antenna.

Tran and Sibille 2006, [37] presents a spatial multiplexing scheme for UWB-MIMO. In this type of antenna, the multiplexing rate equals to the no. of transmitters may be obtained. Various applications of UWB technology includes high definition video transmission requires a rates up to 1.6Gbit. Spatial multiplexing plays a very important role to increase the throughput. Also, the simulation of this antenna is performed on HFSS software.

A.A Eldek 2006, [38] presents a numerical study of ultrawideband microstrip fed tap monopole antenna. In this antenna, there is a requirement of improving the bandwidth characteristics of the antenna. For this, a small slit is added on the one side of the monopole antenna. Its simulation is performed on the HFSS. The antenna have an ability to provide the bandwidth of 2.8 to 28GHz. Also it is well known that from all the field including internet to wireless network appliances, there is increase in demand of the wireless communication. At last, this antenna is a good for wireless handheld components.

Ran and Chang 2006, [39] presents an annual ring antenna for UWB applications. Return loss better than 10db is the bigger achievement of this type of antenna. In this, the parameters which are used to find the antenna characteristics are also studied. To make the better performance of the bandwidth, there is an addition of finite metal plane. One of the principle qualities of this antenna is its radiation characteristics are entirely steady in the working data transmission. The average efficiency of this antenna is 81%.

QU *et.al* 2006, [40] presents band notch function for UWB round reception apparatus. In its type of antenna configuration, a CPW is with band notched function is represented. In this design, the value of the impedance matching is maintained for the proper functioning of the antenna elements. The arched notch is one of the important parameter to control the band notched function.

Chayono *et. al* 2006, [41] presents an antenna which is very useful for UWB applications. It is a composition of half disk with inverted triangle is attached on the ground plane. The main function of the slit is to get matching on wide frequency. In its examination there are two method for accomplishing receiving wire impedance. One is resistive loading and other is geometry control. Geometry control method is considered better than impedance control. The main function of the slit on the ground plane is to control impedance matching.

Kim and Park 2006, [42] presented an antenna which is band rejected with parasitic strip. The parasitic strip is very useful for UWB applications. The designed is fabricated on the FR4 substrate. It basically operates between 3 to 17GHz. In this design, the antenna is fed by the microstrip line and utilizes strip for band rejection. We know that ultra wideband has received greater attention in the wireless world. The main motivation behind this research paper is to band notch this UWB antenna with strip.

Liu et al 2007 [43] presents an antenna for portable wireless applications. The antenna is called as UWB MIMO antenna. This antenna configuration is having two microstrip elements on the side of the substrate. The elements of the antenna are orthogonal to each other. So as to build the disconnection and data transmission, two ground stubs are utilized. Simulation is performed on HFSS to calculate the antenna performance, efficiency, gain, and radiation characteristics etc.

Y.Sung 2007 [44] dually sharped notched band antenna. The configuration of antenna consists of circular shaped 50ohm microstrip feed line. Its geometry consists of two resonators and ground plane.

Roshandel et al 2007 [45] Microstrip square ring monopole antenna which is very useful for UWB. This type of structure is prepared in such a way that the feeding is done by sing1e microstrip line. Its radiation and time domain characteristics are calculated by the different type of experiments.

Choo et al 2008 [46] presents a recreation of MIMO channel limit with receiving wire polarisation variety. In its fabrication, the main focus will be on the realistic tri monopole antenna structure. The results shown by its simulation structure shows that it is very beneficial for uncorrelated MIMO channel.

Chiu and Murch 2008,[47] presents four port antenna for MIMO applications. Its design is fabricated on the FR4 substrate. The configuration of the antenna is such that it can operate at 2.48GHz. Also in its design, the mutual coupling is less, which can increase its performance. MIMO antenna is a very important technique for increase the capability of wireless transmissiona.

Matin *et. al* 2007, [48] presents patch antenna for UWB applications. In the analysis of this design, U-slot antenna is presented. Parameters of this antenna design are also varied to get the desired result. The parameters which re varied includes ground, patch, feedline etc. Also we know that microstrip patch are currently widely used applications for the wireless applications. At last, a stacked patch type antenna is presented in this paper, which is analysed, and fabricated.

Vuong *et. al* 2007, [49] presents U-slotted antenna for UWB applications. Its design is having a particular dimension. The antenna is formulated on the fr4 substrate. The feeding of the antenna is done by using microstrip line. The antenna shows good conditions for UWB applications. Because UWB antennas shows interest after get approval from FCC.

Hong *et. al* 2007, [50] presents planar UWB antenna with new band notch design. In this type of antenna configuration, the antenna is composed of radiation patch. Partially modified ground plane makes its impedance matching better . Its vital characteristics that makes it different from another type of configuration is its modification in ground plane. The addition of slots in its configuration improve the impedance bandwidth of the antenna. Also, in order to obtain 5.5 GHz, a T- shaped stub is embedded inside a elliptical slot.

Ray *et. al* 2007, [51] presents Ultrawideband elliptical monopole antenna . Its configuration is composed of substrate, patch and ground. The bandwidth variation of this design is directly related to the ellipcity ratio. Various parametric analysis have been performed on the HFSS to measure bandwidth and radiation pattern of this configuration. Also we know that the demand of the antenna with bandwidth variation is increasing day by day. In this analysis, elliptical monopole configuration of the antenna have been investigated. Various parametric also been performed on the HFSS. As bandwidth variation is directly proportional to the ellipticity ratio. Therefore, bandwidth variation with ellipticity ratio is also studied in design.

Li and Liu 2008, [52] consists of two UWB antennas integrated with resonator with the help of which wideband operation is achieved. According to FCC, the operation of this antenna is having a suitable range. It in the range of 3.1 to 10.6 GHz. On simulating this antenna on HFSS, it gives a better impedance matching. In order to feed the antenna, a novel feeding mechanism is used. After various analysis, it is proved that this antenna is very good for wireless communication.

Yin *et al* 2008, [53] presents a UWB-MIMO antenna which is very useful in the field of Local area network. The design of the antenna is analysed on HFSS. In order to have a better wideband operation, this antenna have a two monopoles. Also, a good isolation is achieved in this design. At last, this monopole antenna shows excellent properties.

Rajgopal and Sharma 2008, [54] presents a UWB pentagon shaped microstrip antenna. In this different types of planar monopole antenna have been studied. Previous results shows that wider the slot is having the wider impedance bandwidth. Also research shows that square slot with square shape gives square impedance bandwidth. Studies also shows that better radiation pattern is obtained. The antenna consists of microstrip slot with stubs on the ground plane. Results also shows that combination of feedline and stub provides a wide impedance bandwidth. Radiation pattern of this antenna is omnidirectional.

Gao *et. al* 2008, [55] presents a printed rectangular patch antenna which is very useful for UWB applications. Also its characteristics are related to its return loss. Its parameter is also having effect on the communication module. Therefore, the impact of the significant parameters of the antenna on the return loss is also studied. The fabrication of the antenna will be on the rogers substrate and is fed by the microstrip line. This is also very suitable for broad communication applications.

Guo *et al* 2009, [56] presents a quasi-self-complimentary antenna. The design of this antenna is such that it is feed by microstrip feed line to have better results. The dimensions of this antenna is 30*20mm respectively. A perfect impedance matching is achieved by simulating this antenna on HFSS software. It also provides impedance bandwidth with better radiation properties.

Dong *et al* 2009, [57] presents UWB antenna with two frequency notches are presented. To optimize the performance, the current distribution is mechanism is used. Interference is present in wireless and UWB system because of the broad operating frequency range. The important problem presents in the narrowband is the disturbance, which can be eliminated by integrating a filter resonator in the radiating element to achieve a goal of band notched function. Different kind of techniques have been used like U-shaped etc to achieve a better impedance bandwidth in order to have a better performance.

Zhang *et. al* 2009, [58] presents ultrawidebnd MIMO antenna with tree like geometry to enhance wideband isolation. The size of the antenna is having a 35*40 mm. The easiest way to achieve wideband isolation by using a structure which is similar like design on the ground plane. In order to have better performance, gain, bandwidth are also measured. It is easy to cover the whole UWB of 3.1GHz to 10.6GHz with the help of obtain impedance characteristics. Also, the measured isolation is better than UWB band.

Yang *et. al* 2009, [59] presents a compact dual band feed reflection choke and circular antenna. This antenna plays extremely critical job in the field of remote applications. The main motive to design this antenna is to find a low cost and low profile antenna. Also the antenna performance is observed on the HFSS software. The absolute effectiveness of this antenna is half. Also the value of the coupling coefficient is below -18DB. This technique is very suitable for broad communication applications. At last, in its design of the antenna, we would be able to provide the low cost solution for the reflector antennas.

Wadefalk *et. al* 2009, [60] realisation of linearly polar antenna for 1-10GHz. The final result of this antenna will show frequency band higher than realised before. Also, for this type of antenna, the value of the reflection antenna is better than -10db. In order to improve the final design of this antenna, FTDT (Finite difference time domain) solver of the feed. Its manufacturisation process is carried over the PCB (Printed circuit board).

Dissanayake and Esselle 2010, [61] presents the technique to halt the interference between UWB system and wireless network. For having a filtering effect, a slot resonator is integrated in the UWB antenna. In this analysis, the desired frequency of antenna is calculated. Its configuration is quite simple ac compare to other designs. In this, the notch frequency is also investigated.

Nazh *et. al* 2010, [62] presents a planar elliptical dipole antenna for UWB communications. In this design, there is an investigation of the radiator for the UWB applications. In this design, the elliptical orbits are widely used for increasing purpose of gain and bandwidth of the antenna. In order to increase the gain performance of the antenna, elliptical slots are used. Final results of this analysis consists of standing wave ratio of greater than 5.5. The time response of the signal is calculated by the IFFT of the signal. Radiation characteristics, gain, bandwidth can be calculated by the both the measurement and simulation results. At last the results were shown that antenna is best suitable for the UWB applications.

Guo *et. al* 2010, [63] presents double U slot rectangular patch antenna. In this design of antenna, substrate, patch and feedline makes an antenna structure. The configuration of the antenna is such that it consists of low impedance matching. Various studies have been conducted by the researchers to maintain a good performance of the antenna.

Li *et. al* 2010, [64] a ring monopole antenna have been investigated. The feeding technique utilized in this design is coplanar waveguide or microstrip feedline. The geometry of the antenna is having three parts in which transmission lines and planar resistors are also installed. As we know that for operating in a multiple separated frequency band, wireless communication system require their frequency bands. Power divider is crucial RF components which is used in various microwave circuits.

Ku *et.al*, [65] presents compact band notched antenna for UWB applications. This antenna is easy to design The configuration of antenna is such that it is composed of 15*15*1.6 mm3. In this type of antenna design, a good impedance matching to achieve is the major target.The important characteristics of this type of design is good frequency rejection characteristics. The effect of frequency interference is also lower, which makes it perfect design for use.

Ray and Tiwari, [66] presents coplanar waveguide printed hexagonal monopole configuration which is useful for UWB applications. In the parametric investigation of this configuration, the effect of feed gap have been studied. To accomplish this task, two different feed arrangements are done. UWB have some different types of properties like compact size, wideband isolation etc.

Thomas and Srinivassam, [67] presents UWB rectangular printed antenna with band dispensation. Its configuration is not so difficult. Its design can be easily realized on a HFSS software. These are few important characteristics that makes it different from other type of configuration. These slots are very useful. They are used to boost the impedance matching. They also used to improve the high frequency radiation characteristics.

Park and Jung, [68] presents compact MIMO antenna with high isolation. In its design of paper, the antenna is composed of two monopoles with connecting line facing the monopole and is orthogonal to the the ground plane. The final result upon its implementation on the HFSS gives excellent isolation characteristics. The antenna is basically designed for 2.4 to 2.5GHZ. In order to reduce the effect of mutual coupling, a connecting line is introduced. At last, this antenna is expected to have high diversity and high efficiency.

Ojaroudi *et. al* 2011, [69] presents a monopole antenna with enhanced bandwidth for UWB applications. This antenna is very famous for communication point of view. The geometry of the antenna have ultrawidebnd applications. The antenna is having a radiating patch. Also, it have the ability to provide the fractional bandwidth of more than 130%. One of the important advantage of this antenna is that it satisfies the return loss of 10DB. This antenna is easy to fabricate and also have the easy configuration.

Hsu *et. al* 2011,[70] presents implementation of broadband isolator with metamaterial inspired resonator. In this design, an antenna with excellent isolation characteristics is observed. The main function of the metamaterial resonator is it can behave as insulator and can be located into a compact MIMO system. The insulators play very important role. Its function is reduce the mutual coupling which is present in the antenna elements. Also we know that the in order to boost the data transmission of the signal, the SNR or the signal width will be increased.

Liu *et. al* 2011, [71] presents an antenna for Ultrawideband applications. Its design is composed of a planar monopole antenna. Circular ring with ground plane makes it well suitable for radar applications. Impedance bandwidth also plays a very important role during its fabrication. The final outcome of the antenna shows that antenna is having the capability to achieve a wide bandwidth of 122%.

Ma and Wunew 2011, [72] presents a band notched folded strip antenna. The geometry of the antenna is fork radiator and 40 microstrip line. With the purpose to achieve a band rejected property, the forked shaped strips are folded back. An equivalent model is presented which is based on the band notched characteristics. Also, various parameters are analysed on the HFSS software. The radiation properties are investigated by using transfer function of antenna. Also, in order to obtain a 5.5 GHz WLAN band, a pair of T-shaped stubs are embedded between the radiation patch. The final outcome of the antenna performance indicates the final return loss.

Lee *et al*. 2012, [73] presents a wideband planar monopole antenna. The geometry of the antenna is composed of slots which are L-shaped, which is very useful to produce a band notched characteristics. It is also easy to fabricate. Then the analysis of the antenna is performed on the HFSS software.

Chang *et. al* 2012, [74] presents a printed MIMO antenna for neutralisation line for wireless UWB applications. In its design, the location of the monopole is at exact opposite corner of the PCB and space d equally between the small portions. In this, a monopole antenna system decoupled by the neutralisation line technique. In its design, each antenna is having a equal size. The main characteristics of the neutralisation line is that it does not occupy too much space. Also the design is simulated on the HFSS software.

Abidin *et. al* 2012, [75] presents a wideband MIMO diversity monopole antenna which is very useful for Wireless applications. The configuration of the antenna is composed of two radiators placed symmetrical to each other. Neutralisation line is also present in this design. The basic function of the neutralisation line is to diminish the mutual coupling in the antenna elements. Also, it have an added advantage of good impedance matching. The antenna is practically implemented on the HFSS software. Also in its design, a low profile, compact antenna is studied in the paper which will provide a reliable data connectivity with high data rate.

Ko and Murch 2012, [76] presents compact integrated UWB MIMO diversity antenna for wireless applications. The configuration of the antenna is having installed two feed ports with more than 20DB isolation. The major advantage of this antenna is in wireless communication. It also provides a diversity signal and may act duplexer which allow the transmitted and received signals to be well isolated. One of the important application of diversity antenna is that it helps to improve the performance of the communication system.

Yang *et. al* 2012, [77] presents design of compact dual-polarised antenna. The configuration of antenna is such that it has two unique characteristics. One of the characteristics is constant beam width and other one is fixed phase centre location. The configuration of this type of antenna is such that it is practiable to put whole of the feed system inside the cryostat. One of its vital importance of this antenna is it provides a super sensitivity which is very beneficial to reduce the temperature.

Jung and Lee 2013, [78] compact band UWB reception antenna. In this design, an antenna with excellent isolation characteristics is observed. The main function of the metamaterial resonator is it can behave as insulator and can be located into a compact MIMO system. The insulators play very important role. Its function is reduce the mutual coupling which is present in the antenna elements. Also we know that the in order to boost the data transmission of the signal, the SNR or the signal width will be increased.

Hong *et al.* 2013, [79] presents an elliptical card UWB antenna. Its design is such a way that it is having a radiating element and ground p1ane. This antenna is adjusted to have band rejection with wireless local area network (5.1 to 5.8 GHz). Overall satisfactory performance can be achieved by using this antenna. This feeding mechanism of this antenna in such a way that a noble feeding mechanism is used to feed the antenna.

Kaiser *et al.* 2013, [80] presents an idea of UWB technology which is used to achieve high data rates which is more than 1GB/s. It is also easy to design an fabricate. Due to which it is more suitable for indoor communication system. UWB has attracted much of the attention of the researchers in the field of wireless communication. UWB is a short range communication technology. It is used for short range communication system.

Azim and Aslam 2014, [81] presents microstrip tapered slot antenna. The fabrication of the antenna is done after its analysis on the HFSS. This antenna is fabricated on the FR4 substrate with dimensions 22*24 mm. The final result shows that antenna has better impedance matching, gain etc. over an operating bandwidth of 3.1 GHz to 10.6 GHz.

Emadian *et al.* 2014, [82] presents a band notched printed round like receiving wire. To achieve the wideband operation. The geometry consists of circular like slot, trident shaped feedline. This design is very crucial for wireless application point of view. The radiation pattern of antenna consists of partially modified ground pane. Modification in the shape of ground plane makes it different in terms of traditional monopole antenna. The main function of these slots is to improve the impedance bandwidth and radiation performance. It is very useful for wireless applications which makes it very popular in communication market.

Lin and Jung 2015, [83] presents a monopole antenna system decoupled by the neutralisation line technique. In its design, each antenna is having a equal size. The main characteristics of the neutralisation line is that it does not occupy too much space. Also the design is simulated on the HFSS software.

Wael Abd Ellatif Ali 2017, [84] presents a UWB MIMO antenna which are very helpful for UWB applications. The configuration of antenna consists of 4 symmetrical circular element in order to have better communication. The two sides of antenna are symmetric. There is also a presence of radiators on both the sides of the antenna. It is very useful in applications like radar. Mutual coupling reduction is also very important to maintain the performance of antenna. Finally, the result consists of -10Db return loss, which is a satisfactory performance of the antenna.

Sarkar *et. al* 2017, [85] presents a multiple antenna system which is compactible for UWB applications. The design of antenna consists of the edge square patch antenna with feed. The main function of feed is to provide circular polarisation. During its analysis on the HFSS, two printed dipole antenna are placed adjacent to each other. Also, this antenna is suitable for wireless applications.

CHAPTER 4

COMPACT ORTHOGONAL PLANE UWB MIMO ANTENNA WITH POLARISATION DIVERSITY

UWB is growing technology now a days. It is a type of technology which is used to transmit the data at low levels. There are various fields in which UWB technology is used. This technology is now become an important research topic for researchers. The basic idea behind MIMO is that it uses multiple antennas installation at transmitter and receiver terminals. Also MIMO antenna is installed for the motive of low mutual coupling. Also MIMO technology have vast applications in the field of radar imaging, cancer detection etc.

4.1 INTRODUCTION

MIMO is a widely used wireless technology now a days. In MIMO technology, the limit and reliability of the transmitted information can be expanded because of rich dissipating condition. Also it is more important to maintain the isolation between the antenna elements. Also, UWB technology is too much popular research topic now a days. Self-complimentary antenna has many benefits because of its conservative size and transfer speed. The important area of research in MIMO antenna is to turn down the mutual coupling. In order to increase the wideband detachment, a T-shaped slot is etched between the antenna elements [86, 87]. UWB MIMO antenna is first type of antenna which is composed of anti-interference and polarisation diversity characteristics. Without using decoupling technique, it is possible to achieve high isolation. Dual polarisation can also be achieved by placing the antenna elements orthogonally and perpendicularly [88].

4.2 CONFIGURATION AND ANTENNA DESIGN

The designing of such type of antenna is composed of dimension 35*35. The antenna is designed on Rogers's substrate having thickness of 1mm, permittivity 3.5. On the substrate, the patch is designed. Below the substrate and patch, a ground is designed. The good impedance matching also results in better performance of the design. The various steps are performed and simulations are performed on HFSS Software. In this design, CPW feeding is provided to the antenna. The design of antenna is composed of semi-circular shaped radiator. Both the radiators are fed by 50ohm micro strip line. For better impedance matching, various parameter of antenna are simulated. Air box boundary is also designed to complete the simulation process. The dimensions of ground plane are identical as that of substrate. In order to enhance the port isolation, the arrowhead shaped ground is also very useful.

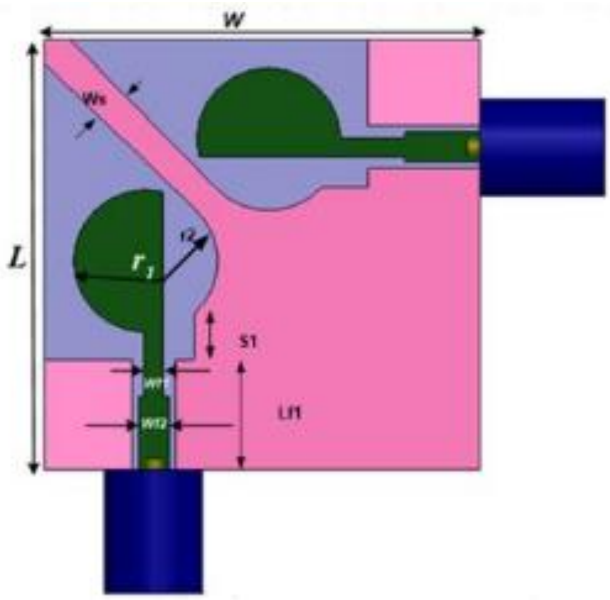


Figure4.1 Configuration of the antenna

Figure 4.2 Fabricated Antenna Design

At last, good isolation is achieved because of complimentary antenna. Filtering technique is very beneficial in the UWB antenna to avoid the interference. Efficient band antenna with notched characteristics can be obtained in this design. The good impedance matching makes it very effective in the field of wireless applications.

TABLE 2 GEOMETRICAL PARAMETERS OF ANTENNA

Parameters	Values(mm)	Parameters	Values(mm)
L	35	**H**	1
W	35	**W_s**	3.5
wf_1	2.5	**R_2**	5.8
wf_2	2	**Lf1**	6
R_1	5.8		

The parameters of the antenna is as follows- L_{sub} = 35mm, W_{sub} = 35mm, H_{sub} = 1mm. Two radiation patches are designed in order to cover the UWB application. Initial study shows that high frequencies are on the left half of the radiating patch and lower frequencies are on the right half of the radiators.

4.3 RESULTS AND DISCUSSION

4.3.1 *S*-Parameter

This investigation demonstrates the outcome of parameters on the antenna execution. When the length of the feedlines varied, then there is increase or decrease in the performance of the antenna. When the length of the branches of the antenna increases, the notched band is shifted towards higher frequencies. This also helps to turn down the mutual coupling between the antenna elements. This is on the ground that it will enable a long present way to generate resonance for low cut off frequency. Therefore the size is one of the most important challenge while designing the MIMO antenna.

Parametric study of S- parameters

Effect of feedline width 1 variation (Wf1)

The output of design is strongly affected by the feedline variation. In this type of variation, we will get s-parameter which is S_{11} and S_{12}. Both of these parameters are shown in the figure below. It is clear from Figure that from 6 GHz frequency onwards, the antenna has better impedance matching.

The plot after 6GHz frequency is below -10Db return loss. It is appeared from the graph the 4.5GHz frequency to 7GHz frequency, there is poor impedance matching. The below plot is for three different values (Wf1=2.3mm, 2.5mm, 2.7mm). The optimized value of plot is at Wf1=2.5mm whereas Wf1=2.3mm and Wf1= 2.7mm are its nearest values.

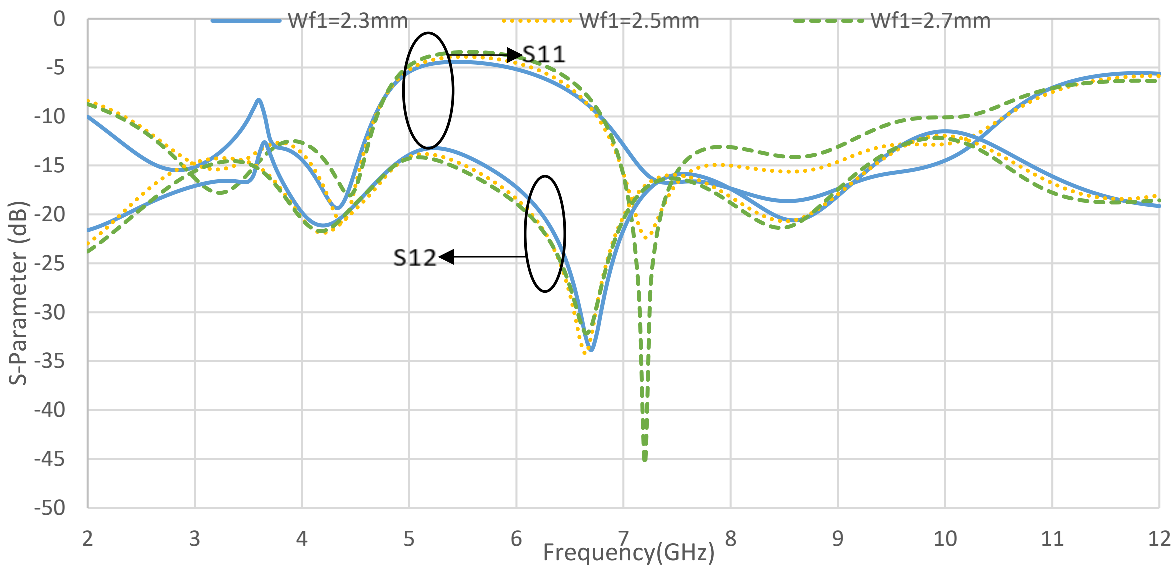


Figure 4.3 Schematic of Simulated S-parameter S_{11} and S_{12} of the antenna

Effect of feedline width2 variation (Wf2)

The effect of feedline2 variation on the output is discussed below. Three values of feedline2 are Wf2=1.3mm, Wf2=1.5mm, Wf2=1.7mm. Out of these three values, Wf2=1.5mm is the best optimized value. S_{11} and S_{12} parameters are shown in the figure. From the plot, it is clear that it have better impedance matching. And from frequency 7.5GHz to 9.5GHz, it again shows the better impedance matching. From the plot, there are two s-parameter of Wf2, which are S11 and S12 respectively. From the plot there are two s-parameters of wf2 which are S_{11} and S_{12} individually. From the figure it is clear that S11 has lower cut off frequency of 2.1 GHz. Similarly, it have higher cut off frequency of 9.2GHz.

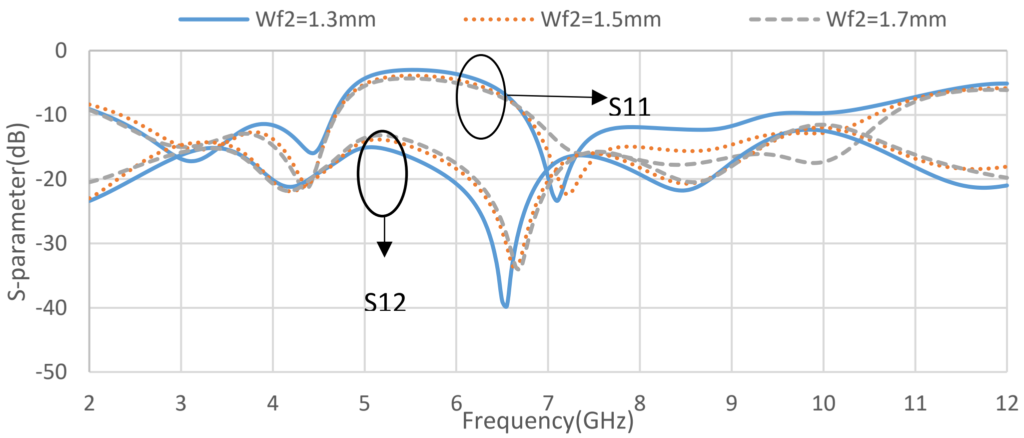


Figure4.4 Schematic of Simulated S-parameter S_{11} and S_{12} of the antenna

Effect of gap variation (g)

The variation of gap between the two feedlines will also put impact on the S-parameters of the antenna configuration. The three estimations of gap variation are g=1.8mm, g=2mm, g=2.2mrespectively. Out of these three qualities, g= 2mm is the best optimized value. The S-parameter S11 and S12 are shown in the plot below. From the plot, it is clear that S11 parameter have 1ower cut off frequency of 2.5GHz. and higher cut off frequency of 10GHz respectively. Plot of gap variation is shown below.

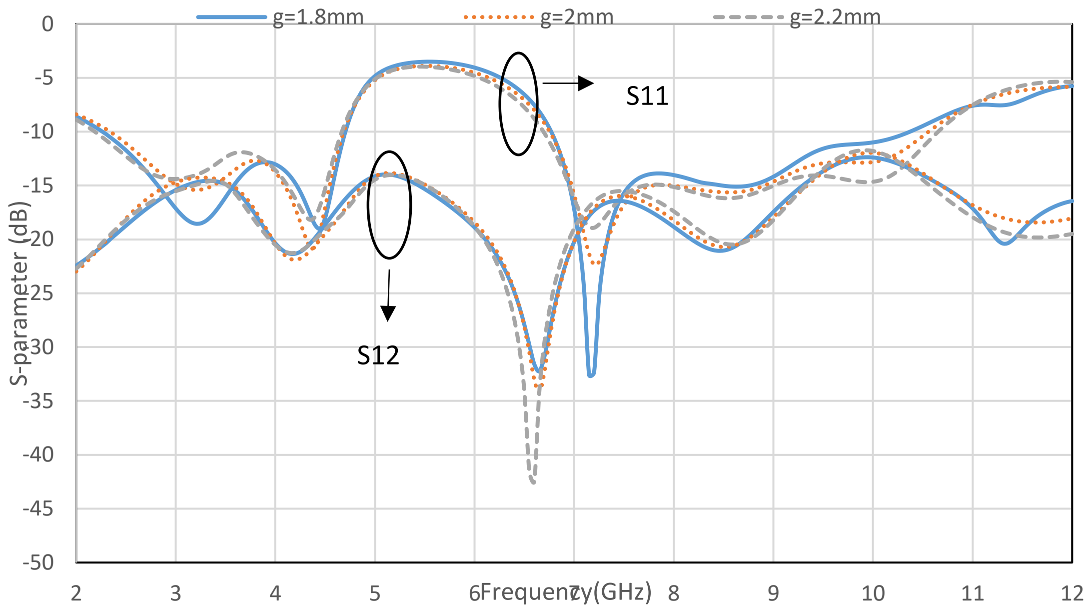


Figure 4.5 Schematic of Simu1ated S-parameter S_{11} and S_{12} of the antenna

Effect of radius variation

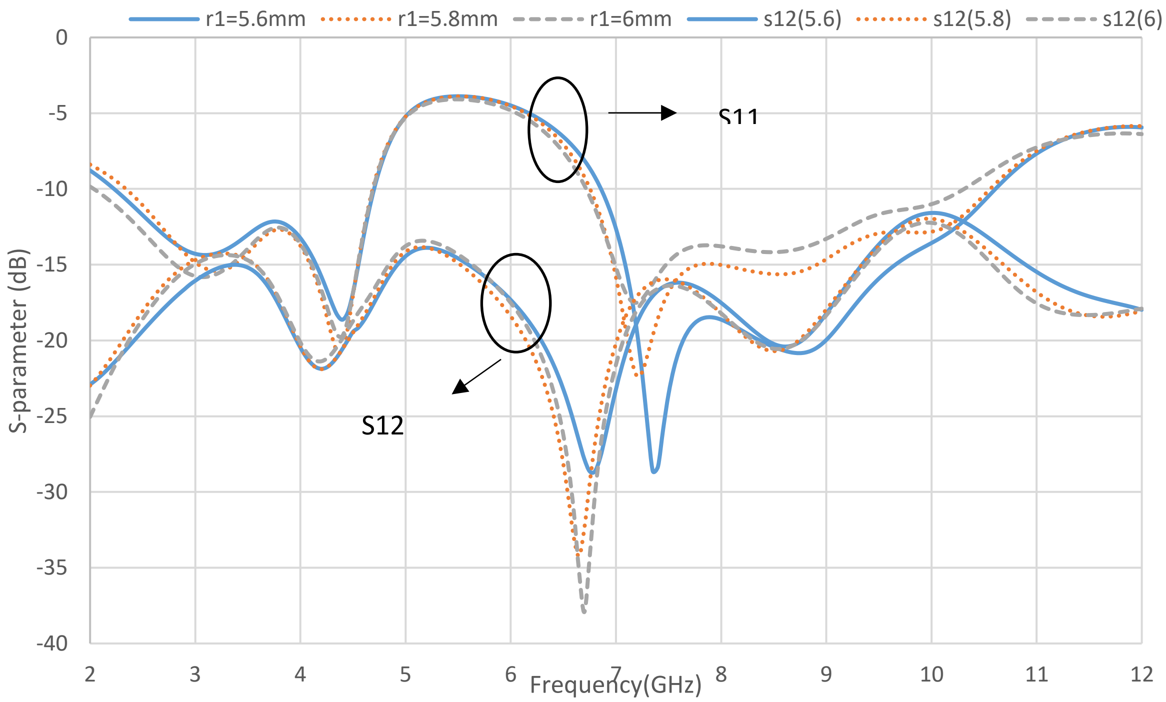


Figure 4.6 Schematic of Simu1ated S-parameter S_{11} and S_{12} of the antenna configuration.

The best optimized value of the patch radius is 5.8mm. S11 and S12 plots of the patch radius variation is shown in above. The S11 parameter has lower cut off frequency of 2.4 GHz and higher cut off frequency of 10.5 GHz respectively.

The figure shown below have better impedance matching from 2.5 GHz to 4.5 GHz and 7.5 GHz to 10.5 GHZ respectively. Also, it is clear that from the figure that mutual coupling is further reduced to get the better results.

The effect of the patch radius variation on the S-parameter of the antenna configuration is also shown.

Effect of radius (r2) variation

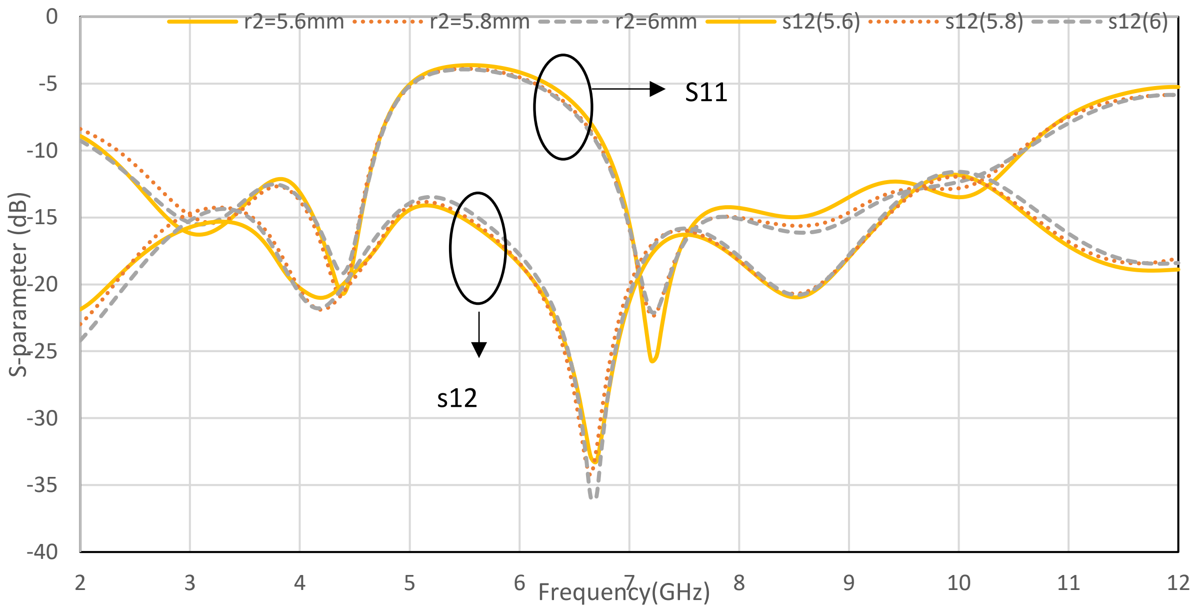


Figure 4.7 Schematic of Simu1ated S-parameter S_{11} and S_{12} of the antenna

Effect of radius (r2) variation on the S-parameter is also shown in the plot given below. From the plot, it is clear that it has better impedance matching from 2.5 GHz to 4.5 GHz. The optimized value of this plot is r2= 5.8mm. The plot shows better impedance coordinating from 7 GHz to 10.5 GHz respectively. The lower cut-off frequency of this plot is 2.3 GHz.

From the figure of antenna design indicated above, it is clear that antenna fabrication is taken on the FR4 substrate. Its S-parameter is shown in figures 8.1 to 8.5. The process of fabrication of antenna is taken on the FR4 substrate. It is clear from the figure that simulated results cover the 2.3 GHz to 10.5 GHz with S11<-10Db and S12< -10.5 Db. Envelop Correlation factor plays a significant job in the descent variety execution of the radio wire. From this design, it is clear that a good isolation can be accomplished by introducing the complimentary structure. The antenna with these improvements can be a very perfect for UWB applications. Therefore, the requirement of the impedance matching has been fulfilled In order to verify the simulated results, the fabrication of the antenna is done on the FR4 substrate. The use of wireless technology has become too popular during the last decade. For fullfill the demand of wireless technology, MIMO plays a very crucial role. No doubt the MIMO is providing better servicing in the field of wireless communication but it also have some drawbacks which the researchers are trying to improve.

4.3.2 Radiation Pattern

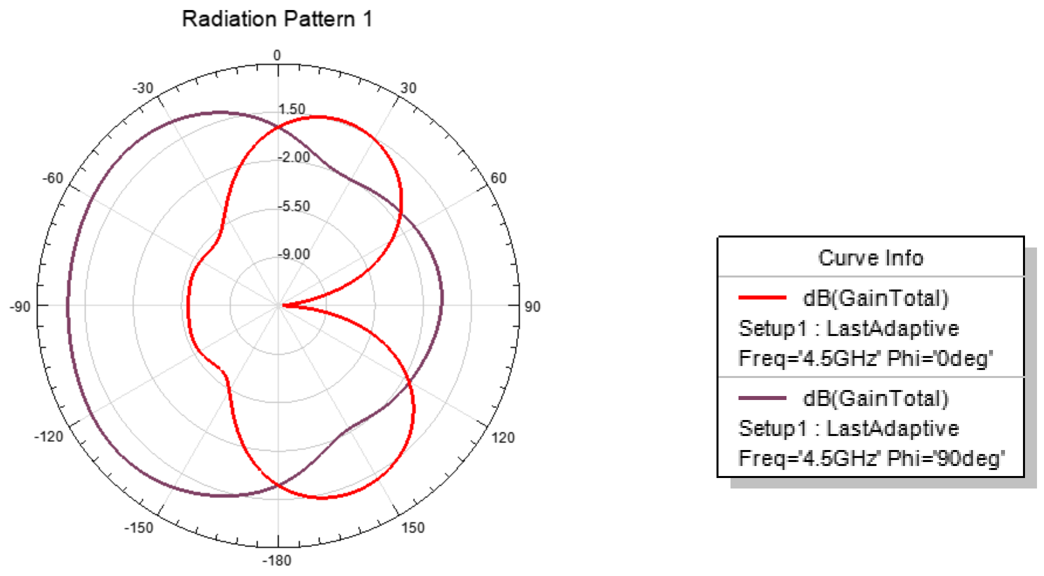


Figure 4.8 Radiation pattern at 4.5GHz

4.3.3 Simulated and measures results of design

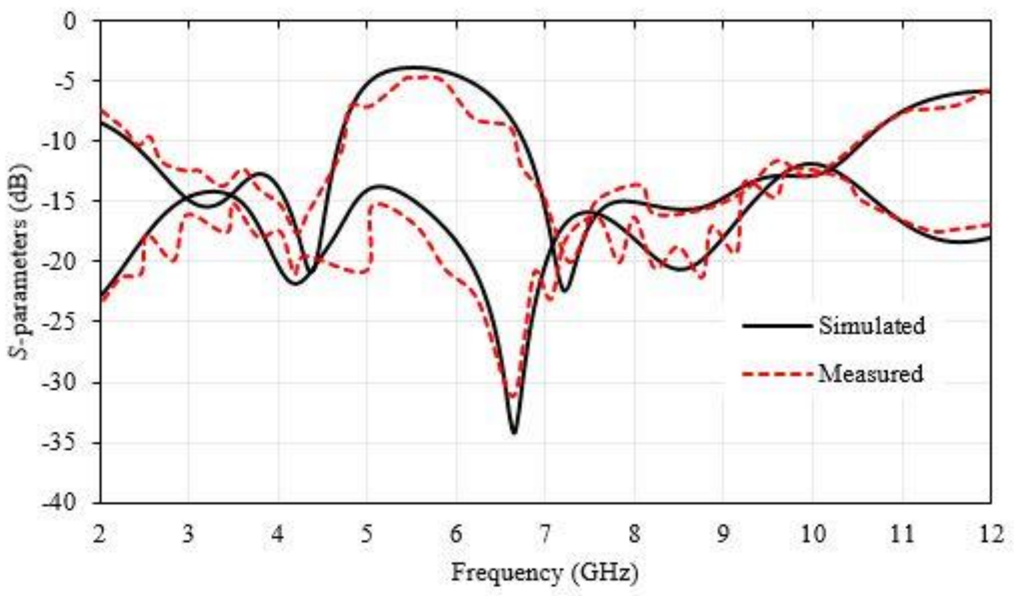


Figure.4.9 Simulated and measured results for design1

4.4 CONCLUSION

Wireless technology have faced a no. of challenges for higher data rates, better quality of performance. MIMO is very good technology to fulfill the demand of wireless communication. Present communication system depends more on MIMO technology. MIMO plays very crucial role to fulfil the demand of present communication technology. Presently, 3G and 4G technology requires MIMO technology for large data transfer and for better speed and accuracy. The idea of MIMO technology is become more popular during the last decade. No doubt MIMO is very crucial for communication system but MIMO is facing a lot of challenges which the researchers are trying to improve.

CHAPTER 5

COPLANAR WAVEGUIDE FED (CPW) PLANAR MONOPOLE TWO PORT MIMO ANTENNA FOR UWB APPLICATIONS

A CPW planar monopole two port MIMO antenna is presented. The antenna consists of two semi-circular radiators present on the substrate. As this geometry is compact quasi self-complimentary, therefore ground and patch (radiators) are present on the same height. The two radiators are fed by using two quasi self-complimentary feedlines. In this paper, the fully recommended HFSS procedure is followed. Substrate of particular dimensions is taken and patch is also designed on the substrate. The dimensions of various elements of substrate are varied and on the basis of simulations, plot below -10db is obtained. The plot follows the UWB (ultrawideband) procedure.

5.1 INTRODUCTION

In past when MIMO antenna was not invented, lot of data was wasted while travelling from sender to receiver. Due to the coming of obstacles coming in the path of travelling data, the receiver was not able to get proper quantity of data. To overcome this issue of antenna, a concept of MIMO antenna was discovered with the help of which data losing problems was solved. UWB is a very fast growing technology, which transmits signals at low energy level. UWB is quickly developing innovation, which transmits signals at low vitality level. The principle favourable position of UWB is in the field of short range information transmission, radar imaging. Likewise it has low multifaceted nature, minimal effort low power thickness and high information rates [89]. There are various method to boost the bandwidth of UWB antennas for communication purposes, which are substrate with low dielectric constant, substrate thickness increase and different types of feeding techniques [90, 91].As it were we can say that the size and transfer speed of receiving wire is clashing. i.e. improvement of one can corrupt the exhibition of other . Therefore to increase the bandwidth of elliptically and circularly monopole antenna, recently many techniques such as adding finite metal plane[92], adding slot to one side of radiating element[93], adding additional stub to the one portion of circular patch[94]. Because of the development of ultra-band communication system, such as WLAN, WiMAX and so on. In recent years, bunches of papers have been distributed to planning to dispense with narrowband with UWB receiving wires. Some of them are applying parasitic element [95], using resonant stubs, embedding resonant cells and making use of half mode substrate integrated technology. Therefore the self-complimentary antenna has constant input impedance and can be designed for wideband operation. Due to these features, Self-complimentary antenna are highly recommended for wideband operation. It may be more convenient for antenna engineers to to design self-complimentary antenna. Such imperfect SC complimentary antennas are called quasi self-complimentary antennas (QSCA). Despite of imperfectness, QSC antennas still has the capabilities to show wideband operation and constant input impedance. The fabrication of the SCA is on the ground plane and transform the input impedance for wideband applications. The first SCA antenna was fabricated with broad impedance bandwidth. When the geometry of antenna is complimentary to itself, then, then frequency independent impedance property is achieved. For wireless universal serial bus dongle applications, there is QSCA reception apparatus with triangular score inserted on the small scale strip line. The miniaturisation of ultrawidebnd antennas is attracting much of the interest from industry and academia. Different varieties of UWB antenna shave been presented in the past few years.

5.2 CONFIGURATION AND ANTENNA DESIGN

QSCA antenna is structured on fr4 substrate. The configuration of the required antenna is appeared in Figure 1. The length and breadth of antenna is of dimensions of 41* 30 mm respectively. After that a QSCA ground is created on substrate. The height of the substrate is 0.8mm. Two semi-circular radiators are designed on the ground. The ground is created as same the height of substrate. Besides it, two feedlines are drawn which are used to feed the antenna . The length, breadth and height of the substrates are denoted by Lsub, Wsub, hsub respectively. According to FCC (Federal communication commissions), the antenna is designed for UWB (ultrawidebnd operation) which is 3.01 to 10.6 GHz. By performing the various simulations, various efforts are done to perform UWB operation. Then various design steps are followed in HFSS to design the required antennas.

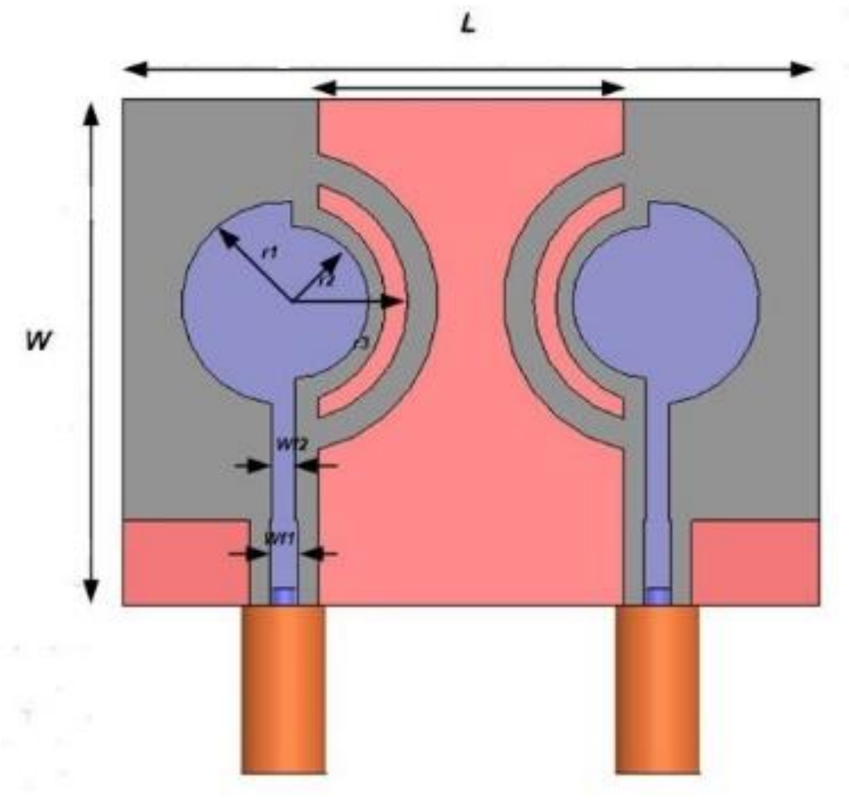


Figure 5.1 Configuration and geometry of the required antenna

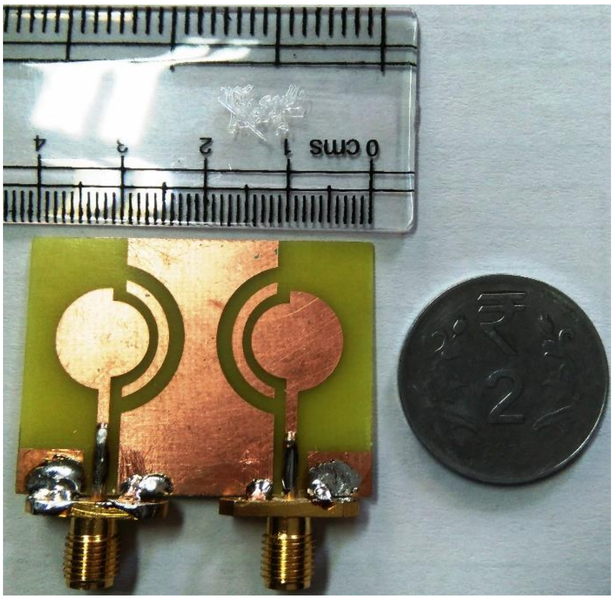


Figure 5.2 Fabricated Antenna Design

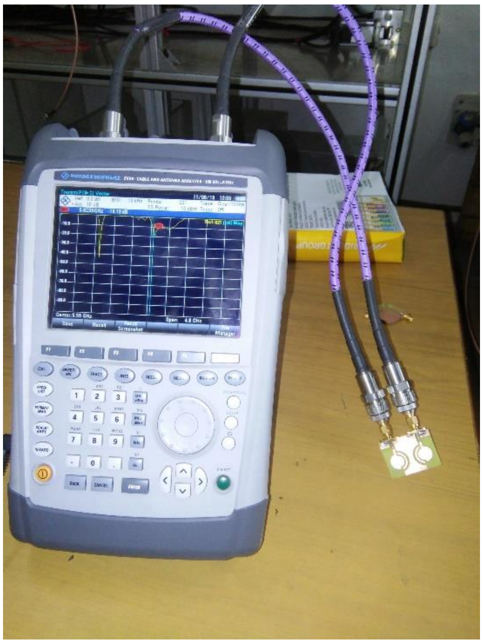


Figure 5.3 Antenna output during Testing in RF Lab

TABLE 3 PARAMETERS OF ANTENNA.

Parameters	Values(mm)
L	41
W	30
Wf1	1.6
Wf2	1.4
R1	6

R2	6
R3	7

5.3 RESULTS AND DISCUSSIONS

5.3.1 S-Parameter

The measured and simulated result of the antenna is appeared in Figure 2. The outcome demonstrates that antenna has a data transmission of 5.8 to 10.3 GHz. The simu1ated results shows that the return loss is not exactly -10db. The antenna is analysed and optimized in terms of operating bandwidth and return loss using HFSS. The result shown in the figure indicates that 5.9 GHz to 10.6 GHz. Thus, the impedance matching requirement of the antenna is being satisfied. For good performance, the mutual coupling of the antenna should be less than -15db. The creation of radio wire is on FR4 substrate for the verification of the simulation results. The measured and simulated results are in great understanding.

Effect of feedline width 1 variation

The output of design is strongly affected by the feedline variation. In this type of variation, we will get s-parameter which is S_{11} and S_{12}. Both of these parameters are shown in the figure below. It is clear demonstrates from Figure that from 6 GHz frequency onwards, the antenna has better impedance matching.

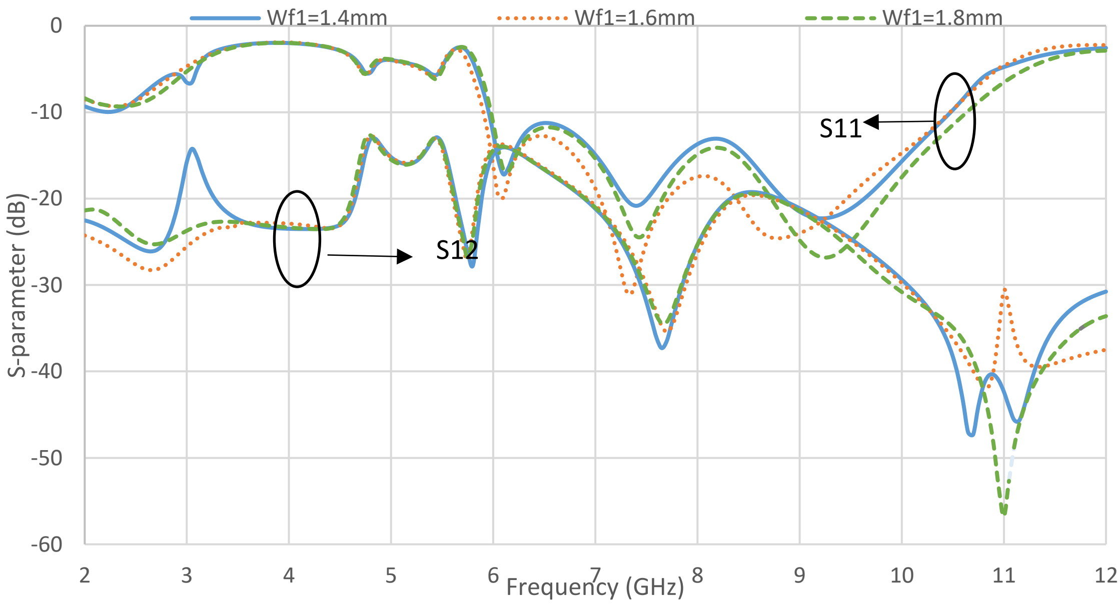


Figure 5.4 Schematic of Simulated S-parameter S_{11} and S_{12} of the antenna

The plot after 6GHz frequency is below -10Db return loss. From the plot it is clear that from 2GHz frequency to 6GHz frequency, there is poor impedance matching. The above plot is for three different values (Wf1=1.4mm, 1.6mm, 1.8mm). The optimized value of plot is at Wf1=1.6mm whereas Wf1=1.4mm and Wf1= 1.8mm are its nearest values.

Effect of feedline width 2 variation

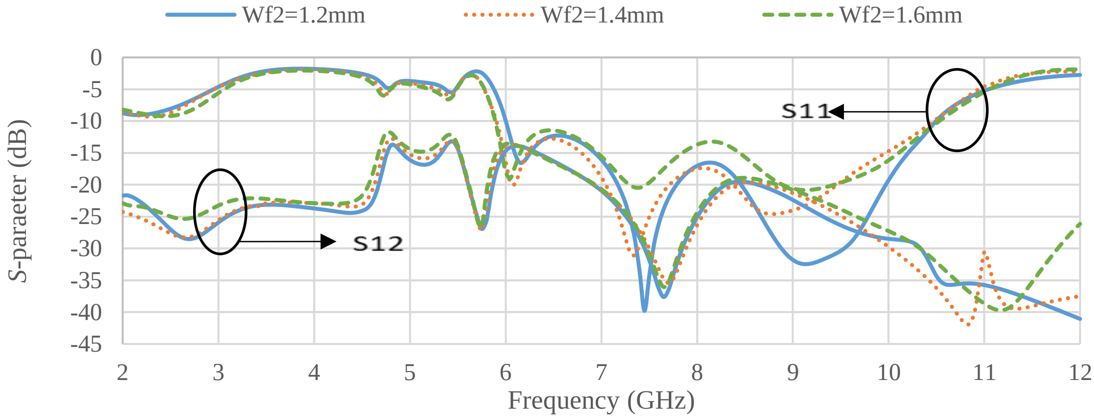


Figure 5.5 Schematic of Simulated S-parameter S_{11} and S_{12} of the antenna

The effect of feedline2 variation on the output is discussed be1ow. Three values of feedline2 are Wf2=1.2mm, Wf2=1.4mm, Wf2=1.6mm. Out of these three values, Wf2=1.4mm is the best optimized Value. S11 and S12 parameters are shown in the figure. From the plot, it is clear that it have better impedance matching. And from frequency 6.2GHz to 10.5GHz, it again shows the better impedance matching. From the plot, there are two s-parameter of Wf2, which are S_{11} and S_{12} respectively. From the figure it is appeared that S11 has 1ower cut off frequency of 6 GHz. Similarly, it have higher cut off frequency of 10.5GHz.

Effect of ground width variation

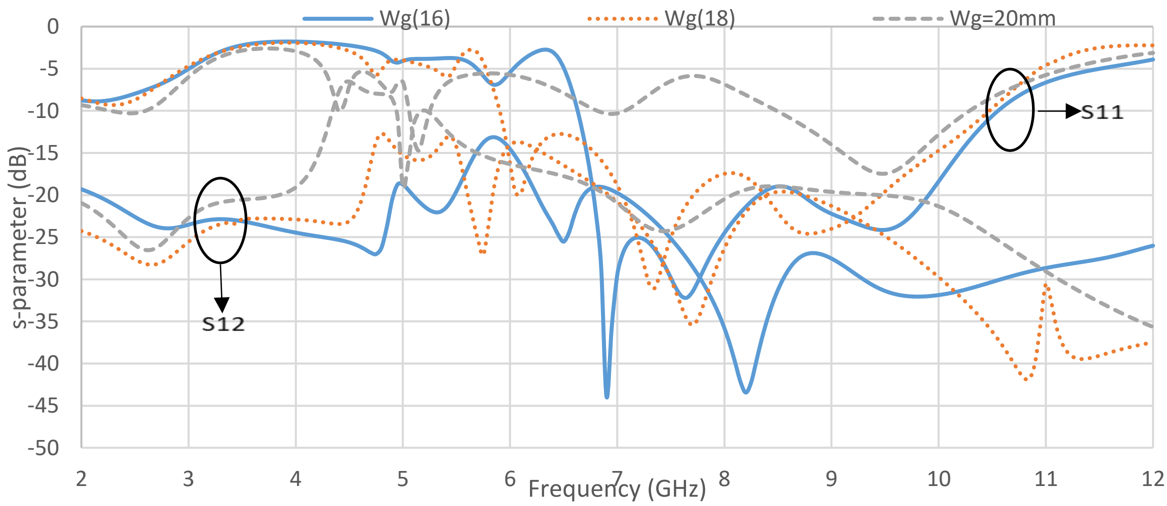


Fig 5.6 Schematic of Simu1ated S-parameter S_{11} and S_{12} of the antenna

The variation of ground width will also put impact on the S-parameter of the antenna. By adjusting the value of the ground variation, we will get better impedance matching results. Wg=18mm is the best optimized result of the antenna configuration. Plot showing the S-parameter of the antenna is shown below. From the plot, it is clear that from 6.8 GHz onwards, the antenna provides a better impedance matching. The 1ower cut off frequency of the S11 parameter is 6.8 GHz.

Effect of patch radius r1 variation

Patch radius variation will also have significantly impact on the performance and S-parameter of the antenna. Three values of the patch radius are r1=5.8mm, r1=6mm, r1=6.2mm respectively. The best optimized value of the patch radius is r1= 6mm. From the plot, it is clear that the from 6.2 GHz onwards, the antenna has better impedance performance.

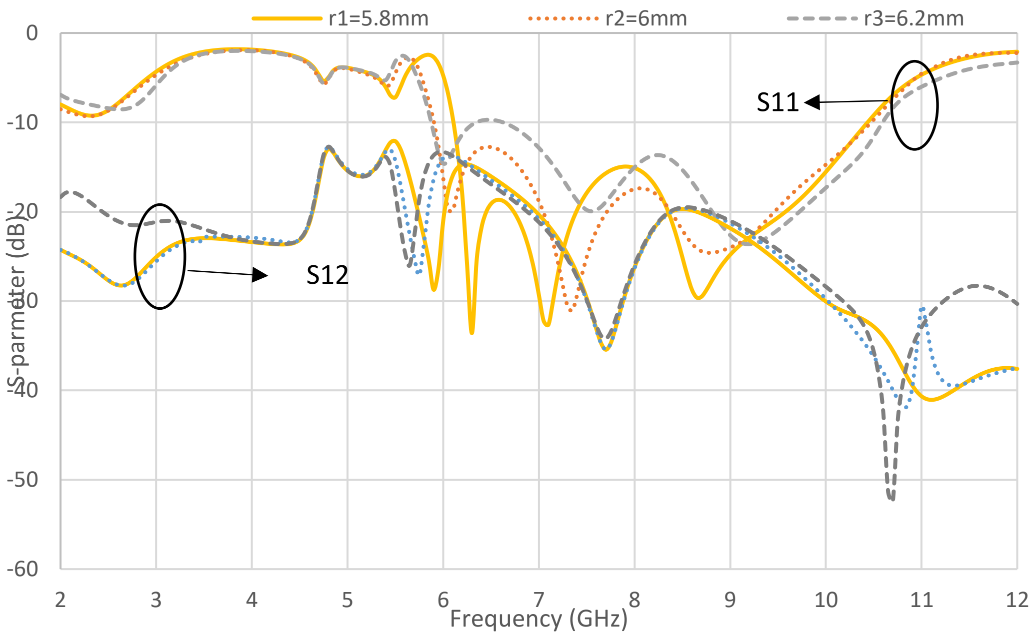


Figure 5.7 Schematic of Simu1ated S-parameter S_{11} and S_{12} of the antenna

Effect of radius r2 variation

Three optimized values of the radius r2 variation are r2= 6.8mm, r2=7mm, r2= 7.2mm. The best optimized value of the radius r2 variation is r2= 7mm. From the figure given below, it is clear that the plot shows good impedance matching after 7 GHz onwards. The antenna is analysed and optimized in terms of operating bandwidth and return loss using HFSS. The result shown in the figure indicates that 5.9 GHz to 10.6 GHz. Thus, the impedance matching requirement of the antenna is being satisfied. S_{11} and S_{12} are the two parameters which are clearly indicated on the plot designed below. Also, according to FCC, the plot should be between 3.1 GHz to 10.6 GHz respectively. The impedance matching requirement is being fulfilled in this plot drawn below.

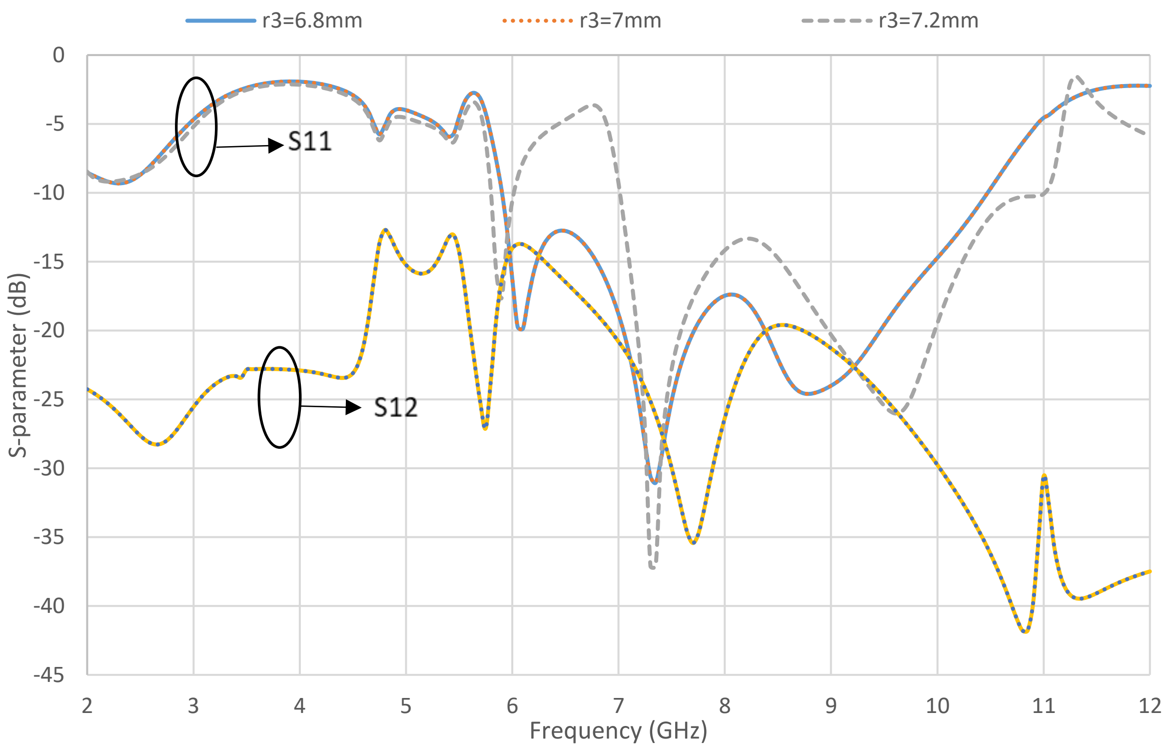
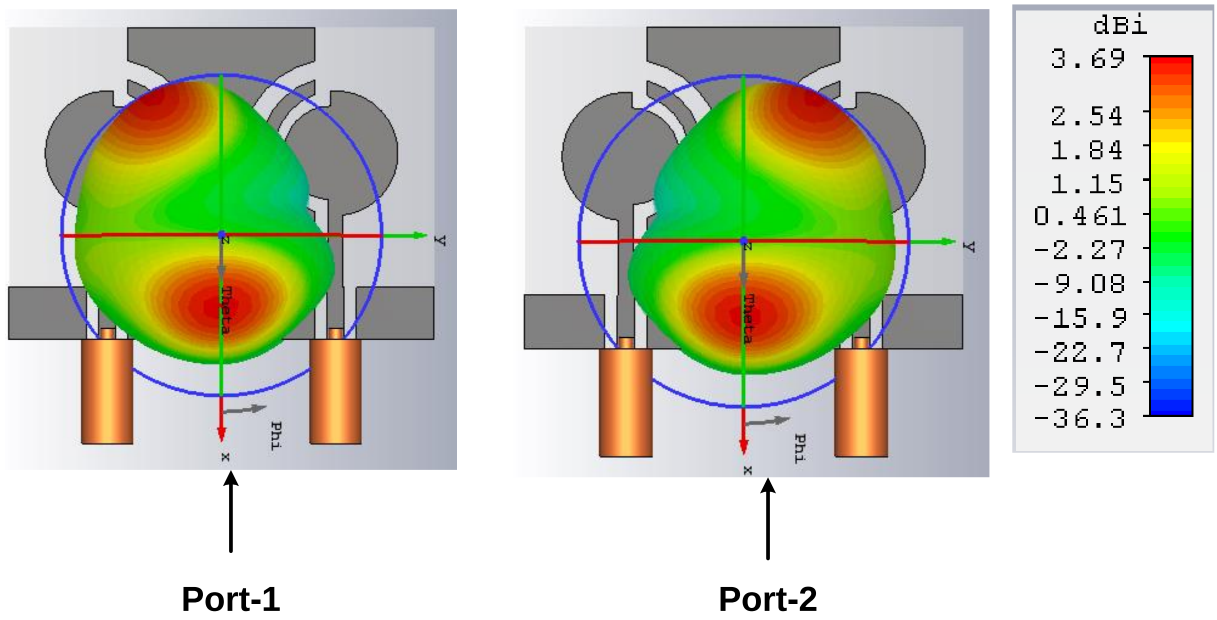


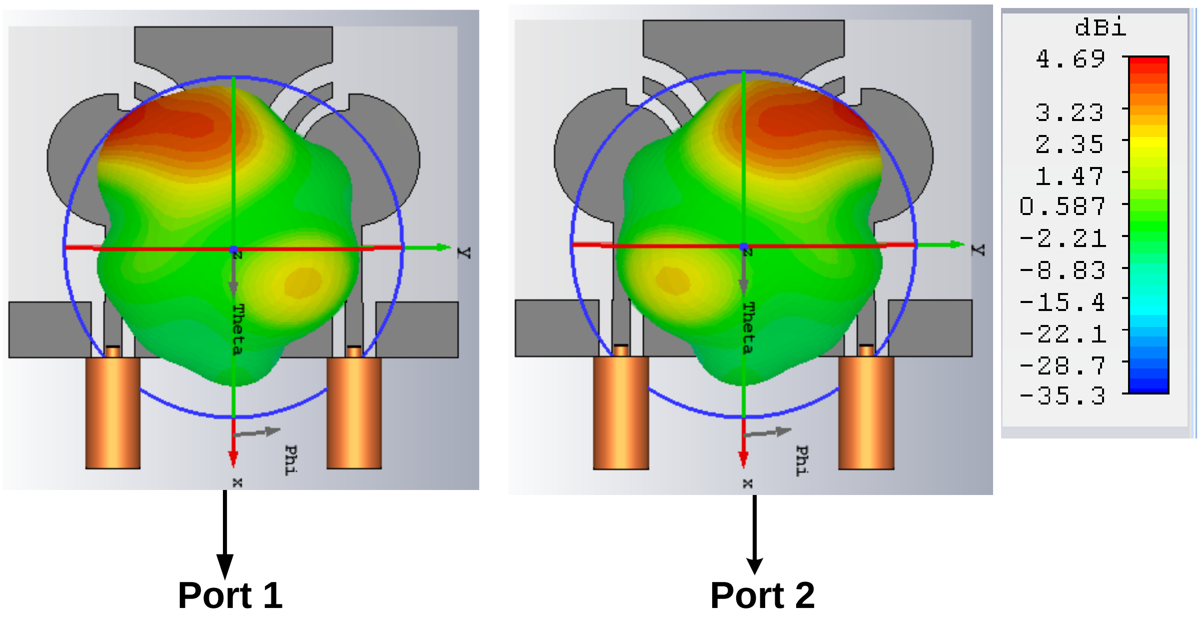
Figure5.8 Schematic of Simu1ated S-parameter S_{11} and S_{12} of the antenna

5.3.2 Radiation Pattern

The radiation pattern of the above antenna is shown in the Figure below



(a)



(b)

Figure 5.9 Simu1ated radiation pattern (a) 7GHz (b) 9 GHz

The simu1ated radiation pattern at resonant frequencies of 7GHz and 9GHz are shown in the Figure . It manifests that omnidirectional radiation pattern ahs been achieved. There is stability in the radiation pattern at all resonant frequencies.

5.3.3 Diversity parameter

5.3.3.1 Diversity Gain 5.3.3.2 Envelope Correlation Cofficient 5.3.3.3 Mean Effective Gain.

Frequency	***Diversity Gain***	***ECC***	***MEG-1***	***MEG-2***	***MEG Ratio***
7 GHz	9.99	0.001	-3.01	-3.01	1
9GHz	9.99	0.001	-3.01	-3.01	1

5.3.4 Simu1ated and Measured results of design

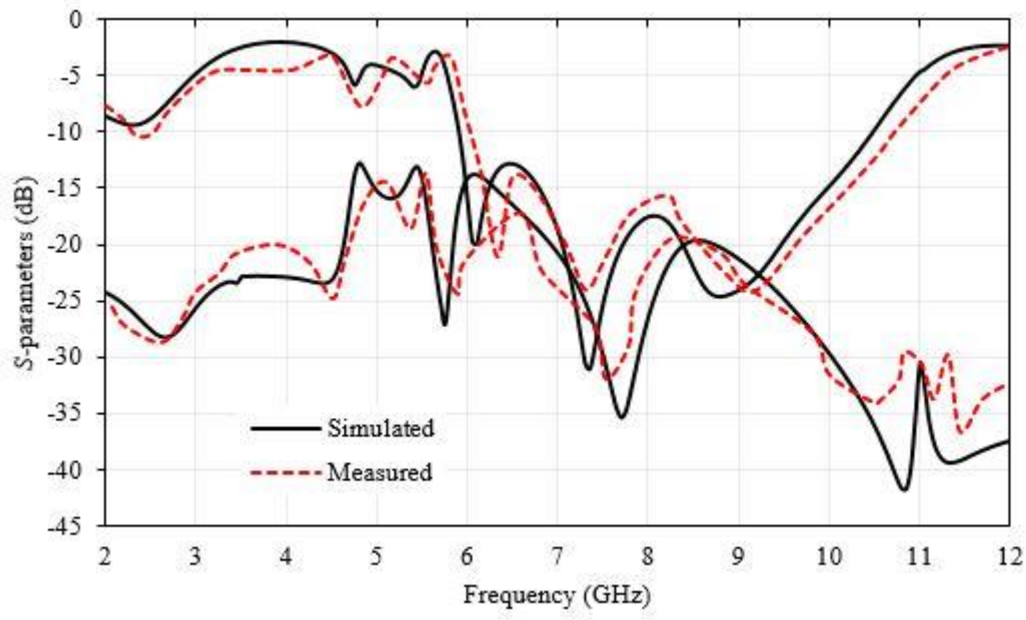


Figure 5.10 Simu1ated and Measured results of design

5.4 CONCLUSION

CPW fed two port MIMO antenna is designed. Different parametric analysis has been performed in HFSS. In this design, UWB bandwidth of 6.1 GHz to 10 GHz is achieved. To achieve the UWB bandwidth, lots f efforts are applied. The measured results is also performed in lab. Simu1ated and measured resu1ts are compared in the plots. Finally,this antenna is suitable for wireless application purpose.

CHAPTER 6

CONCLUDING REMARKS AND FUTURE SCOPE

Wireless technology is one of the important science in today's world. Wireless designers have faced a no of challenges of high data rates and better quality services. There are various problem in wireless technology like fading and multipath distortion. MIMO is the beneficial technology to meet the demand of high data rates, spectral efficiency etc. The use of MIMO technology is become very much popular during the last decade. The increasing demand of potential is being fulfilled by the MIMO technology. No doubt MIMO is one of the emerging technology for future, but it have so many challenges which the researchers are trying to improve.

The present communication system requires high data rates with high speed and accuracy. To fulfil the growing demand of communication system, MIMO plays a very important role. Patch antennas, which are low cost, low in weight, planar or conformal layout, easier to fabricate, and able to be integrated with electronic or signal processing circuitry show good compatible with MIMO systems. To assist roaming Internet access via cell phones etc, MIMO with long term evolution is used.

REFERENCES

[1] K.G Thomas, " Microstrip patch antenna." *IEEE Trans Antenna Propagat.* Vol.49, no.6, pp. 954-960,1970.

[2] H. Mardani and S. A. Aghdam, "Configuration of microstrip patch antenna," *IEICE Electron. Exp.*, vol.8, no. 20, pp. 1698–1702, 2011.

[3] Y.J REN and K.Chang, "Microstrip line feed.", *IEEE Antennas Wireless Propag* Lett 5(2006), 274-276.

[4] Vuong, "Aperature coupled technique*." IEEE Trans Antenna Propagat* (2007), 2563-2365.

[5] Guo and Jhang, "Aperture coupled technique." *IEEE Trans Antenna Propaga* 5(2007) 1189-1192.

[6] Jhnag and Liu , " Proximity coupled technique." *IEEE Trans Antenna Propagat* 53(2005) 3500-3504.

[7] J. Yang, M .Panteleev, P. Kildal and L. Heldneer, "Microstrip line and its electric fied lines." *IEEE Transactions on Antenna and Propagation*. Vol.60, no.5, pp.2010-2218, 2012.

[8] Tzyh-Ghuang Ma and Sung-Jung Wunew, "Band-notched folded strip monopole antenna for Ultra wideband applications", vol. 54, no. 11, pp. 3075–3081, 2011.

[9] S. Ko and R .Murch, "Compact integrated diversity antenna for wireless communication." *IEEE Trans Antenna Propagat.* Vol.49, no.6, pp. 954-960, Jun 2012.

[10] Y. Mushiake, "The Input Impedance of a Slit Antenna", *Joint Convention Record of Tohoku Sections of IEE and IECE of Japan*, June 1948, pp. 25-26., 1998.

[11] G. Srivastava ,S. Dwari , B .K. Kanjiuia , "A Compact 4*4 ultrawidebnd (UWB)band notched MIMO antenna." *IEEE international microwave and RF conference* (IMARC), Bangalore, 1999: pp.275-598, 1999.

[12] W. Abd Ellatif and Boutejdar, "A monopole antenna with enhanced bandwidth using triangular defected microstrip structure," *Microwave opt technol Lett* 2002; 58:1514-9., Vol. 55, no. 12, pp.375-256,2000.

[13] A.L.Zaki , M.H Abdou and Ali WA, “Design and fabrication of rectangular ring monopole array with parasitic elements for UWB applications. *Microw opt technol Lett* 2002; 58:2268-73.

[14] Ibrahim Ahmed A, Abdalla Mahmood A and Boutejdar Ahmed, “Resonator switching for UWB antenna in wireless applications”. *Antenna Propagat* 2003; 9(13):1468-77.

[15] Ibrahim Ahmad A, Hamed hashim FA and Yahin Eman, “A compact planar UWB antenna with bandnotched charactersitics. ICET; 2003, P.1-4.

[16] Yi-Cheng Lin and Kuan-Jung, “ Hung presents a compact ultra wideband rectangular apertures antenna and band notched designs” vol. 54, no. 11, pp. 3075–3081,2015.

[17] Wael Abd Ellatif Ali July 2017, “presents a paper presents compact size 4 × 4 cm² UWB MIMO antenna for UWB applications.” vol. 46, no. 2, pp. 294–295,2017.

[18] Y. sharma, D. Sarkar and K. saurav, “Three element MIMO antenna system with pattern and polarisation diversity for wireless applications.”vol. 59, no. 14, pp. 598-458, 2015.

[19] T.C Tang and K.H Liu, “An ultrawideband MIMO antenna with dual band notched function.” *Antenna and wireless propagation letters*. IEEE, vol. 13, pp. 1076-1079, 2014

[20] V. Tran and A. Sibille, “Spatial multiplexing in UWB MIMO Communications.” *Electron Le*tt. , vol. 42, no.16, pp-931-932, 2006.

[21] S. Park and C. Jung, “A wideband planar monopole antenna.” *IEEE Trans Antenna Propagat,* vol.51, no.4, pp.901-903, April 2003.

[22] K. Kim and S. Park, Analysis of the small band rejected antenna with the parasitic strip for UWB, *IEEE Trans Antennas Propag* 54 (2006) , 1688-1692.

[23] Y.J REN and K.Chang, “An annual ring antenna for UWB communications.”, *IEEE Antennas Wireless Propag* Lett 5(2006), 274-276.

[24] Brandenburg, LH; Wyner, AD (May–June 1974). "Capacity of the Gaussian Channel with Memory: The Multivariate Case". *Syst. Tech. J*. 53 (5): 745–78.

[25] Salz, J (July–August 1997). "Digital transmission over cross-coupled linear channels". *Technical Journal*. 64 (6): 1147–59.

[26] S.Yin, Lieu and Z-D Wang, “A compact UWB antenna for wireless applications.” *IEEE. Trans. Antenna Propagat.* , vol. 55, no.12, pp.3391-3397, August 1998.

[27] Yi-Cheng Lin and Kuan-Jung, “ Hung presents a compact ultra wideband rectangular apertures antenna and band notched designs” vol. 54, no. 11, pp. 3075–3081,2015.

[28] Yi-Cheng Lin and Kuan-Jung, “ Hung presents a compact ultra wideband rectangular apertures antenna and band notched designs” vol. 54, no. 11, pp. 3075–3081,2005.

[29] Ri and chu, “Digital transmission over cross-coupled linear channels". *Technical Journal*. 64 (6): 1147–59

[30] Kiminami, “small ultrawidebnd microstrip fed tap monopole antenna vol.46, no. 2, pp 294-295, March, 1998.

[31] M. Aggrawal February 1998, “UWB Magnetic antennas.” In IEEE Int,Symp pp…604-607.

[32] Wang and Yin, “Capacity of multipath propagation” *Microwave. Antenna propagat. Lett*, vol. 4, no. 4, pp. 437-435, 2010.

[33] M.J Amman and Z.N Chen, “A wideband planar monopole antenna.” *IEEE Trans Antenna Propagat*, vol.51, no.4, pp.901-903, April 2003.

[34] K .Bahadori and Y .Rahmat-Samii, “An elliptical card UWB MIMO Antenna for Wireless Communications.” Presented at the *Eur. Conf. Antenna Propagat. (EuCAP)*, nice, vol.52, no.5, France, 2004.

[35] Abdollahband, Zakir and Amman, “UWB monopole Antenna with dual band-notched characteristics is presented.” *IEEE Trans. Antenna Propagat*, vol.53, no.11, pp 3500-3504, December 2005.

[36] J. Liang, C.C. chiau and C.G Parini, “Study of circular disc antenna for UWB applications.” *IEEE Trans Antenna Propagat* 53(2005) 3500-3504.

[37] V. Tran and A. Sibille, “Spatial multiplexing in UWB MIMO Communications.” *Electron Le*tt. , vol. 42, no.16, pp-931-932, 2006.

[38] Eldek, “Numerical study of Ultrawideband microstrip fed monopole antenna.” *Progress in Electromagnetic Research*, PIER 65, pp. 59-69, 2006.

[39] Y.J. Ren and K. Chang, An annual ring antenna for UWB communications, *IEEE Antennas Wireless Propag Lett 5* (2006), 274–276.

[40] Qu and Sung, "Band notched UWB circular monopole antenna." *IEEE Antennas Wireless Propagat Lett6*, 2006.

[41] R. chayono , M. Haneishi and Y. kimura , " Inverted triangle printed monopole antenna with halfdisk for UWB applications. " *Microwave conference Yokohama, Japan,* 2006, pp. 1944-1997.2006.

[42] K. Kim and Park, "Analysis of band rejected antenna with parasitic strip for UWB." *IEEE Trans Antenna Propagat* 54(2006) 1688-1692.

[43] Liu, "Wideband microstrip monopole antenna with frequency band notch function."vol. 15, no. 11, Dec 2007.

[44] Y. Sung, "Compact ultrawideband rectangular aperature antenna and band-notched design." *IEEE Trans. Antenna Propagat*. Vol. 54, no.11, pp.3075-3081, 2007.

[45] Roshandeal and Murch, "Microstrip Square ring monopole antenna for UWB applications." Vol. 12, no. 12, 2007.

[46] Choo and Wang, "MIMO channel capacity with antenna polarisation diversity." Vol. 55, no. 12, pp. 2048-3254, 2007

[47] Chiu and Murch, "Four port antenna for MIMO applications." Vol. 12, no. 12, Dec 2007.

[48] M.M .Matin, B.S Shariff, "Probe fed stacked patch antenna for UWB applications." *IEEE Trans antenna propagate* 55(2007), 2385-2388.

[49] Vuong, "U-slotted antenna for UWB applications*." IEEE Trans Antenna Propagat* (2007), 2563-2365.

[50] Hong and Chiu, "Planar UWB antenna with band notched structure."*Microwav. opt technol Lett* 51(2007) 2365-1236.

[51] K.P Ray and Y. Ranga, "Ultrawideband elliptical monopole antenna." *IEEE Trans Antenna Propaga* 5(2007) 1189-1192.

[52] Yangon Li and WEN Ying Liu, "Two ultrawideband antenna integrated with resonator for wideband operation." vol. 53, no. 11, pp.3500-3504, 2008.

[53] S. Yin, Lieu and Z-D Wang, “Acompact UWB antenna for wireless applications.” *IEEE. Trans. Antenna Propagat.* , vol. 55, no.12, pp.3391-3397, August 2008.

[54] S.K Rajopal and S.K Sharma, “Performance of ultrawideband pentagon shaped antenna for wirelesss communications.Antenna and propagation society international symoposium,CA, 2008,pp. 1-4.

[55] G.P Gao, Yang, J.S Zang and F.J Wang, “Double printed rectangular patch dipole antenna for UWB applications. “ Microwave opt technol Lett 50(2008) , 2450-2452.

[56] L. Guo, S.Wang, X-D cher and C.Parini, “Printed quasi complimentary antenna for ultrawideband.” *IEEE Antenna wireless propagat*. Let. Vol. 8, pp. 554-557, 2009.

[57] Yuan Dong, Wei Hong and Chen yu, “Development of ultrawideband antenna with band notch characteristics.” *IEEE Trans Antenna. Propagat.,* vol 56, no.9, pp.2894-2902,2009.

[58] C.Y Zang and J.Y Su, “complimentary antenna fed by microstrip line.” Vol. 57, no.14, pp. 2896-2901, 2009.

[59] J. Yang and T .ostling, “A compact dual band feed for reflector antennas based on choke horn and circular eleven antenna.” *IEEE Trans Antenna*.” Vol 57, no. 10, pp.3300- 3302, 2009.

[60] Wadefallk presents, “Realisation of linearily polar antenna for 1-10GHz.” Vol. 45,pp. 300-302, 2009.

[61] Tharaka Dissanayake and Karu P. Esselle, presents To prevent interference between ultrawideband (UWB) systems and existing wireless systems, creating notches in the UWBradiated field, vol. 46, no. 2, pp. 294–295,2010.

[62] H. Nazli, E. Bicak and B. Turetken, “A design for planar elliptical antenna applications.” *IEEE Antenna wireless propagation let 9(2010)*, 264-267.

[63] Guo and Jhang, “double U slot rectangular patch antenna.” vol.48, no.10, pp-3126-3229, 2010.

[64] J.X Xaio, M.F Wang and G.J Li, “A ring monopole antenna for UWB application.” *Microwave Opt Technol Lett* 52 (2010), 179–182.

[65] H.W Liu,C.H.Ku and C.F Yang, “Compact monopole antenna with bandnotched characteristics.” *IEEE Antenna wirelesss propagation Lett.* , vol. 9, pp. 397-400, 2010.

[66] K.P Ray and Tiwari, “Ultrawideband printed hexagonal monopole antenna.” *Microwave. Antenna propagat. Lett*, vol. 4, no. 4, pp. 437-435, 2010.

[67] K.G Thomas and M.Srinivasan, “An ultrawideband planar rectangular printed antenna with band dispensation.” *IEEE Trans. Antenna Propagat. Lett*, vol. 58, no.1, pp. 27-34, Jan. 2010.

[68] S. Park and C. Jung, “Compact MIMO antenna for high isolation.” Electron Lett Vol no.46, 390-391, March,2011

[69] Ojaroudi, Kim and Jhang , “ A monopole antenna with enhanced bandwidth with inverted T-shaped slots. “ vol.52, no.4,pp. 2056-2859, 2011.

[70] C. Hsu, kim and Liu, “Implementations of broadband isolator using metamaterial resonator and T-shaped branch for MIMO antenna.” *IEEE Trans. Antenna Propagat* vol.59, no.10, pp-3936-3939, 2011.

[71] J. Yang, M .Panteleev, P. Kildal and L. Heldneer, “Design of compact dual polarised 1.2-10 GHz feed for decade bandwidth.” *IEEE Transactions on Antenna and Propagation*. Vol.60, no.5, pp.2010-2218, 2012.

[72] Tzyh-Ghuang Ma and Sung-Jung Wunew, band-notched folded strip monopole antenna for Ultra wideband applications”, vol. 54, no. 11, pp. 3075–3081, 2011.

[73] W. S. Lee, D. Z. Kim, K. J. Kim and J. W. Yu, “Wideband planar monopole antennas with Dual band-notched characteristics.” vol. 54, no. 6, June 2012.

[74] S. Su, C. Lee and F. Chang, “MIMO antenna using neutralisation line.”*IEEE Trans Antenna Propagat*., vol-60, no.2, pp.456.463, Fed. 2012.

[75] R.A Alhmeed, Z.Z Abidin, N. J. McEwan, “Wideband printed monopole diversity MIMO antenna for WiFI/WiMAX application.” *IEEE Trans Antenna Propagat.* , vol.60, no.4, pp. 2028-2035, April.2012.

[76] S. Ko and R .Murch, “Compact integrated diversity antenna for wireless communication.” *IEEE Trans Antenna Propagat.* Vol.49, no.6, pp. 954-960, Jun 2012.

[77] Yang, Mu and chu, “design of compact dual-polarised antenna.” vol.59, no.10, pp-3936-3939, 2012.

[78] J. Jung and H. Lee , “presents a compact band notched ultra wideband antenna with the use of a modified ground plane” vol. 56,no. 9, pp. 2894–2902,2013.

[79] Hong and Lee, “A two-element diversity planar antenna for a multiple input multiple-output application is presented.” vol. 46, no. 2, pp. 294–295, 2013.

[80] Kaiser presents UWB technology combined with multiple transmit and receive antennas(MIMO) is a viable way to achieve data rates of more than 1 GB/s for wireless communications” vol. 56,no. 9, pp. 2894–2902”,2013.

[81] Rezaul Azim and Mohammad Tariq Islam, presents a compact micro strip line feed ultra-wideband (UWB) tapered-shape slot antenna is presented, vol. 57, no. 14, pp.2894–2902,2014.

[82] Emadian, Changiz Ghobadi and Javad Neuroma, presents, “A band notched printed circle likeslot antenna to achieve white band operation*.” IEEE Antennas Wireless Propag. lett.*, vol. 8,pp. 554–557, October 2014.

[83] Yi-Cheng Lin and Kuan-Jung, “ Hung presents a compact ultra wideband rectangular apertures antenna and band notched designs” vol. 54, no. 11, pp. 3075–3081,2015.

[84] Wael Abd Ellatif Ali July 2017, “presents a paper presents compact size 4 × 4 cm² UWB MIMO antenna for UWB applications.” vol. 46, no. 2, pp. 294–295,2017.

[85] Yashika sharma, Debdeep Sarkar and Kushmanda saurav, “Three element MIMO antenna system with pattern and polarisation diversity for wireless applications.”

[86] S.Zhang, Z. zing and J. Xiong, “ Ultrawideband MIMO diversity tree like structure to increase wideband isolation.” *Antenna and wireless propagation letters, IEEE,* vol. 8, pp. 1279-1282, 2012.

[87] Mao and chu, “Compact uwb MIMO antenna with dual polarisation.” *Antenna and propagation, IEEE transactions on,* vol. 62, no. 9,pp. 4474-4494, August, 2014.

[88] T.C Tang and K.H Liu, “An ultrawideband MIMO antenna with dual band notched function.” *Antenna and wireless propagation letters*. IEEE, vol. 13, pp. 1076-1079, 2014.

[89] Y.J REN and K.Chang, “An annual ring antenna for UWB communications.”, *IEEE Antennas Wireless Propag* Lett 5(2006), 274-276.

[90] M.M. Matin, B.S. Sharif, and C.C. Tsimenidis, "Probe feed stacked patch antennas for wideband application*." IEEE Trans Antenans Propag* 55 (2007), 2385-2388.

[91] S.H. WI, Y.B. Sun, I.S. Song, S.H. Choa, I.S. Koh, Y.S. Lee and J.G. Yook, "Packeged level integrated antennas based on LTCC technology*." IEEE Trans Antennas Propag* 54 (2006), 2190-2197.

[92] H. Nazli, E. Bicak, B. Turetken and M. Sezgin, "An improved design of planar elliptical dipole antennas for UWB applications." *IEEE Antennas Wireless Propag* Lett 9 (2010) ,264-267.

[93] K. Kim and S. Park, Analysis of the small band rejected antenna with the parasitic strip for UWB, *IEEE Trans Antennas Propag* 54 (2006) , 1688-1692.

[94] K. P Ray and Y. Ranga, "Ultrawideband printed elliptical monopole antennas." , *IEEE Trans Antennas Propag* 55 (2007) , 1189-1192.

[95] H. Mardani and S. A. Aghdam, "A novel multi-notch compactmonopole antenna for UWB applications," *IEICE Electron. Exp.*, vol.8, no. 20, pp. 1698–1702, 2011.

[96] H. Mardani, S. A Aghdam, and M. Mardani, "An effective approach for creating multi-notch characteristics in monopole antennas," in *Proc. ICEDS*, Apr. 2011, pp. 1-4.

[97] M. Abdollahvand, G. Dadashzadeh, and D. Mostafa, "Compact dual band notched printed monopole antenna for UWB application,"*IEEE Antennas Propag*., vol.9,pp. 1148-1151, 2010.

[98] Y. Dong *et al.*, *"*Development of ultrawideband antennas with multiple band notched characteristics using half mode substrateintegrated waveguide cavity technology," IEEE Trans. Antennas Propag., vol. 56 no.9, pp. 2894-2902, Sep. 2008.

[99] L. Guo, X.Chen and C. G. Parini, "Miniature ultrawideband antenna for wireless universal serial bus dongle applications," *Microw. Antennas Propag*., vol. 6 ,no. 1, pp 113-119 , 2012.

Harishankar Singh

RAJAT SHARMA FINAL REPORT

ORIGINALITY REPORT

17%	8%	6%	14%
SIMILARITY INDEX	INTERNET SOURCES	PUBLICATIONS	STUDENT PAPERS

PRIMARY SOURCES

1	en.wikipedia.org Internet Source	1%
2	Submitted to Higher Education Commission Pakistan Student Paper	1%
3	dspace.thapar.edu:8080 Internet Source	1%
4	crescent.progress.com Internet Source	1%
5	Submitted to Rajarambapu Institute of Technology Student Paper	1%
6	Submitted to University of Bradford Student Paper	<1%
7	Submitted to Universiti Teknikal Malaysia Melaka Student Paper	<1%
8	Submitted to University of Northumbria at Newcastle	<1%

Rajat