COMPACT ULTRA-WIDE BAND MULTIPLE INPUT MULTIPLE OUTPUT ANTENNA

By

Faiz Khalid

A thesis submitted to the Faculty of Electrical Engineering Department, Military College of Signals, National University of Sciences & Technology, Pakistan in partial fulfillment of the requirements for the degree of MS in Electrical (Telecom)

November 2017

THESIS ACCEPTANCE CERTIFICATE

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Signature: ______________________

Name of Supervisor Assoc Prof Farooq Ahmed Bhatti, PhD

Date: ______________________

Signature (HoD): ______________________

Date: ______________________

Signature (Dean): ______________________

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ABSTRACT

In recent era, the demand of Ultra-Wideband (UWB) is increasing in medical science, radar technology and Wireless Personal Area Network (WPAN) applications because of high data rate and channel capacity. Several antenna designs have been proposed to incorporate the high data rate and capacity, i.e., Multiple Input Multiple Output (MIMO) based antenna that provide the higher data rate and channel capacity. However, designing the compact antenna, while meeting the commercial requirement of UWB-MIMO system and other design constraint, is becoming more challenging for design engineers. One of the most promising solution is to use the planner microstrip antennas for achieving higher data rates, compact size, low profile, low cost, easy to fabricate, ultra-wide bandwidth and multiple antennas on a single structure but to achieve the higher data rate is still an open research problem.

Therefore, this thesis provides a solution for higher data rate of printed microstrip antenna for UWB-MIMO communication by using the inherent property of multiple antennas on same structure. This proposed solution provides higher data rate of UWB system using multiple antenna elements on single board along with the miniaturization of UWB-MIMO antenna using an isolation technique. In this regard, a compact UWB-MIMO antenna, consists of two monopoles with separate transmission feed lines and an isolation structure on the back side, with a compact size of 24mm x 29mm is proposed. The staircase cutting, U-shape cutting and ground plan etching on the backside of transmission feed line are used to achieve ultra-wide bandwidth. The two U shape monopole antennas are placed at 5mm and a stripe line of width 2mm connected to ground is introduced to increase the isolation between elements. The isolation is further improved

by creating a slot in the middle of ground plan. A novel UWB antenna of smallest size of 26mm x 30mm with high value of isolation greater than 25 dB is presented in this thesis.

DEDICATION

Dedicated to my parents, especially to my mother, and my dear ones for their continuing support and encouragement throughout my Master's course work and research

ACKNOWLEDGEMENT

First of all, I would like to say thank you to my supervisor Associate Professor Dr. Farooq Ahmad Bhatti who helped me and assisted me during my research work. His kindness and encouragements had always been a morale booster whenever I had problems during my research phase. I am impressed by his humble and kind nature. Besides, I would also like to say thank you to my thesis committee members respected Brig Abdul Rauf, PhD, Brig Imran Rashid, PhD and Lt Col Adil Masood Siddique, PhD.

I can never forget the efforts of my parents which brought up to this stage of my life and without their prayers and support I could never be so much successful in my life.

And above all, Thanks to Allah Almighty for everything.

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Chapter 1

INTRODUCTION

1.1 Overview of UWB MIMO Technology:

In past century, many wireless communication system and protocols have developed to meet the requirement of government sectors, commercial and defense organizations. To accommodate different communication system and protocols the regulator authorities have allocated the limitation in bandwidth, transmission power and range. In 2002 Federal Communication Commission (FCC) have introduced the ultra-wide band technology for commercial applications [1]. It has very large bandwidth 3.1GHz to 10.6GHz and to avoid interference its power is kept low. Therefore, low power and high bandwidth are the fundamental advantages of UWB system. UWB systems performance limits due to low power and vulnerability of multipath fading. To increase data rate, channel capacity and to overcome multipath fading, a MIMO technology incorporated with UWB systems. Hence, UWB-MIMO is a short range, broad band, high data rate and reliable communication system. [2], [3]. Advantages of UWB-MIMO system such as mitigation of interference, high data rate and reliable link make it suitable for the applications high data rate wireless communication systems and radar system.

1.2 Research Motivations:

1.2.1 Compact UWB MIMO Antenna with high isolation:

In past, few years the trend in modern communication system and UWB MIMO system is towards miniaturization. Antenna is an integral part of any wireless communication system. Printed microstrip antennas are widely used in UWB applications due to its compactness and conformity. To introduce MIMO technology in UWB antenna, high isolation between antenna elements is required. Increasing research have been devoted to design an antenna that can provide ultra-wideband impedance bandwidth and good radiation properties with compact size and high isolation between antenna elements.

In literature, one can find multiple techniques to achieve high isolation in UWB-MIMO antennas, like defecting the ground structure [4], [5], spatial and angular variations of antenna elements [6-8] using heterogenous antenna elements [9]. But using the defecting ground and spatial angular variation techniques increases the size of antenna. While using the heterogenous antenna elements increases the complexity of antenna design.

There also exists a simple technique inserting stubs between antenna element to achieve high isolation for UWB-MIMO antenna [10], [11]. However, this tends to large size of antenna and compromise the compactness.

In [12] a compact antenna size of 22 mm x 36 mm was achieved but isolation S21 is less than -15dB. In [13] two stair case monopoles antennas are separated by comb structure connected to ground plan to achieve compact size of 20 mm x 30 mm but its isolation is less than -20dB and the comb structure increase the complexity of antenna design.

Therefore, a compact simple printed microstrip antenna that can provide high isolation MIMO function for UWB antenna is the scope of this thesis.

1.3 Contribution of Thesis:

1.3.1 Compact MIMO Antenna with High Isolation for UWB Applications:

The UWB-MIMO antenna with high isolation is very important in UWB-MIMO system. Moreover, miniaturization trends in UWB-MIMO devices especially in for Wireless Personal Area Networks (WPAN) requires antenna to be compact in size. In this two element UWB-MIMO antenna with isolation greater than -20dB is presented. The size of antenna is 20mm x 30mm and is smaller the size as compared of other antennas in [12-13]. The design of proposed consists of simple two stair cased monopoles placed at a distance 0.25λ0. The high isolation is achieved by inserting a 0.8mm wide stub between elements and etching a slot in ground plane. The geometry of antenna is optimized to achieve the best possible results.

Chapter 2

LITERATURE REVIEW

2.1 Printed UWB Antenna:

2.1.1 Introduction:

Antenna is known as a sensor or a transition device that converts electromagnetic radiated energy to electric signals. It also transfers electromagnetic energy from guided medium to un guided medium which means it can transmit and receive electromagnetic waves. Many different types of antennas are available in literature such as wire antennas, aperture antennas, printed antennas and lens antennas. Microstrip antenna is a major type of printed antennas. A common microstrip antenna consists of two metallic conductor layers separated by a dielectric medium, as shown in Figure 2.1. Usually one layer serves as radiator and other as ground. Now a days microstrip technology have become very popular because of their compactness and conformity in metallic gadgets. Microstrip antenna with complete ground is tend to low bandwidth and single resonance frequency. This discourage the use of microstrip antenna for UWB systems as it requires large bandwidth. Printed planner antenna with complete ground plane is an example of standing wave antenna and it cannot support traveling wave [14]. Due to standing waves, these types of antennas have one resonant frequency and narrow bandwidth. There exist many different configurations in which a wide bandwidth for UWB system can achieve [14]. All these types of antennas support traveling waves. In contrast to standing wave, traveling wave are principally real and cause multiple resonance frequencies in an antenna. By using the bandwidth enhancement techniques these multiple frequencies band can overlap to yield a wide bandwidth for UWB system.

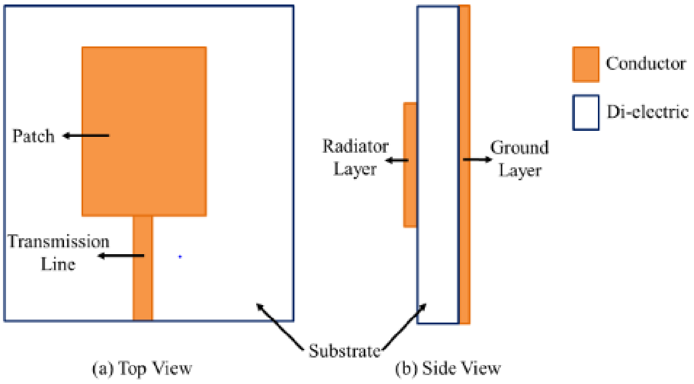

Figure 2.1 Printed Microstrip Antenna

2.2 Types of Microstrip UWB Antennas:

In this section, major types of printed UWB antennas will be presented. The radiation properties and key features of these antennas are discussed.

2.2.1 Vivaldi Antenna

Vivaldi antenna is an example of tapered waveguide. Basic profile of a Vivaldi antenna is shown in Figure 2.2. Its broad band response is due to tapered structure. Wave traveling inside the antenna does not undergo strong reflection because of the tapered structure of the antenna. It supports traveling waves because of the absence of reflectors. Presence of traveling waves reason the broad band response of Vivaldi antenna. Vivaldi antenna are widely used in radar applications due to high gain and directional radiation pattern [15].

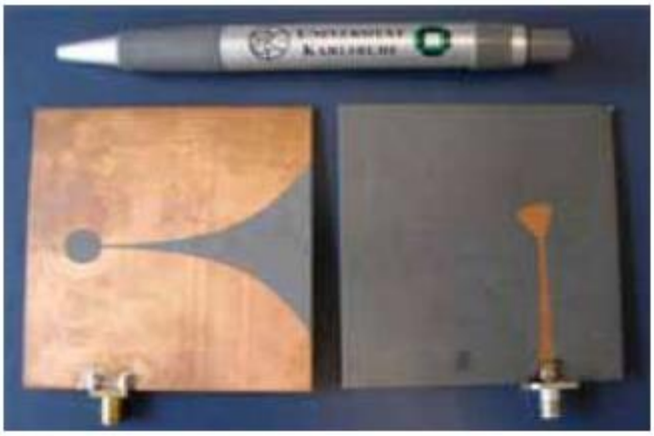

Figure 2.2 Vivaldi Antenna

2.2.2 Spiral Antenna

Spiral antenna is an example of self-balancing antennas. Such antennas have constant input impedance over a frequency band [15]. Self-balancing structure of spiral antenna (shown in Fig 2.3) provides the UWB bandwidth. Spiral antennas have bidirectional radiation pattern and its limitations are large size structure.

Figure 2.3 Printed Spiral Antenna [15]

2.2.3 Bowtie Antenna

Ramesy et al. have presented that angular constant structure has frequency independence in impedance bandwidth and radiation properties [14]. Bowtie Antenna is a type of frequency independent antenna (FIA). A microstrip bowtie antenna is shown in Fig 2.4. Bowtie has directional radiation pattern and widely used in high gain applications. Limitations of this antenna are complex feeding structure and large size.

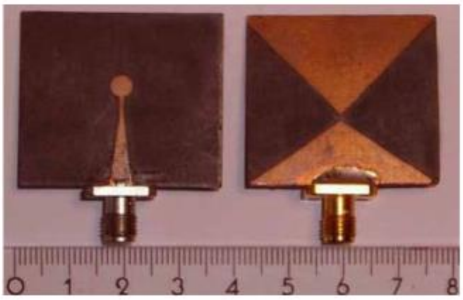

Figure 2.4 Bowtie Antenna [14]

2.2.4 Log-Periodic Antenna

Log-Periodic Antenna consists of dipole antenna array. Each dipole elements are narrow band and excited separately. It has multi resonance antennas which to have high bandwidth. Log-Periodic Antennas are wide used in high gain application because of directional radiation pattern. Disadvantages are large size and complex feeding structure.

Figure 2.5 Log-Periodic Antenna

2.2.5 Monopole Antenna

Microstrip Monopole Antenna is identical to microstrip patch antenna. Main difference between the two antennas is the size of ground plane. Patch antenna has complete ground plane while monopole has truncated ground plane. The truncated ground plane plays an important role in broad bandwidth of monopole antenna. Ramesy et al. have showed that slot cavity between radiator patch and ground supports traveling waves [14]. These traveling waves enables the multiple resonance frequencies. Monopoles are widely used in modern wireless communication system because they can be deigned to very compact size.

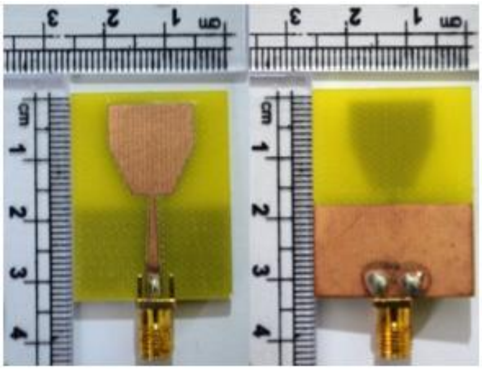

Figure 2.6 Printed Monopole Antenna

2.2.6 Slot Antenna

Slot Antenna is variant of monopole antenna, as shown in Fig 2.6. In comparison to monopole, the radiating part is slotted ground plane. The slot cavity in ground plane supports traveling waves. Slot antenna has omnidirectional radiation pattern and very compact size.

Figure 2.7 Slot Antenna

2.2.7 Comparison

Table 2.1 shows the comparison of UWB antenna in terms of two important properties that are compact size of antenna type and radiation pattern type. High gain UWB antenna have directional radiation pattern and low gain have omnidirectional radiation pattern. In any antenna designing, there is tradeoff between antenna size, impedance bandwidth and radiation properties like gain. Monopole and slot antennas are widely used because of their large impedance bandwidth and size compactness but their radiation patterns are omnidirectional which tends to low gain. Modern wireless communication antenna with compact size and moderate gain is preferred.

Type of Antenna	**Type of Radiation Pattern**	**Size Compactness**
Vivaldi	Directional	Low
Log-Periodic	Directional	Low
Spiral	Bi-Directional	Medium
Bowtie	Bi-Directional	Medium
Slot	Omnidirectional	High
Monopole	Omnidirectional	High

Table 2.1 Comparison of Printed UWB Antenna Types

2.3 Wide Bandwidth Techniques in Printed Monopole

Bandwidth enhancement and improvements are one of the prominent features in microstrip monopole antennas. In this section, different wide enhancement techniques available in literature will be presented. These techniques fall into two categories, one is expanding existing frequency bands and second is creating resonant frequency bands. In first technique, the aim to expand the impedance resonant bands to guarantee substantial overlap between bands. These overlapping of resonant bands is the essential condition for ultra-wide bandwidth. In second, bandwidth is enhanced by creating new resonant bands.

2.3.1 Expansion of Existing Resonant Bands

In monopole antenna profile, there is a gap (cavity) between radiating patch and ground. This gap is to support traveling waves at high frequencies [14]. The first resonance frequency of monopole is due to standing waves while resonance at high frequencies is due to this gap. Therefore, the shape and size of gap plays a very important role in determining the bandwidth of monopole. The bandwidth enhancing techniques explain how to modify and change the shape and size of the gap. In other words, this gap in known as the impedance matching network for high resonant frequencies.

One of the basic techniques to enhance bandwidth is to taper the radiating patch. In [16], a monopole antenna with coplanar waveguide (CPW) feeding technique is presented. Tapering of the radiating patch and ground of an antenna is applied to achieve the bandwidth for 2.45-10.65 GHz. This technique helps to expand impedance bandwidth at lower resonant bands. Tapering of radiating patch reduces the effective capacitance between radiating patch and ground.

Tapering of transmission line is also a bandwidth enhancement technique, used to match impedance between patch and transmission line. In [17], it is shown that tapering of transmission line of monopole antenna gives a wide impedance bandwidth of (3-12) GHz. Another important technique to enhancement impedance bandwidth is to introduce cuts in the patch and ground plane of monopole antenna. In [18], a monopole antenna with cuts in ground plane is presented to achieve the overall impedance bandwidth of (2.8-11) GHz. These cuts in ground plane reduce the effective capacitance between ground plane and patch of the monopole.

The antenna in [19] is monopole with staircase stepped patch. These cuts improve the impedance by reducing the inductance effect of radiating patch.

Monopole with U shape cut and staircase stepped patch is presented in [13]. The U shape cut is used to improve the impedance mismatch for lower resonant bands while staircase stepped cuts for high resonant bands. The overall impedance bandwidth achieve by this antenna is (3-12) GHz.

2.3.2 Creation of New Resonant Bands

As already explained that gap between ground and patch of the monopole antenna plays a very important role in impedance bandwidth. In [19] it is shown that the patch, gap and ground plane formed an equivalent dipole antenna. Therefore, the ground plays an important role in the radiation properties of the monopole. To create new resonant bands most techniques, insert new currents in ground plane by creating slots. In [20], a fork shape slot is created in ground plane of monopole. The bandwidth of this antenna without slot was (3-10.6) GHz which is improved to (3-14) GHz with the fork shape slot. This slot creates new current paths in antenna. Another technique to create new create new current path in ground plane is to place a parasitic strip near ground plane. In [21] a pi shaped strip is introduced new patch and ground plane of monopole. This strip interacts with ground planes and patch to create new current paths in antenna which results in creation of new resonant band.

2.4 UWB MIMO Antenna

UWB technology is extremely useful for short range low power communication system due to wide bandwidth. The performance of UWB limits in multi path faded environment and a MIMO technology is incorporated with UWB systems. Therefore, to design an antenna with wide bandwidth and multiple elements is required. UWB MIMO antenna is characterized by mutual coupling, correlation and diversity gain between multiple antenna elements. The design of UWB-MIMO antenna is always confronted with the constraints like cost, ease of fabrication, integration with circuits. Modern technology tends toward miniaturization of devices, thus there always be tradeoff between size and mutual coupling of antenna elements.

2.4.1 Techniques to Reduce Mutual Coupling in UWB-MIMO Antenna

According to modern the designing of compact UWB-MIMO antenna with significant mutual coupling of antenna elements is preferable. The main feature of MIMO antenna is mutual coupling. Other properties like correlation and diversity gain between antenna elements are codependent on mutual coupling. Some of the techniques used to enhance isolation between antenna elements are discussed in this section. A comparison of these techniques with respect to compactness is also explained.

2.4.2 Decoupling and Matching Networks

In [22], to achieve very low isolation using decoupling and matching network is explained. A mathematical formula for envelop correlation one of the important parameter to measure isolation in MIMO antenna is also presented.

It is clear from the equation that the value of S11 and S12 should be decreased to improve envelop correlation. A matching network decreases S11, S22 while decoupling decreases S12, S21(in case of 2 element MIMO antenna) [23]. In [24], a hybrid circuit is used as decoupling network. This circuit introduces a 180-degree phase shift between signals from two antenna elements. In [25] parasitic elements are employed between radiating patches to reduce coupling. Designing a decoupling network for UWB is generally not preferred because of the complexity and large size of antenna.

2.4.3 Electromagnetic Band Gap (EBG) structures

Electromagnetic band gap structure can be used a high impedance circuit and block filter. EBG structure consists of an array of metal flanges on a plain sheet. If the flanges are small compare to wavelength, their electromagnetic properties are described by lumped elements capacitors and inductors. EBG structures generally behave as parallel resonant circuits which act as filter to block current flow one surface to another. Therefore, EBG structures have ability to increase isolation between antenna elements.

This technique widely used in Narrow Band MIMO systems because of the design complexity and large size. Recently in [13], an EBG structure is used as decoupling network in a two elements UWB MIMO antenna, but the structure leads to complex design.

2.4.4 Neutralization Line

This technique is based on the concept that two antennas operating on same frequency band can be neutralized to increase the isolation. [26] first proposed this technique. This is widely used in Narrow band MIMO because of simple design. But avoid in UWB system because of achieving a neutralized point for wide band is very difficult and tends to large size.

2.4.5 Defected Ground Structure (DGS)

Researches shows that defected ground can be used as band stop due to the exitance of capacitance and inductance effects [27]. The defects in a ground plane of antenna can store a fraction of energy and this effect can be modeled as equivalent reactive circuits [28]. DGS is introduced on antennas to suppress harmonics, cross polarization and to increase isolation between elements.

In [4], a 2x1 MIMO antenna is presented consisting of two orthogonal half circles with the radiators positioned squarely with respect to a projected T-shaped ground plane, which has a slot at the upper center portion of the ground plane. This slot stops the current flows between the elements hence, enhancing the isolation and matching the impedance. In [5], this technique is used in real sense where circular slot antenna with a stepped ground plane is proposed. A stepped ground plane generates nonplanar connections and discontinuous interfaces between the elements and the system ground planes. This strategy has effectively decreased the mutual coupling and provided 10 dB enhancements in isolation characteristics. The antenna consists of four radiating elements and operates over the range of 2-6 GHz.

This technique is evenly preferable for UWB and narrow band MIMO antennas but generally tends to large size.

2.4.6 Spatial and Angular Distinction

Spatial distinction is simple technique in which elements of antenna are placed at λ/2 distance, where λ is wavelength of the center frequency. In angular variation, respective angle between the feed lines of elements is 90 degrees. Both spatial and angular increase the isolation but tends to large size of antenna.

In [6-8] UWB-MIMO antennas with isolation greater than 10dB are presented but antenna size is very large.

2.4.7 Inserting Stubs

The technique of using stubs to get better isolation also deals with the ground plane instead of the radiating elements. One or more stubs are inserted to enhance the isolation. UWB-MIMO antennas widely used this technique due to competence of dimension.

2.4.8 Comparison

Table 2.2 shows a comparison of MIMO antenna techniques to enhance isolation with respect UWB applications and size compactness.

MIMO Techniques	**Effective For**	**Size Compactness**
Matching and Decoupling	Narrow band MIMO	Small
EBG	Both Narrow and UWB	Medium
Neutralization Line	Both	Small
DGS	UWB	Medium
Spatial and Angular	Both	Small
Inserting Stubs	UWB	Large

Table 2.2 Comparison of MIMO Antenna Isolation Types

In short range modern wireless communication system, a compact UWB-MIMO antenna with greater isolation and acceptable radiation and gain properties is preferable.

Chapter 3

DESIGN OF COMPACT UWB-MIMO ANTENNA

In this chapter, design and analysis of a compact UWB-MIMO antenna is presented. The design process of this antenna is divided in two major stages. First, the design of single element compact UWB antenna. Second stage incudes the MIMO antenna design of first stage UWB antenna. The aim of design process is to come up with a compact UWB MIMO antenna with greater isolation between elements. In the next chapter measured result are discussed for the proof of concept.

3.1 UWB Monopole Antenna

3.1.1 Basic Structure (Stage 1)

The design process started by the selection of dielectric substrate. In this case, a FR4 (with dielectric constant 4.4, thickness 1mm and loss tangent 0.02) is chosen as dielectric substrate. FR4 is very low-cost substrate and easily available in market. The goal of this design is to achieve overall UWB impedance bandwidth while keeping the size of antenna 15mm x 26mm.

The target antenna is kept smaller with respect to 2x1 UWB MIMO antenna. The monopole antenna is chosen for this thesis.

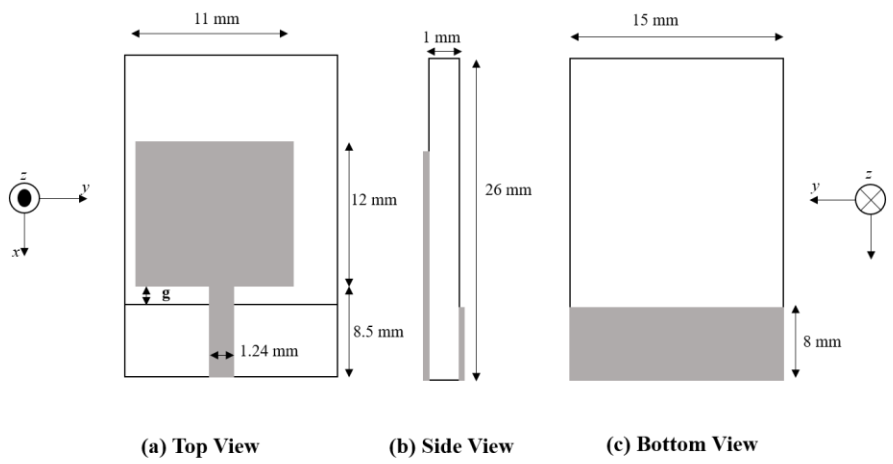

Figure 3.1 Basic Structure of Monopole Antenna in Stage 1 of design Process

In previous chapter it is discussed that monopole antenna has dual benefits as it offers large impedance bandwidth as well as size compactness. Monopole antenna consists of three elements, radiating patch, defected ground plane and transmission feed. The design of monopole antenna starts with the selection of the shape of radiating patch and the transmission line feed structure.

Rectangular patch is selected as radiating element of monopole and its size is 11 mm x 10 mm. The radiating patch of antenna limits the overall size of antenna. The antenna is fed by 8.5 mm long transmission line (TL). The width of transmission line is 1.24 mm so that the impedance of TL is matched to 50-ohm SMA connector. The basic structure of antenna at this stage is shown in Fig 3.1.

3.1.2 Optimization of Patch-Ground Gap (Stage 2)

In Fig 3.1 the variable g shows the gap between the lower end of the radiating patch and the upper end of the ground plane. As discussed earlier in literature review (chapter 2), this gap plays a critical role in impedance bandwidth of monopole antenna. Fig 3.2 shows the simulated S11 (return loss) of monopole antenna (Fig 3.1), for the different values of g (0.5 mm, 1.5 mm and 2.5 mm). The simulated results show that the increment in the value of g, shifts the resonant frequency towards lower value. Also, the large value of g causes the degradation in matching bandwidth. Therefore, an optimize g is 1.5mm because Fig 3.2 shows best result on this value.

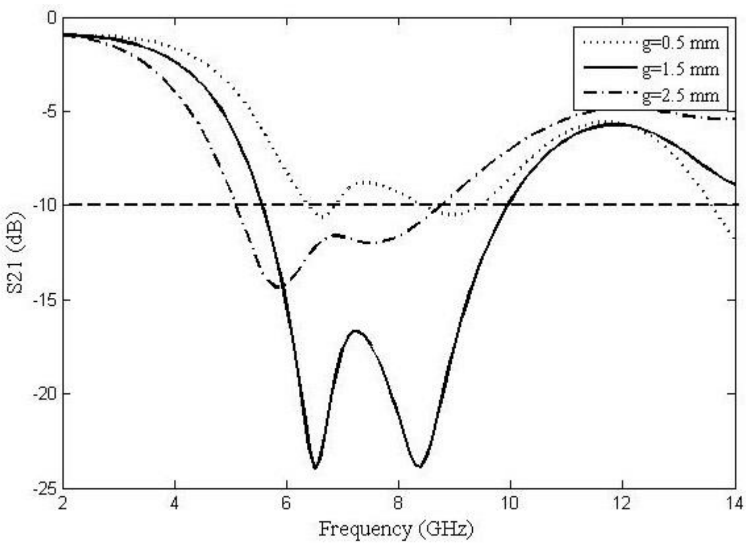

Figure 3.2 Optimization of g in design stage 2 of UWB Monopole Antenna Design

3.1.3 U-shaped cut Monopole (Stage 3)

Fig 3.2 shows that the monopole antenna has two resonant band. First resonant frequency is at 6.5 GHz and second is at 8.4 GHz. Impedance between antenna and source is matched for frequency band 5.8 GHz to 9.9 GHz and rest of the frequencies are mismatched with UWB source. The resonant frequency of 6.5GHz and 8.4GHz is inductive in nature. For higher frequencies the reactance of antenna should be capacitance in nature. This capacitance in monopole can be achieved by etching a U-Shaped slot, as discussed in chapter 2 (literature review). Fig 3.3 shows that by creating a U-shaped slot the resonant frequency shift towards lower end and overall impedance band with increases to 5.4 GHz to 9 GHz.

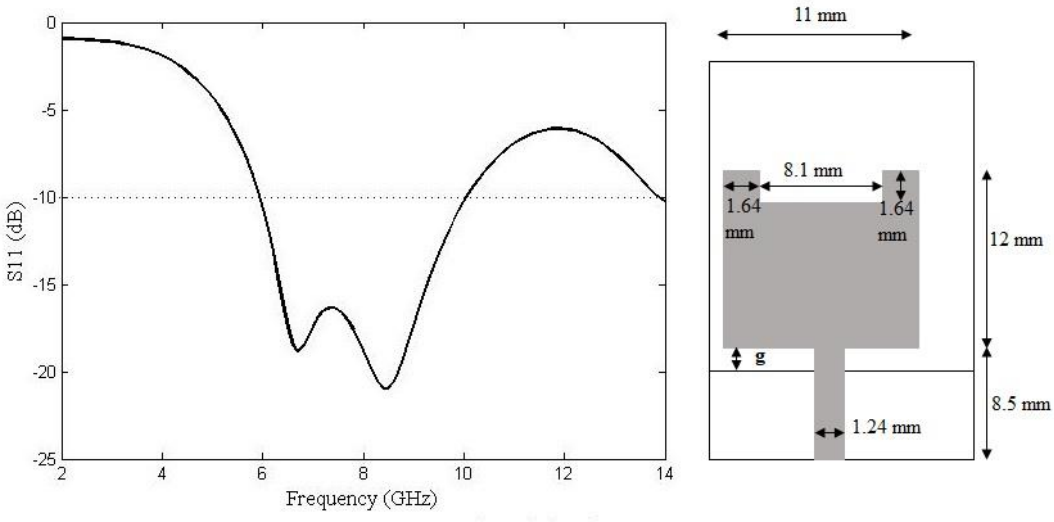

Figure 3.3 Simulated S 11 with U-shaped Slot

3.1.4 Staircase Monopole (Stage 4)

To improve the impedance bandwidth over UWB, the inductance of antenna must be reduced. There exist many techniques in literature to achieve UWB impedance matching on monopole antenna but staircase technique compacts size with UWB matching bandwidth. In Fig 3.4 a monopole antenna with U-shaped slot and staircase is shown. Antenna is matched with UWB source.

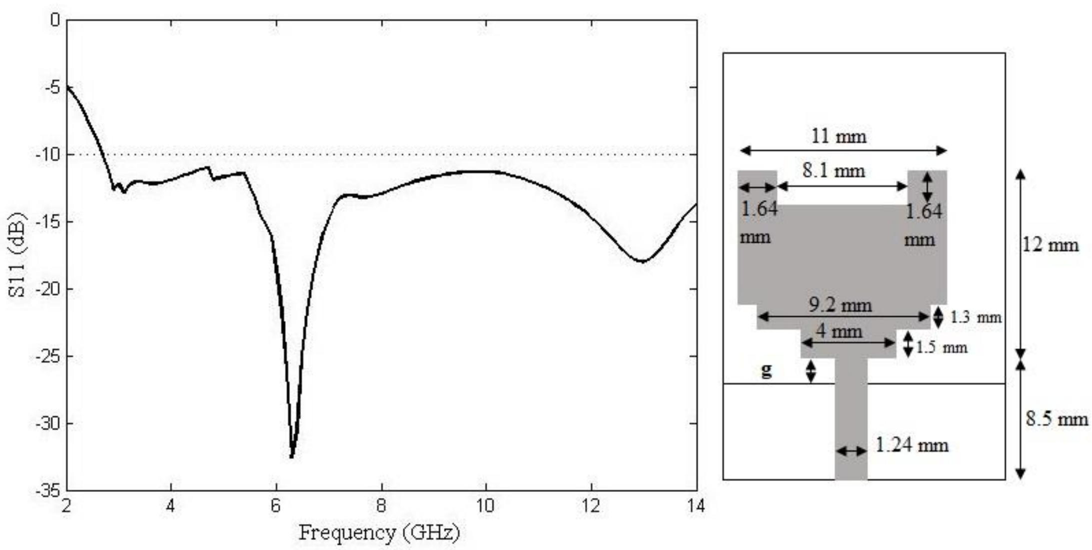

Figure 3.4 Simulated S11 of Staircase, U-shaped Monopole

Fig 3.4 shows that monopole antenna covers the whole UWB. The optimized value of U-shape slot and stairs are shown in Fig 3.6.

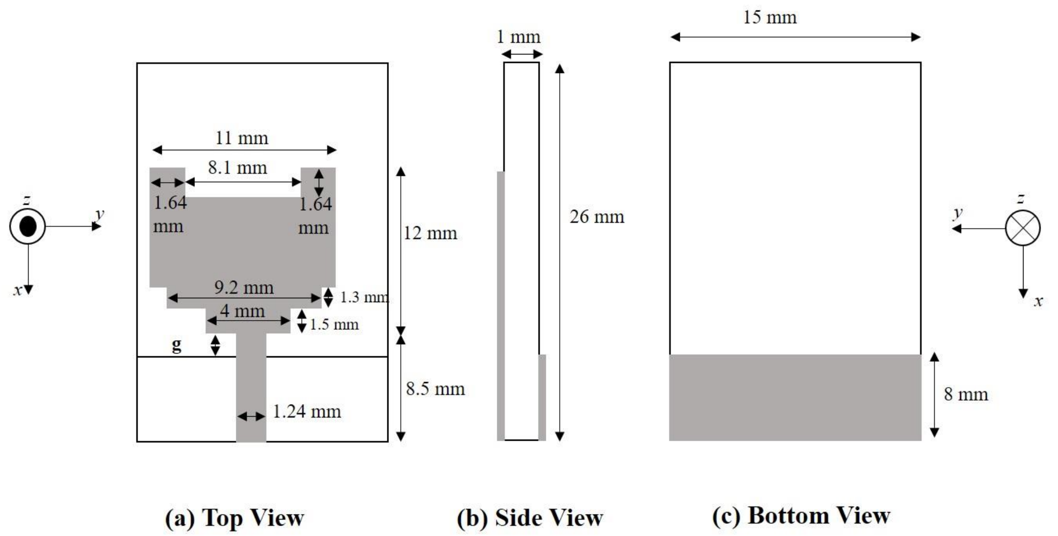

Figure 3.5 Design of UWB Monopole Antenna

3.2 MIMO Antenna Design

3.2.1 Placement of two Monopole Antenna (Stage 1)

MIMO Antenna consist of more than one elements. The design process of MIMO antenna starts with the placement of elements such that the mutual coupling between the radiating elements remains minimum as much as possible. Orthogonal and linear techniques are most commonly used in literature (chapter 2). In this thesis, linear placement technique is used because it tends to compact size and effective in case two elements array. The center frequency of monopole is 6.84 GHz and its wavelength is 44mm. To avoid mutual coupling between monopoles both monopoles should be separated at least 22mm. In Fig 3.6, two monopoles are placed at distance of 19mm. The antenna is mismatched to some frequencies as shown the simulated S11 in Fig. 3.7. Fig. 3.8 shows that the mutual coupling (S21) between elements is also greater than -10 dB to some frequencies. The distance 19mm is an optimized value on which best results are shown (Fig. 3.7, 3.8).

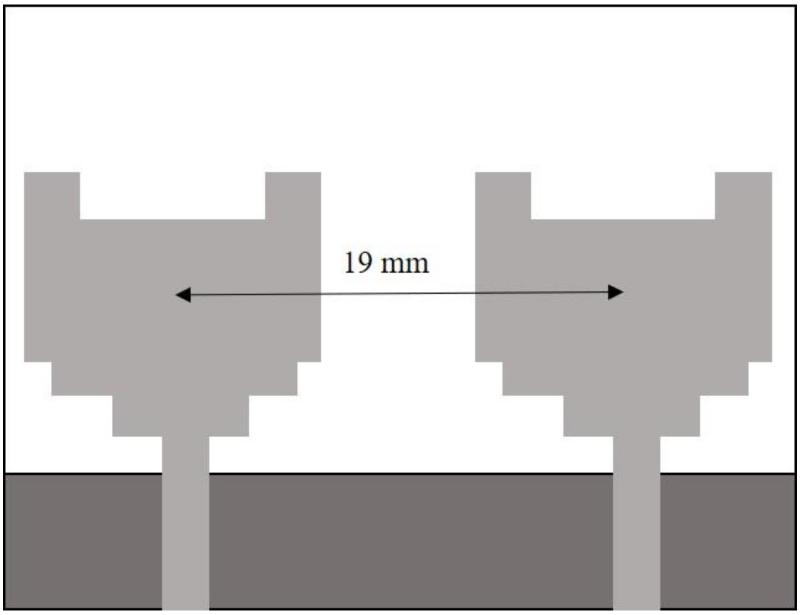

Figure 3.6 Optimized placement of two Monopole Antennas

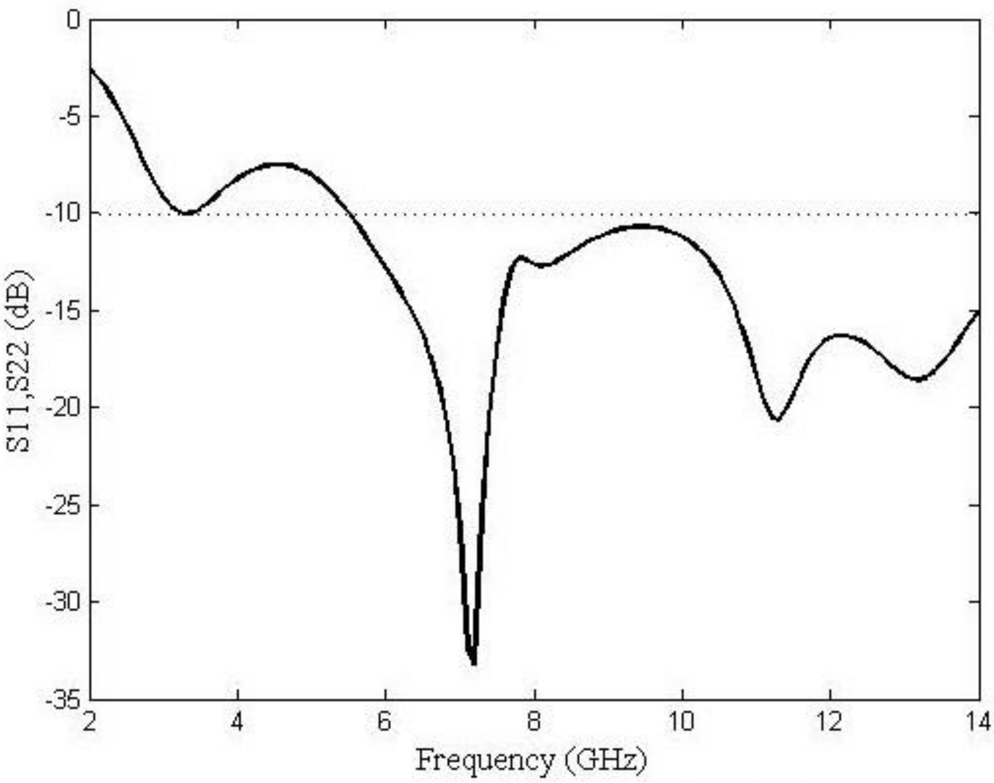

Figure 3.7 Simulated S11, S22 of 2 elements MIMO Antenna

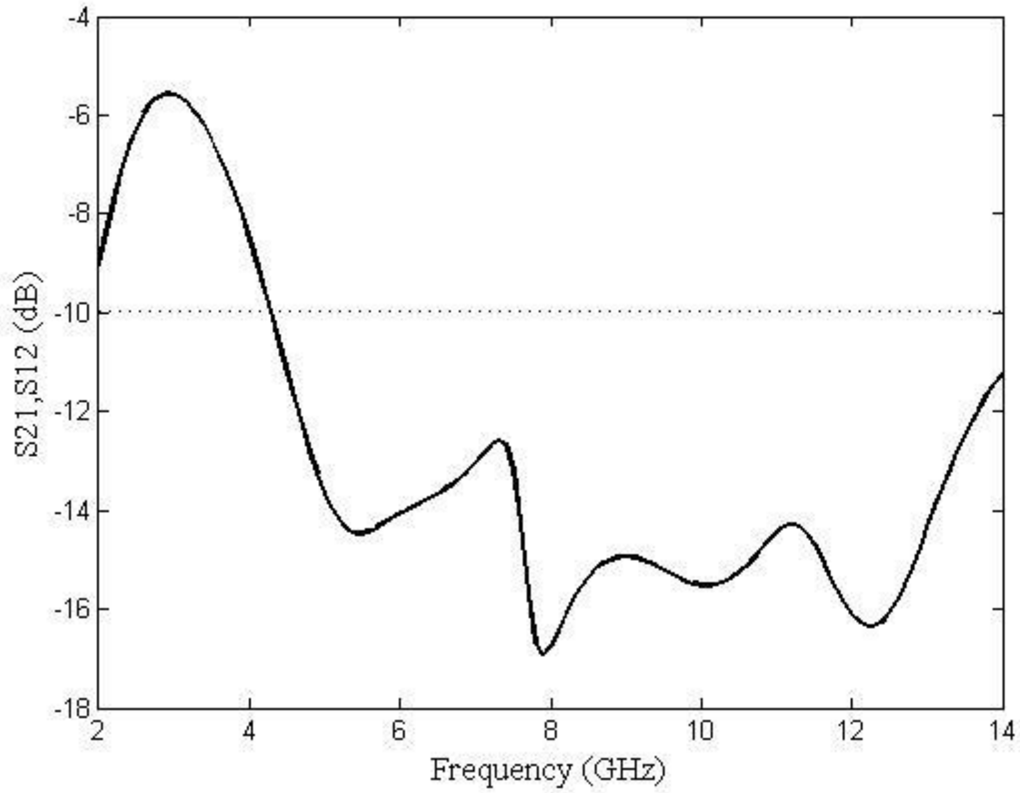

Figure 3.8 Simulated S12, S21 of 2 elements MIMO Antenna

3.2.2 Ground slot below Feed line (Stage 2)

The impedance mismatch of MIMO antenna can be improved by using ground slots below feed lines. The ground plane slot shifts the resonant frequency towards lower values. Two slots are etched from ground plane of MIMO antenna in stage 1, as shown in Fig. 3.9. The simulated S11, S22 and S12, S21 are shown in Fig. 3.10 and Fig. 3.11 respectively. With addition of slots in ground plane the impedance matching is improved and isolation between two monopoles is also increased.

It is already discussed it chapter 2, the slot in ground plane below feed line reduces the inductive effects of monopole but creating a equivalent capacitance circuits between feed line and ground plane.

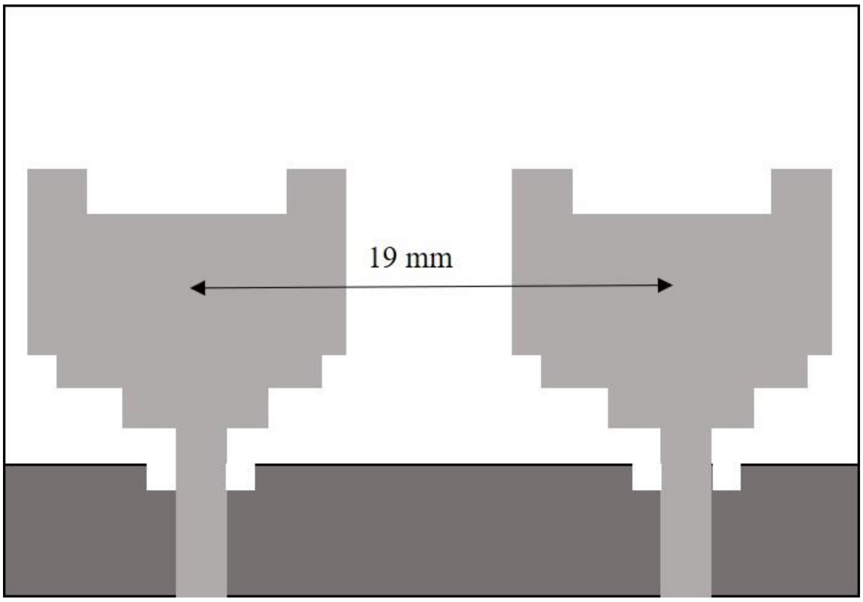

Figure 3.9 MIMO Antenna with Ground slots

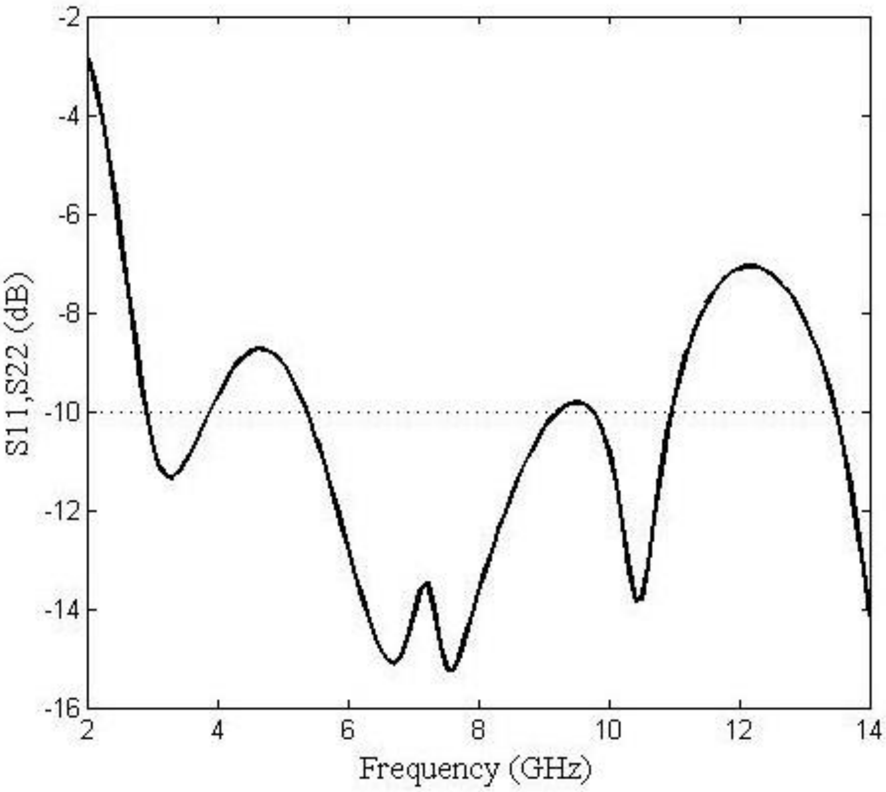

Figure 3.10 Simulated S11,S22 of MIMO Antenna with Ground Slots

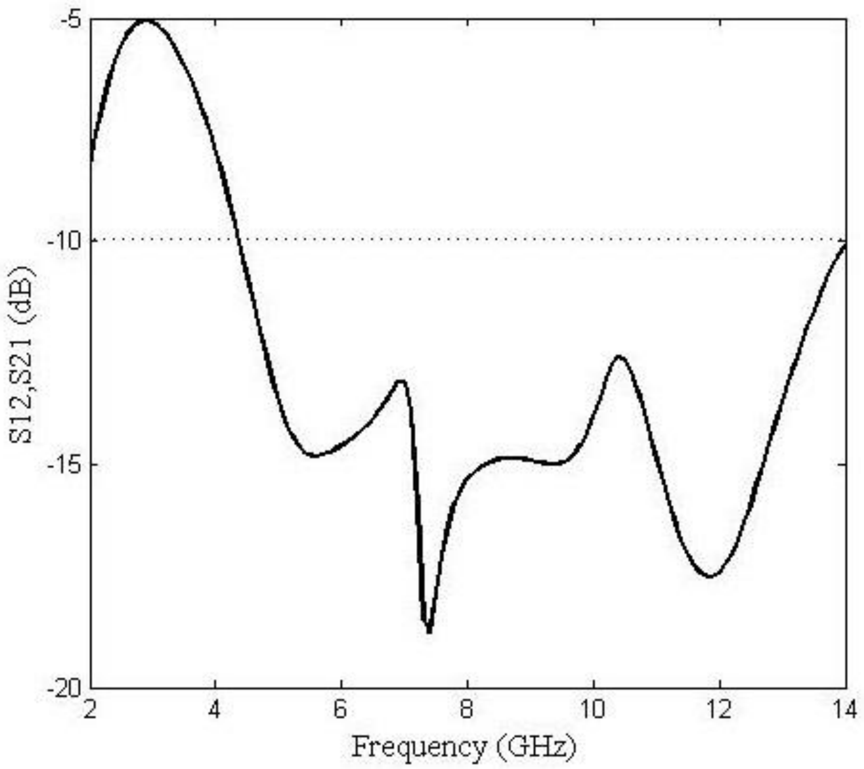

Figure 3.11 Simulated S12, S21 of MIMO Antenna with Ground Slots

3.2.3 Inserting an Isolation stub and ground slot (Stage 3)

Isolation between the radiating elements in MIMO antenna can be increased by inserting a parasitic stub as discussed in chapter 2. Here, a strip line 0.5 mm of width is introduced, as shown in Fig. 3.12. This strip line improves the isolation to -15 dB as well as impedance matching bandwidth, as shown in Fig. 3.13, 3.14. This strip line blocks the current flow from one radiating element to another element, as shown in Fig. 3.15. Fig. 3.16 shows the current density distribution of MIMO antenna at 4 GHz without the insertion of isolation stub. Comparing both Fig. 3.15 and Fig. 3.16 the coupling between elements decreased by the insertion of isolation strip. Reduction of mutual coupling between antenna elements tends to increase the impedance bandwidth.

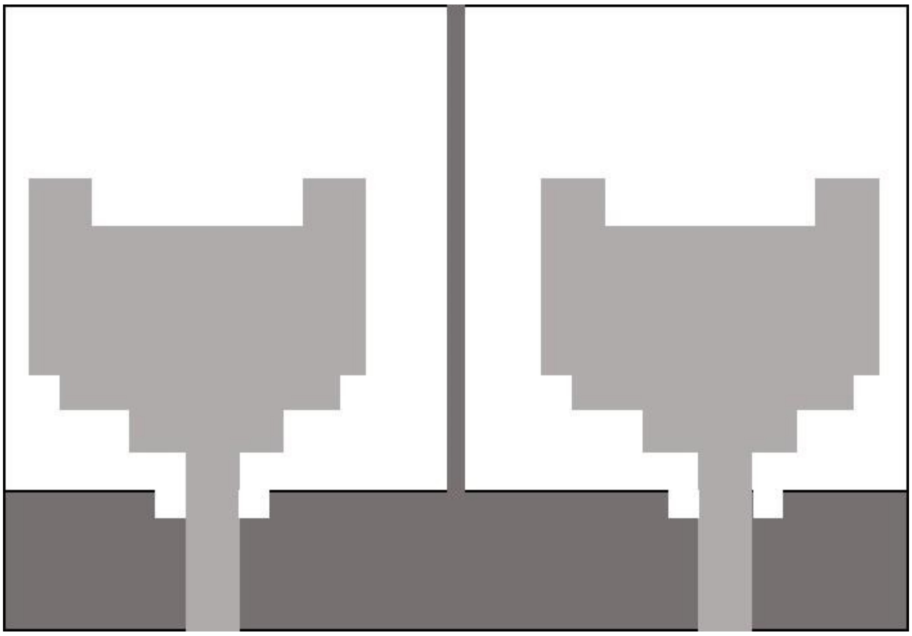

Figure 3.12 MIMO Antenna with Isolation stub

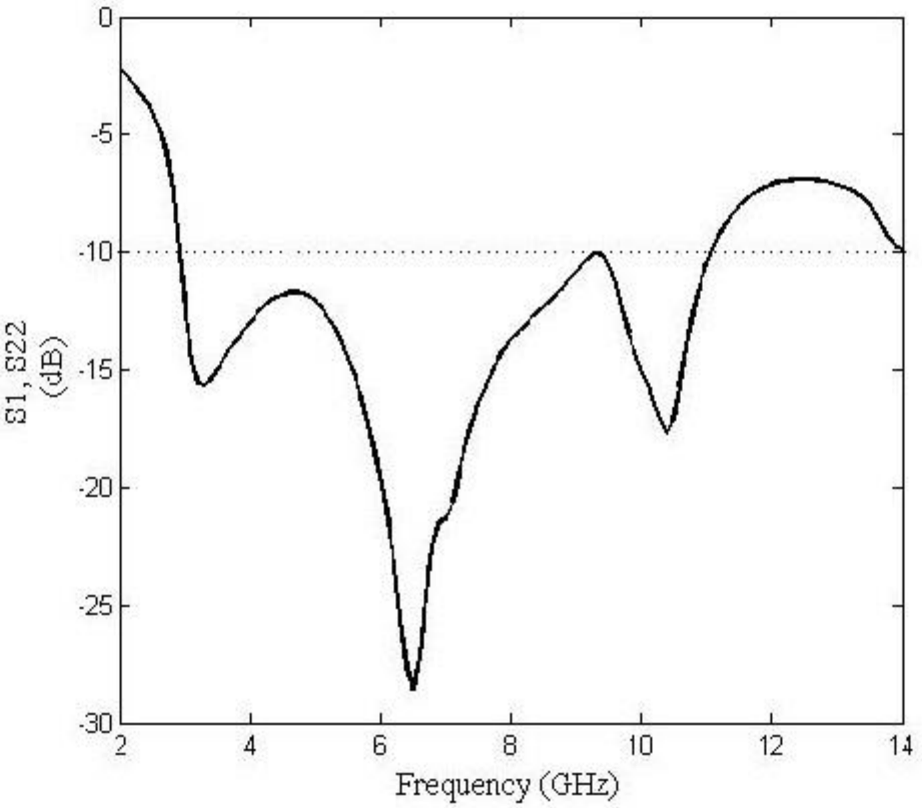

Figure 3.13 S11, S22 MIMO Antenna with Isolation stub

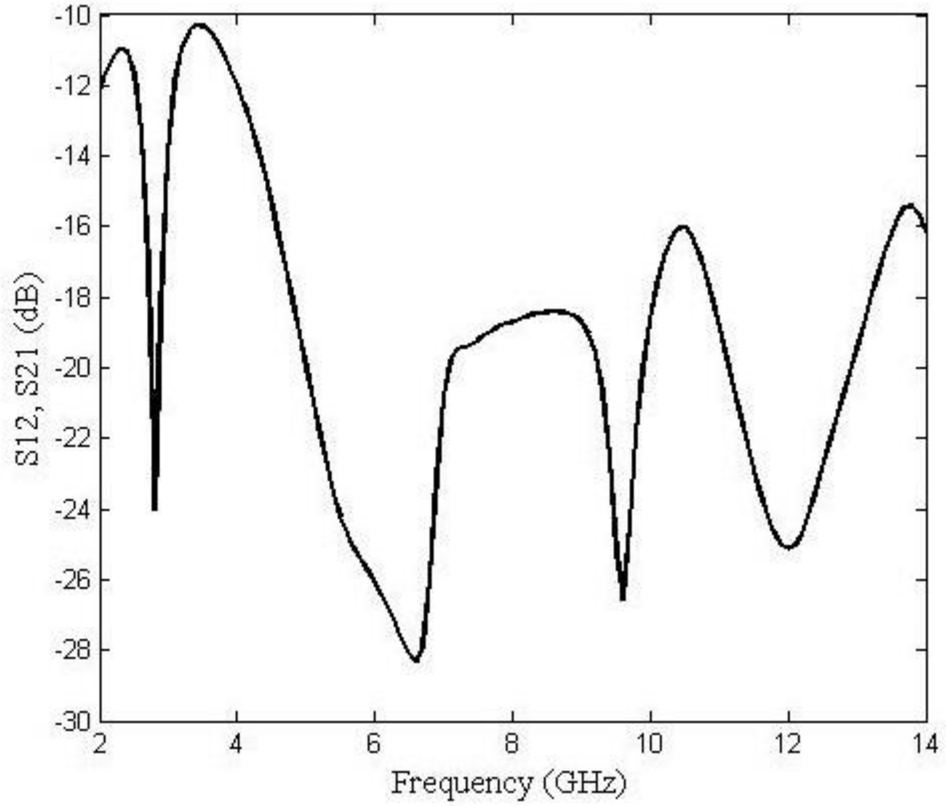

Figure 3.14 S11, S22 MIMO Antenna with Isolation stub

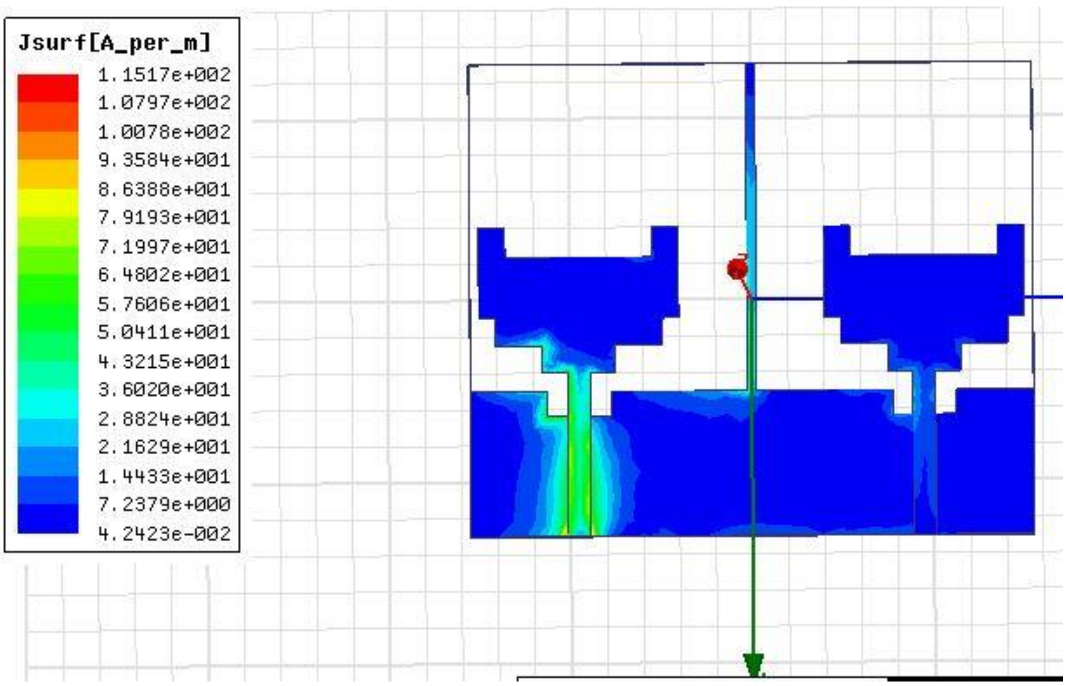

Figure 3.15 Current Density with insertion of Isolation stub at 4GHz

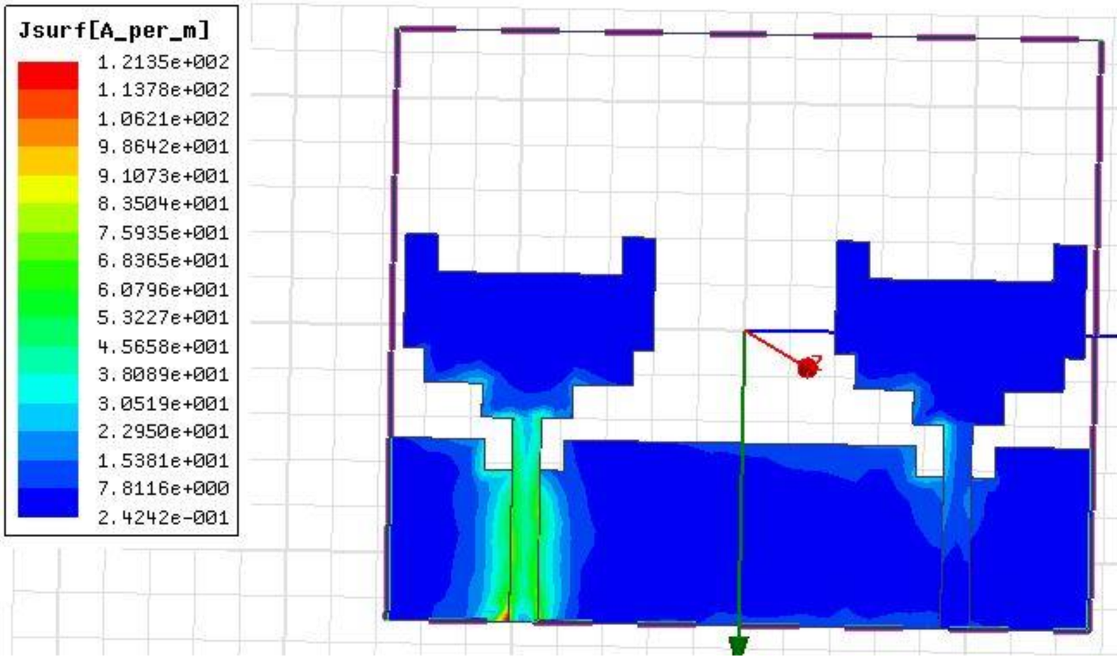

Figure 3.16 Current Density without Isolation stub at 4GHz

The mutual coupling and impedance bandwidth of MIMO antenna further is improved by creating a slot in the center of ground plane. The effects of the slot are shown in Fig. 3.17 and Fig. 3.18.

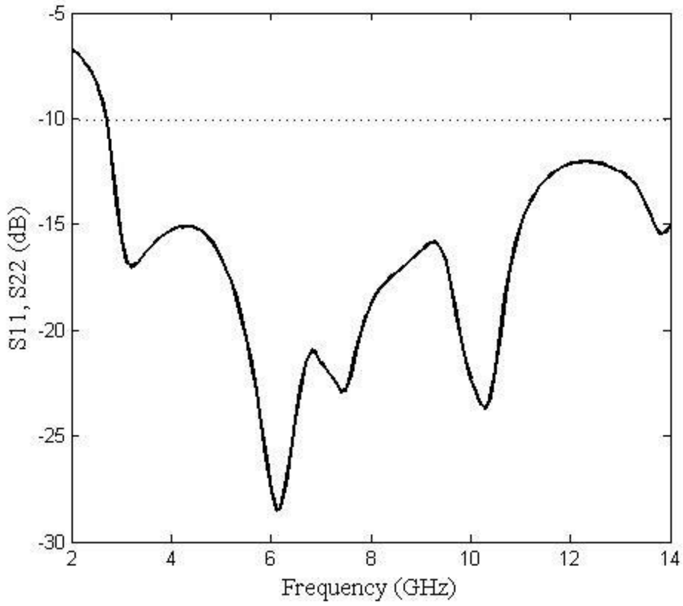

Figure 3.17 S11, S22 of MIMO Antenna with ground Slot

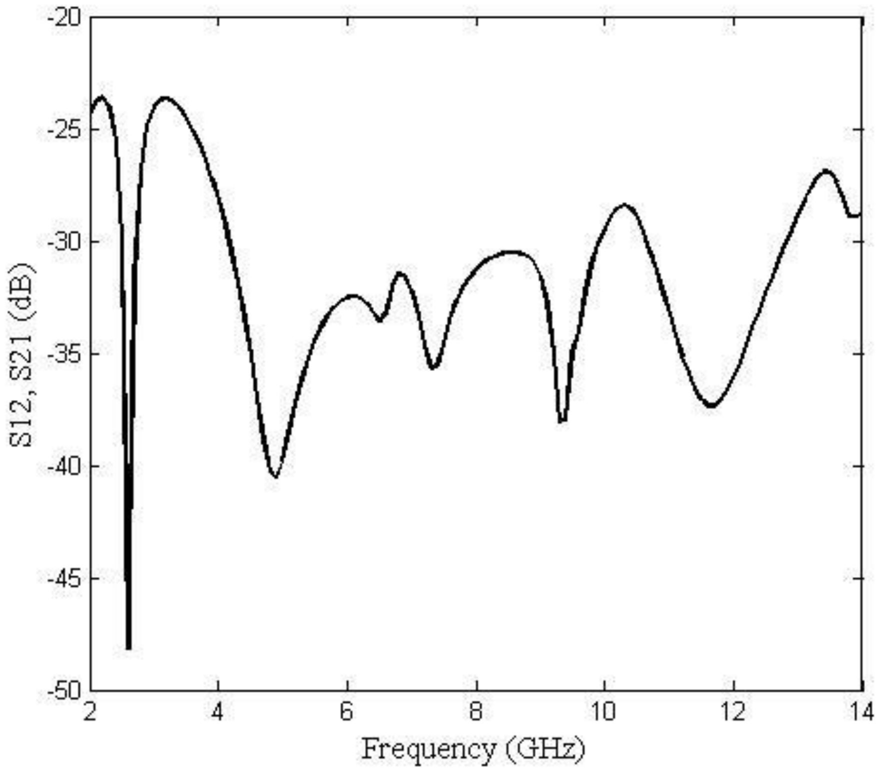

Figure 3.18 S12, S21 of MIMO Antenna with ground Slot

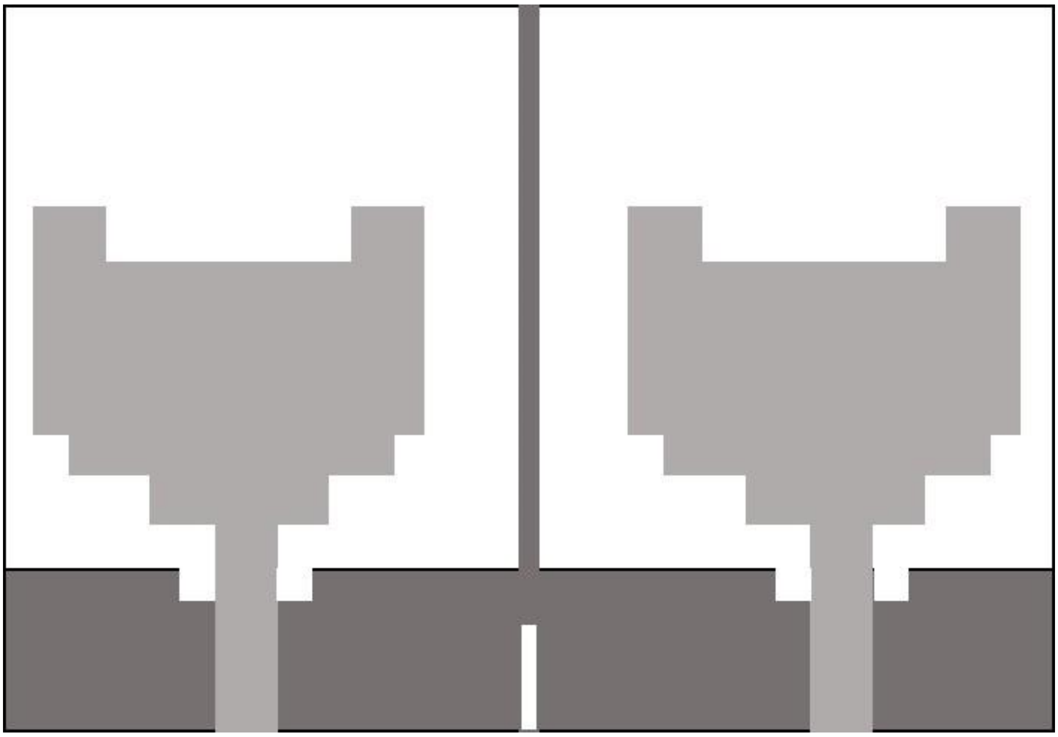

Figure 3.19 Final two elements UWB MIMO Antenna structure

The Final proposed fabricated MIMO antenna design is shown in Fig. 3.20.

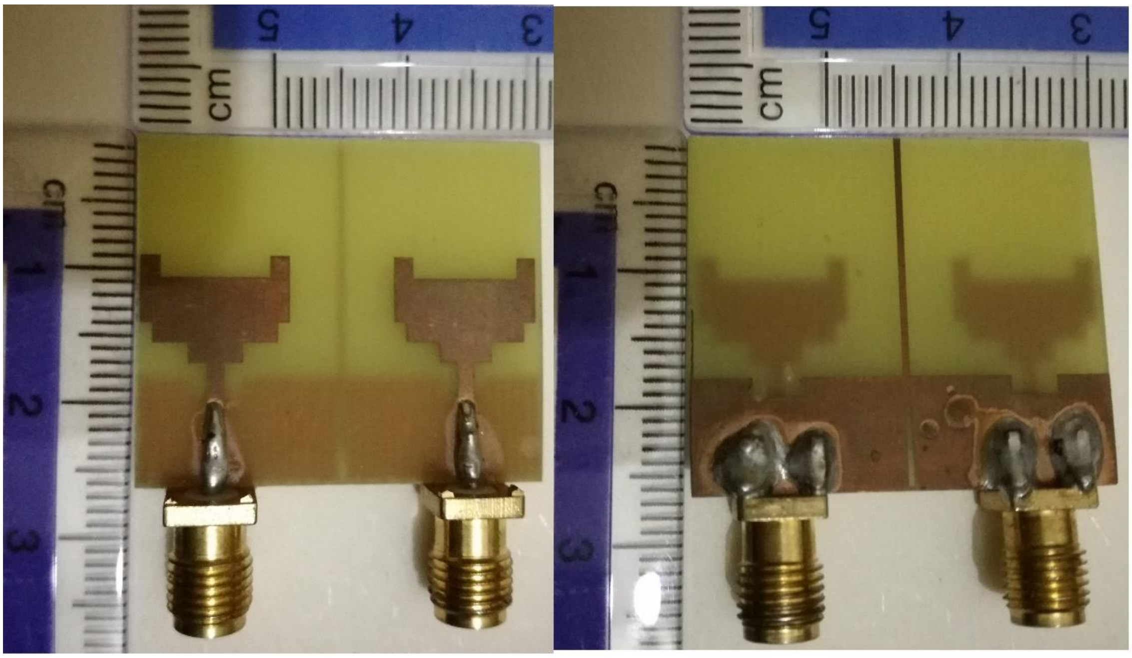

Figure 3.20 Proposed UWB MIMO Antenna

RESULTS AND DISCUSSION

The proposed UWB-MIMO Antenna is fabricated on FR4 (dielectric constant 4.4, thickness 1mm, tangent loss 0.002) substrate. The performance parameters, S11, S22, S12, S21 are measured on Agilent Technology E8362B PNA Network Analyzer. The measured results of S-parameters are shown in Fig. 4.1-4.4. Results in Fig. 4.1-4.2 shows that both elements of proposed antenna have impedance bandwidth for return loss less <-10 from 2 GHz to 14 GHz. Fig. 4.3,4.4 depict the measured isolation between two elements of proposed antenna are less than -20 dB.

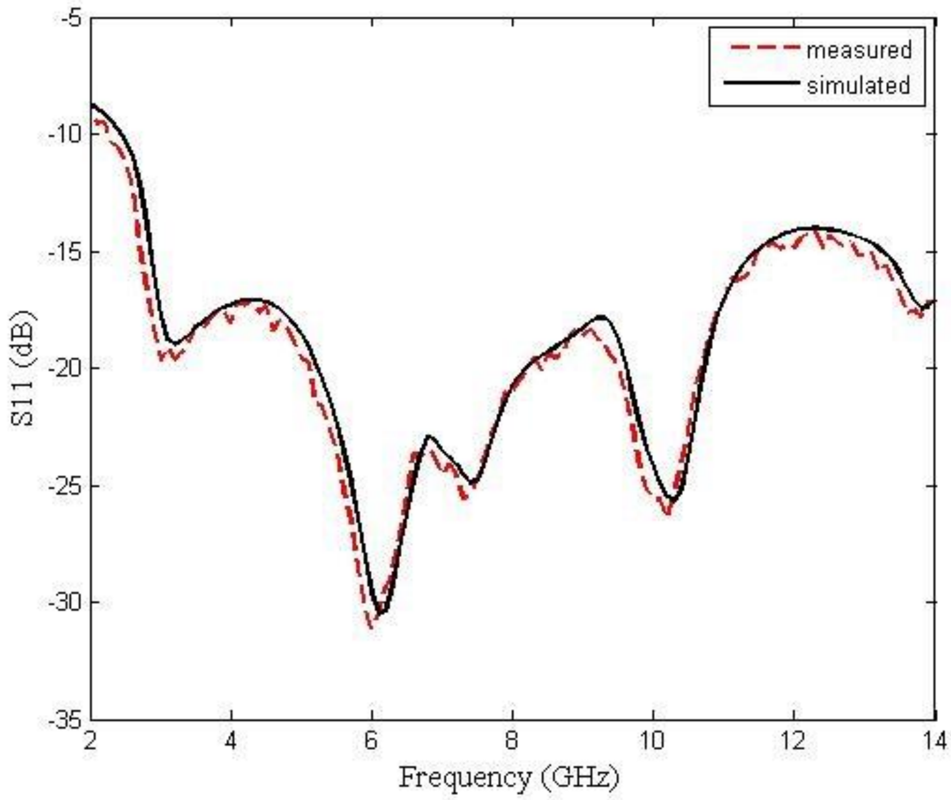

Figure 4.1 Measured S11 of proposed MIMO Antenna

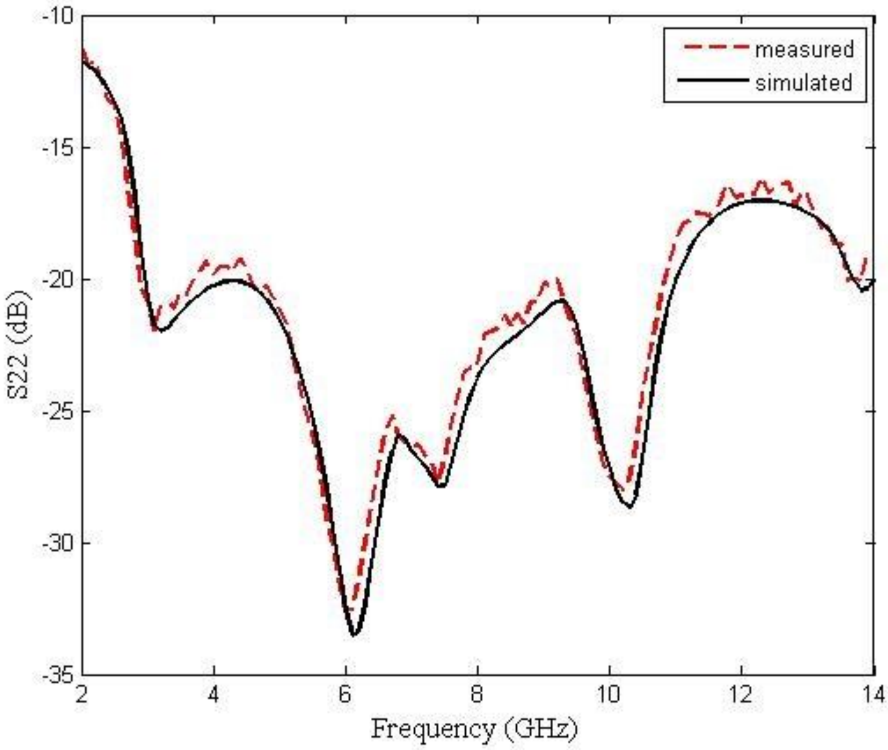

Figure 4.2 Measured S22 of proposed MIMO Antenna

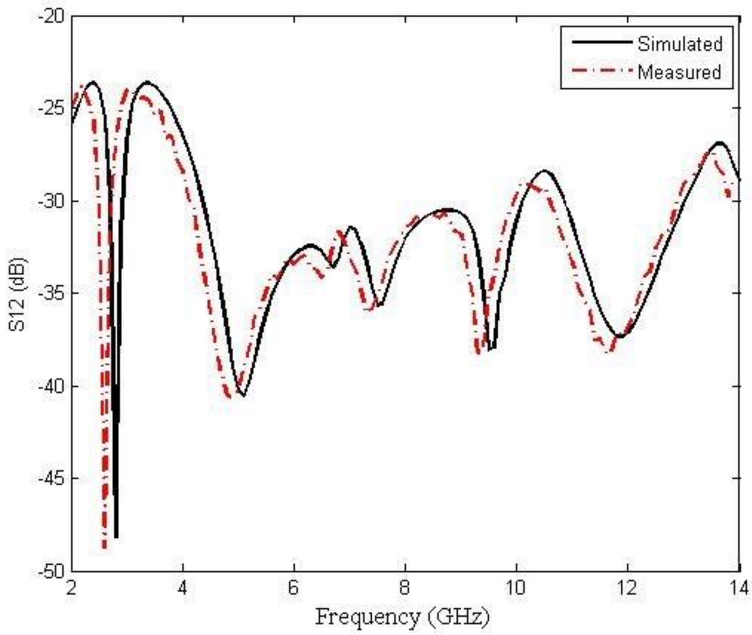

Figure 4.3 Measured S12 (isolation) of proposed MIMO Antenna

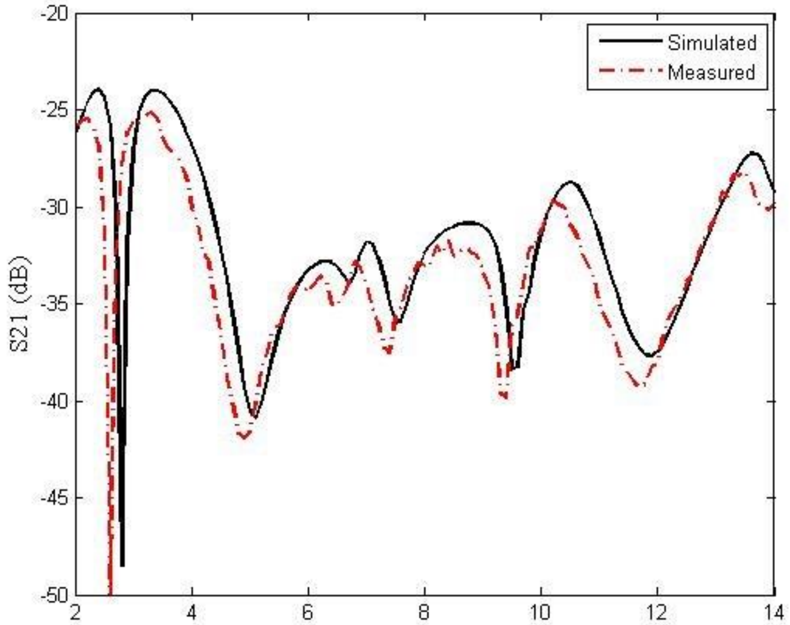

Figure 4.4 Measured S21(isolation) of proposed MIMO Antenna

Fig. 4.5 shows the measured and simulated gain. The value of gain increases as frequency increases, this is due to fact the proposed antenna is compact design.

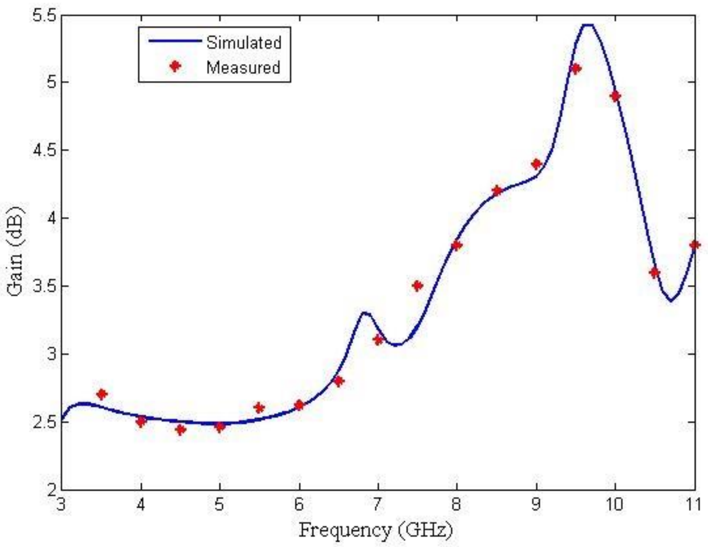

Figure 4.5 Measured Gain Vs Frequency Plot of Proposed Antenna

The radiation pattern of proposed antenna at frequency of 3 GHz, 6 GHz and 10 GHz are shown in Fig. 4.6, 4.7. These plot shows that proposed antenna has nearly omnidirectional pattern throughout UWB frequency band.

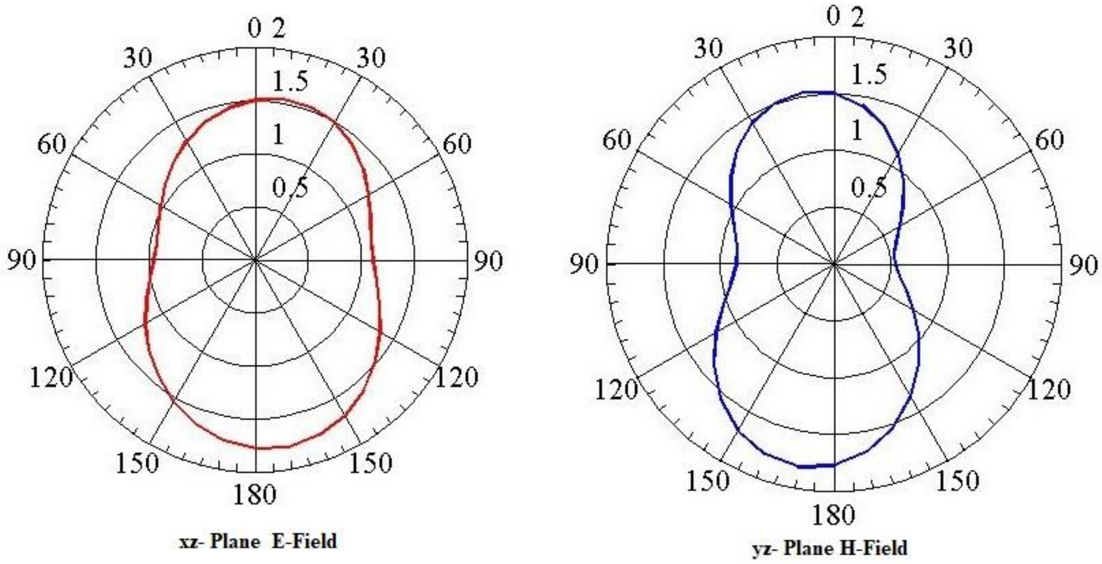

Figure 4.6 E-H Field 2-D Radiation Pattern at 3GHz of Proposed Antennas

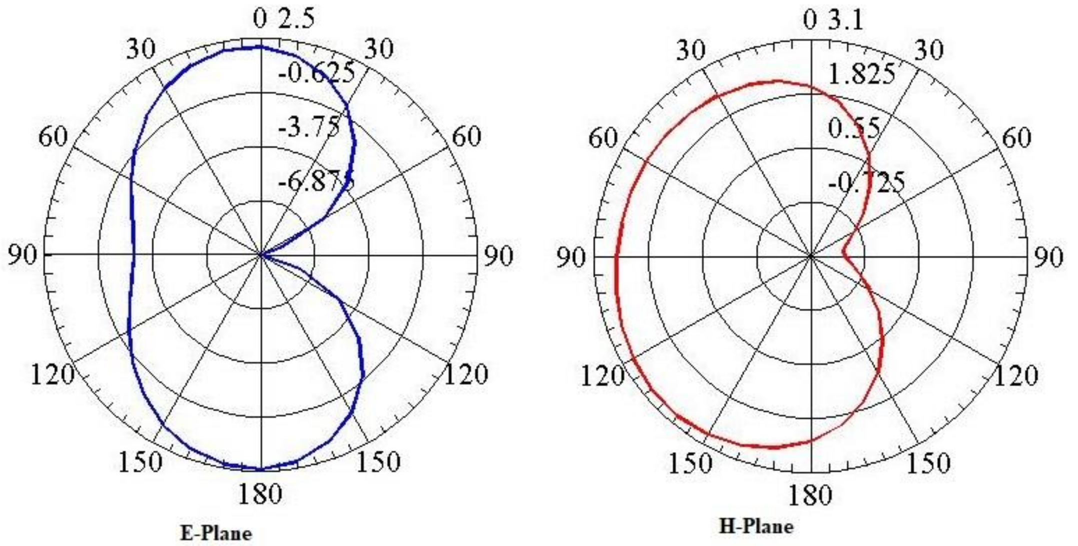

Figure 4.7 E-H Field 2-D Radiation Pattern at 6GHz of Proposed Antenna

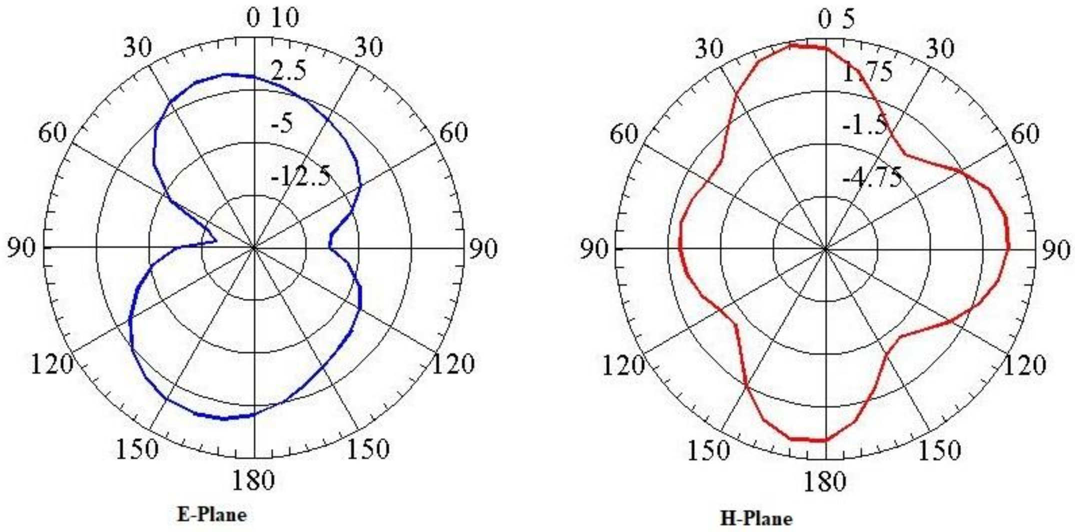

Figure 4.8 E-H Field 2-D Radiation Pattern at 10GHz of Proposed Antenna

4.1 Contribution

The main objective of thesis is to design a very compact two elements UWB-MIMO antenna. After throughout literature review, antenna designing and results and discussion for proof of concept, it is concluded that the proposed antenna is compact in size as compare to existing antennas in literature with greater performance, as shown in Table 4.1.

Table 4.1 Comparison of Proposed Antenna

References	Size (mm^3)	Bandwidth (GHZ)	Isolation (dB)	Gain (dBi)
[29]	26 x 40 x 0.8	2.9 - 10.6	-15	<6.5
[30]	35 x 40 x 0.8	3 - 11.6	-16	<6.5
[31]	32 x 32 x 0.8	3.1 – 10.6	-15	<4.2
Thesis	26 x 30 x 1	2.7 – 14	-25	<5

Chapter 5

CONCLUSION AND FUTURE WORKS

5.1 Conclusion

UWB-MIMO technology is very demanding in modern short-range communication systems, such as WPAN. As with other technologies employed in WPAN, UWB-MIMO devices are expected to be compact and low profile. Printed antennas are ideally suited to incorporate inside space-limited devices because of their planar structure. Designing an antenna that can meet the UWB impedance matching, also having high isolation between radiating elements as well as compact size is a great challenge for antenna designer. This thesis contributes in the field of UWB with the designing of a very compact size MIMO antenna having a very less isolation between elements.

A Novel UWB-MIMO antenna is presented. The proposed antenna is the smallest size of 26 mm x 30 mm with high value of isolation of -25 dB. Comparison of different printed antenna topologies is carried out with emphasis on impedance bandwidth, isolation between elements and size compactness to select potential antenna candidate for UWB applications. After analyzing the strength and weakness of potential antennas, monopole antenna is selected. Miniaturization and broadband techniques for monopole antenna are studied and then employed to develop a very compact monopole antenna of smallest size with UWB response. Design of proposed antenna is very simple and easy to fabricate.

5.2 Future Works

Microstrip UWB antennas incorporated with MIMO have great deal of study and research. Challenges of UWB MIMO antenna with compact size and high isolation have been analyzed and a very small size of 26mm x 30mm with high value of isolation of -25dB has been achieved.

Following further can be done in the same area:

1. To avoids the interferences band such as WiMAX, X-band uplink and downlink with UWB, the antenna needs to have band rejection capabilities.
2. To derive a mathematical expression UWB-MIMO antenna to make design process simple and systematic, using Method of Moment (MOM).

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