REVIEW ON ISOLATION ENHANCEMENT TECHNIQUES FOR MIMO ANTENNAS

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ABSTRACT

Multiple-Input–Multiple-Output (MIMO) technologyuses multiple antenna elements at transmitter and receiver for enhancing capacity in multipath channels.For a powerful MIMO antenna technology the mutual coupling between the antenna elements should be as low as possible.In this paper, a brief review and comparison of various isolation enhancement techniques to reduce mutual coupling between antennas is discussed. A review on techniques like Defected Ground Structure, Decoupling Network, Parasitic Elements, Neutralization Lines and Metamaterials are included in this paper.

Keyword: *-Mutual Coupling,MIMO antenna,Isolation,Defected Ground Structure,Decoupling Network, Parasitic Elements, Neutralization Lines,Metamaterials.*

1.INTRODUCTION:

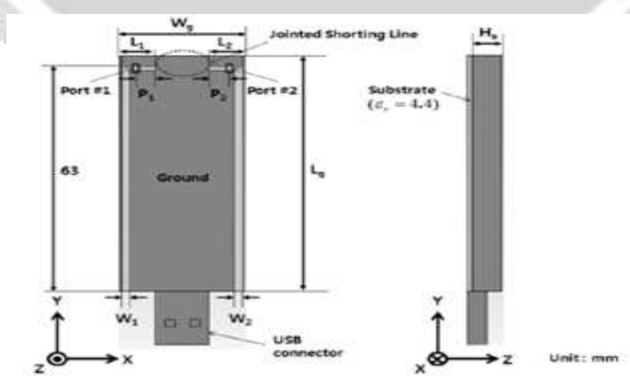
Nowadays Multiple-input-multiple-output (MIMO) technology has become a recent trend in wireless systems to achieve very high bandwidth efficiencies and large data rates. It requires arrays of antenna in the transmitter and receiver. MIMO systems make use of spatial multiplexing technique to transmit the data efficiently. MIMO communication technology has received much recognition as a practical method to considerably increase wireless channel capacity without needing additional power or spectrum in rich scattering environments [1]. A MIMO system consisting of several antenna components are more important than a Single Input Single Output (SISO) system in the terms of increasing channel capacity and reducing transmitted power [2]. Thus, MIMO antennas have received great attention for their ability to overcome the limits of SISO channel capacity. MIMO technology is one of the new paradigm in fourth generation wireless standards which led to increase in the throughput and data rates through the use of multiple antenna setup on the receiver and transmitter sides. For small devices, a typical MIMO antenna array should have compact structure, high radiation efficiency, good radiation patterns, low envelope correlation, and high isolation between the signal ports [3]. Design of such high performance antennas with additional requirement of multiband behavior is an important challenge. MIMO was originated at Bell Labs in the 1997 to 2002 period called BLAST for Bell Labs Layered Space-Time. To realize an effective MIMO system, it is necessary to have a sufficient number of uncorrelated antennas at each end. This leads to a drawback in terms of the antenna size and the achievable isolation between neighbouring antenna elements that would affects the overall diversity performance of the system. In the MIMO communication system, the stronger the mutual coupling between antennas is, the less capacity it will suffer .The high coupling between the antenna elements can degradethe MIMO system's performance. The mutual coupling is higher for antenna elements which is spaced less than 0.5 λ. The presence of mutual coupling degrades the radiation pattern and increases the co-channel interference and changes the input characteristics of the antenna. To overcome the high coupling, isolation enhancement techniques are incorporated.

2.ISOLATION ENHANCEMENT TECHNIQUES:

High coupling between the antenna elements can be caused when the antennas are placed adjacently at a distance less than λ/4. Mutual coupling can be reduced by placing the antennas with some separation distance.The various isolation techniques has to be incorporated between the MIMO antenna element such as Defected Ground Structure, Decoupling Network, Parasitic Elements, Neutralization Lines, Metamaterial, etc., to reduce the mutual coupling. The size, shape, position and dimension of these isolation structures have to be optimized to have huge amount of mutual coupling reduction. Many studies have been carried out to improve the isolation characteristic of a MIMO antenna array. The following section shows the study of various mutual coupling reduction techniques.

3.DEFECTED GROUND STRUCTURE:

The high coupling is caused due to the current produced on the ground plane coupled to the neighbouring elements. By modifying the ground plane structure, the mutual coupling between the antenna elements can be minimized.The Defected Ground Structure (DGS) or a simple ground modification plane has been introduced to provide a band-stop effect mainly by suppressing the ground current flowing between the antenna elements.The DGS can be introduced by the placing of slits which suppresses the field current between neighbouring antenna elements by decreasing the ground plane current. The mutual coupling can be reduced by etching slits and slots on the ground plane. In [4], the mutual coupling between the ports of two rectangular patches is minimized by establishing the defected ground structure under the patch element. It consists of two circular split ring slots that are engraved on the ground plane, each corresponds to the resonating frequency of the patches.The two stop bands are created due to the two split ring resonant slots. By properly choosing the radii dimensions of the circular split ring the required band stop filter the stop band characteristics is obtained at 3.35 GHz and 4.5 GHz. The coupling co-efficient obtained is −33 dB at 3.35 GHz and −27 dB at 4.5GHz.In order to improve the isolation characteristics at LTE and WiMax bands, a symmetric slotted structure and the jointed shorting line are used in order to reduce the interaction between 2 PIFAs. In the proposed MIMO antenna having 2-printed dual band PIFAs with a symmetric slotted structure, the isolation enhancement can be achieved by properly adjusting the electrical length of the current flow between them. While measuring the antenna #1, port 1 is excited and port 2 is terminated by a 50 ohm load. Similarly the S-parameters for antenna #2 are measured in the same way. The geometry and fabricated dual band MIMO antenna using asymmetric slotted structure is shown in Figure 1 and Figure 2. The proposed MIMO antenna having the simulated and measured S parameter characteristics has been shown in Figure 3. From the measured value, the 6-dB return loss bandwidth is 4.66% (from 754 GHz to 790 GHz) for LTE band 13 and 4.68% (2.5 - 2.62 GHz) for M-WiMAX bands. Moreover, the measured isolation value is more than 20 dB over the LTE band 13 (746 - 787 MHz) and is more than 15 dB over the M-WiMAX band (2.5 - 2.69 GHz).



(a) (b)

Fig-1:Dual-band MIMO antenna(Geometric structure): (a) top view and(b) side view.

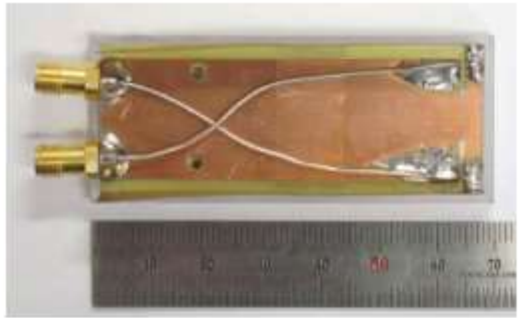


Fig-2: Fabricated MIMO antenna.

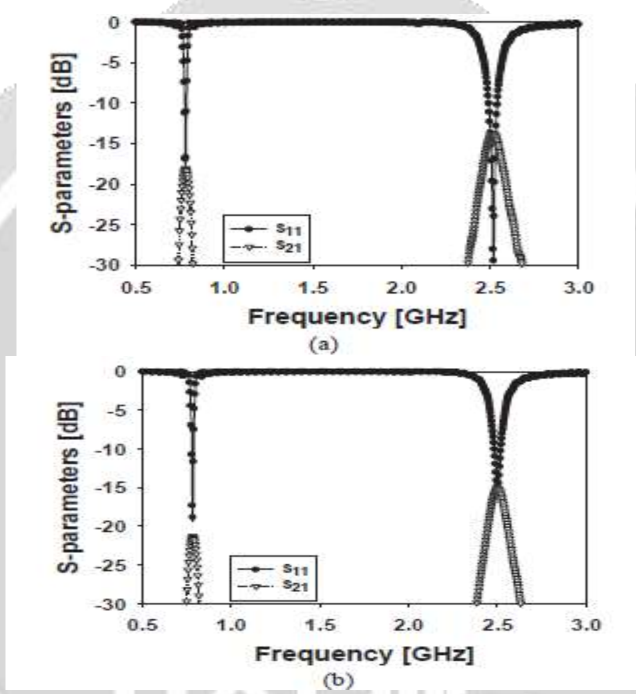


Fig-3: Theproposed MIMO antenna:S-parameter characteristics
(a) Simulated S-parameter characteristics and(b) Measured S-parameter characteristics

4.DECOUPLING NETWORK:

Mutual coupling is the electromagnetic interaction between the antenna elements in an array. The decoupling network is used to reduce the mutual coupling [5], [6]. The coupling between the adjacent antennas can be minimized by providing the negative coupling to decouple the input ports of the adjacent antennas. To enhance the isolation between adjacent antennas lumped elements along with the distributed elements have been used. The advantage of using Decoupling networks (DN) is mainly due to the spatial efficiency. A T-shaped shorting strip is used to reduce the mutual coupling in a three-antenna MIMO system for the WLAN operation [5]. Some branches and tree-like structures were introduced to reduce mutual coupling between radiating elements through the suppression of surface wave propagation. For LTE 700/WWAN operating band, two simple couple-fed PIFAs were used [7]. Using the decoupling structure, isolation of -10 dB and -15 dB are obtained for lower band (704 to 960 MHz) and (1710 to 2170 MHz) higher band respectively. This structure consists of adjourned transmission line with two terminals short circuited to the ground plane element and a capacitor which is implanted at the middle of the line. A floating parasitic digitated decoupling structure for ultra wide band antenna provides wideband isolation characteristics of about 20 dB [8]. The stubs placed on the ground plane of radiator are responsible for achieving wideband characteristics. In [9], indirect coupling is obtained by decoupling network made of two directional couplers. The slots were made into the interelements space to reduce mutual coupling between the antenna elements. The MIMO antenna array comprised of two symmetric back-to-back multibranch monopoles. The geometry and the fabricated design of the proposed MIMO antenna is shown in Figure 4 and Figure 5. In order to minimize the mutual coupling, a strip line which is connected to the two monopoles and a stub connected to the ground plane through a via shorting pin are introduced. The S-parameters of the antenna were measured by an AgilentN5230A vector network analyzer and is shown in Figure 6. The measured 10-dB return loss would cover the needed band.

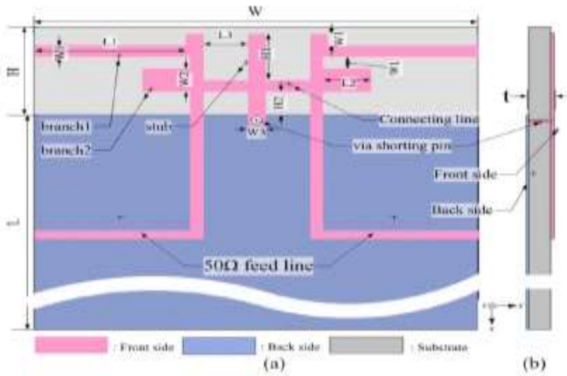


Fig- 4: The proposed MIMO antenna array(configuration): (a) top view and (b) side view.

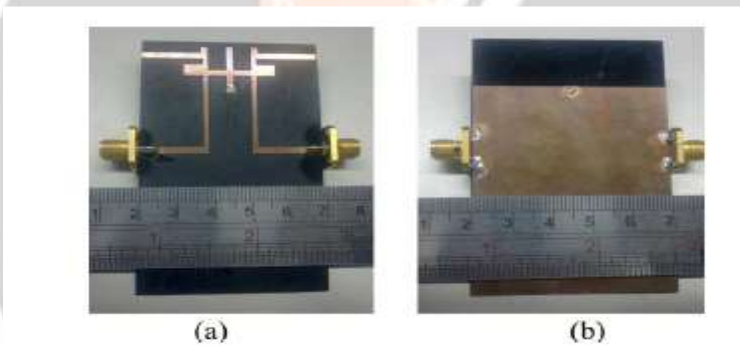


Fig-5:Proposed MIMO antenna array: (a) top view and (b) back view.

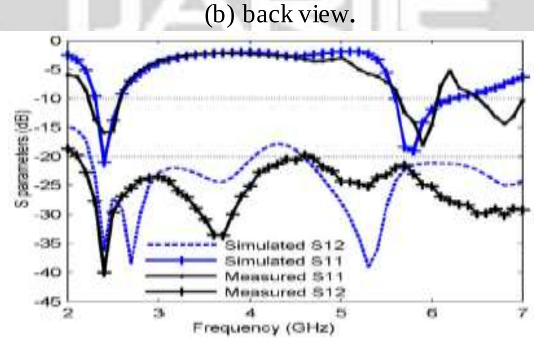


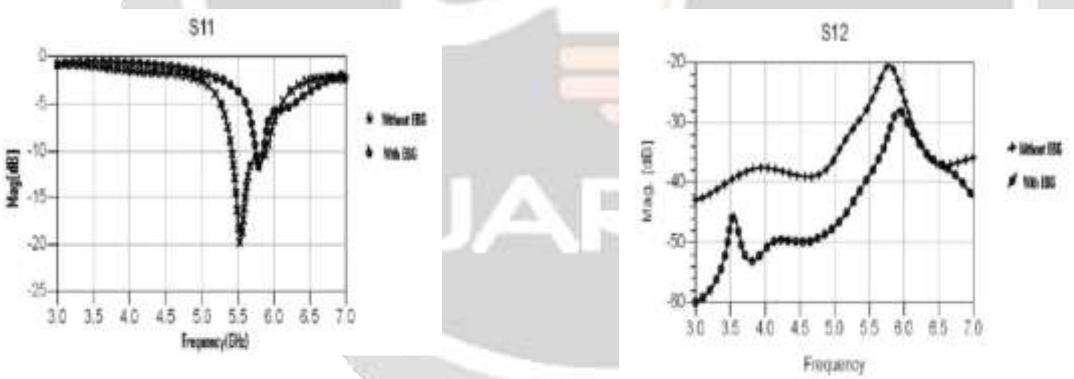
Fig-6:The proposed antenna:S -parameter characteristics.

5. PARASITIC ELEMENTS:

Another method of reducing mutual coupling between two adjacent MIMO antenna elements to enhance its efficiency,isolation and correlation coefficient is to use parasitic elements between the antennas.Parasitic elements are not actually connected to the antennas . These elements are used to terminate some coupled field current between the antennas by creating an opposite coupling field,hence the total coupling on the target antenna gets minimized.

The parasitic element produces an opposite coupling field that decreases the original one,thereby reducing the overall coupling on the victim antenna. To reduce mutual coupling,a T-shaped ground stub along with a slot structure is created between the two square monopole elements.The stub improves the antenna matching characteristics and the slot within it would reflects the radiation from the antenna elements and hence the isolation is improved. The parasitic elements may be of a resonator type, floating or shorted stubs. In the WLAN band, the strips in the ground plane are used to create a stop band which suppresses the interference. The Electromagnetic Band Gap (EBG) structures are metallic or dielectric elements which are arranged in a periodic manner that exhibits one or more forbidden frequency bands. . EBG structures are periodic structures which is also known as photonic band gap structure. Eventhough, the EBG requires a large structure and are more complicated,they are used for reducing the mutual coupling. The Mushroom EBG structure is introduced between the antenna elements that acts as parasitic element and it supports either Transverse Electric (TE) or Transverse Magnetic (TM) waves which are acting as a band-notch filter [10]. A mushroom EBG structure is equal to that of parallel LC resonant circuit. The capacitance is introduced from the gap and inductance from the current along the neighbouring cells. Thereby surface waves are prohibited to propagate and hence decreasing coupling between the antenna elements.The Mushroom EBG structures with slots loaded as in Figure 7 (a) between the monopole antennas reduce the mutual coupling between the rectangular patch elements. Isolation of -36 dB is attained and is shown in Figure 7(b).

(a)

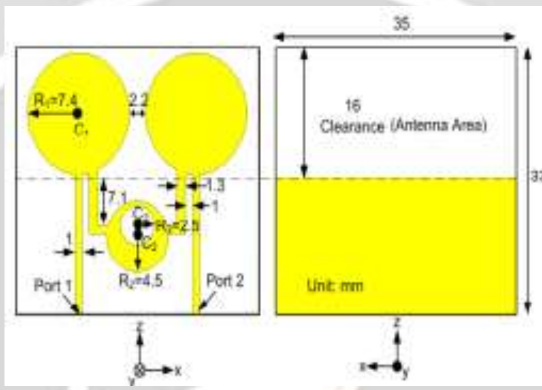


(b)

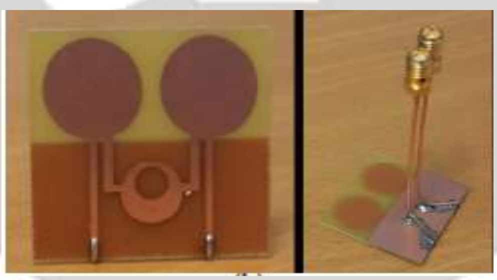
Fig- 7:(a) Geometry of antenna. (b) Measured S11 and S12 parameters.

6.NEUTRALIZATION LINES:

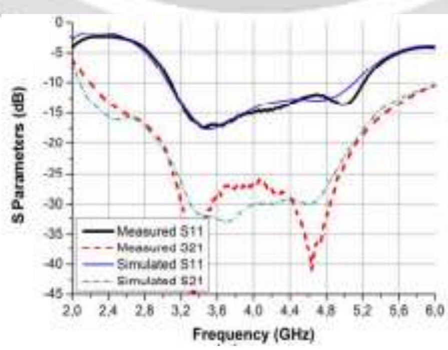
The isolation between the antenna elements can be improved by using Neutralization Line (NL). With the neutralization method,the isolation can be improved since the current of the element antennas of MIMO is neutralized. At the input element, the current has been taken at a particular location where the impedance is minimum and current is maximum and then its phase is reversed by choosing a suitable length for the NL. The coupled current can be reduced by feeding this reversed current is fed to the nearby antenna. In [11], NL which can be inserted between two antennas introduces the certain current on the neutralization lines and creates an extra electromagnetic field to terminate the mutual coupling. The decoupling of port can also be achieved by the use of adjourned metal strip lines which cancels out the reactive coupling between antenna elements and this is referred to as a neutralization technique [12].In [13],the two F like monopole antenna elements are arranged symmetrically in which NL are introduced on the top of the PCB. Each of the antenna elements can be attached to the ground plane through the branch and are called grounded branch. This branch can be observed as a parasitic monopole.Between the two antenna elements,a NL, connected to the main ground plane with a gap to the two grounded branches of the dual-antenna, is entrenched. It provides an isolation of less than -15 dB 1.7–2.76 GHz bands. In [14], a MIMO antenna structure is presented with the neutralization technique to achieve high isolation between the signal ports. Each antenna element is monopole; interim, the spacing of these two elements is only about 0.1225λ0 at 2.45 GHz. The isolation is better than 15 dB with the MIMO structure size only 0.16λ0 × 0.32λ0 at 2.45 GHz. The antenna gain is better than 2 dBi at operating frequency band. In [15], a neutralization line is connected and interleaved between the two circular monopoles on the substrate which are at a distance of 2.2 mm as in Figure 8 (a) and Figure 8(b). The Neutralization Line consists of two metal strips and a metal circular disc. The circular disc has decoupling current paths which are of different lengths to suppress the coupling current on the ground plane. A circular slot made on the monopole antenna reduces the highest decoupling frequencies to 5 GHz. A large capacitance is introduced by adding wideband neutralization line overhead the ground plane. Since the NL is connected to the two antenna elements its quality factor gets increased and hence the bandwidth is decreased.It still covers the UWB-MIMO bandwidth of 3.1 GHz–5 GHz and provides an isolation of above 22 dB which is shown in Figure 8 (c).



(a)



(b)

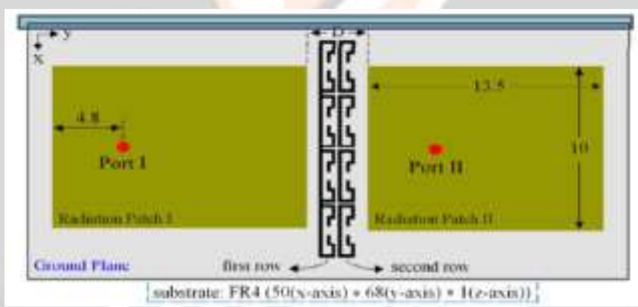


(c)

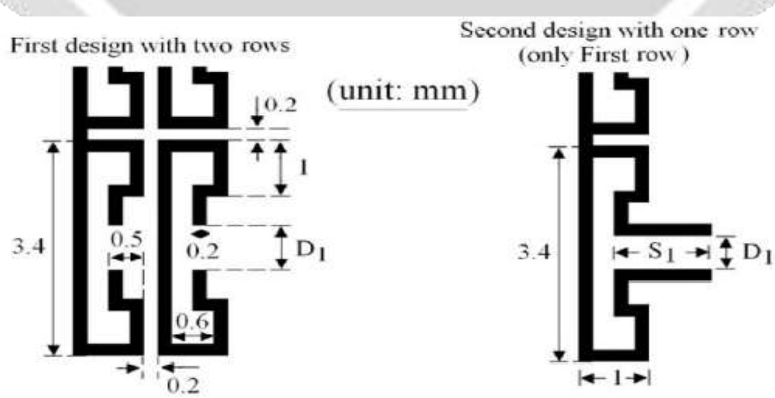
Fig-8: (a) Geometry of antenna. (b) Fabricated prototype. (c) Simulated and measured S parameters.

7. METAMATERIALS:

Metamaterials are materials having the properties not found in nature. Metamaterials (MTM) are materials that have negative permittivity or permeability or both. Based on the survey, Metamaterial based antennas are classified into two types. They are MTM-based antennas and MTM-inspired antennas. MTM-based antennas are one that make use of ENG (Epsilon Negative), MNG (μ-negative) or DNG (Double Negative) substrate. MTM-inspired antennas are the other that only uses the MTM unit cell such as the SRR (Split Ring Resonator), CSRR (Complementary Split Ring Resonator). In [16], in order to efficiently suppress the electromagnetic coupling between closely-spaced high-profile monopole antenna elements, Single-Negative Magnetic (MNG) metamaterials are developed. The most commonly used MTM basic structures for isolation enhancement are the use of Split-Ring Resonators (SRR) and Complementary Split Ring Resonator (CSRR)or the use of Capacitively-Loaded-Loops (CLL).The electromagnetic fields from the neighbouring antenna can be blocked using SRR if the external magnetic field is acting at right angles to the resonator rings [17].To decouple two closely packed microstrip patch antennas, the waveguided metamaterial is utilized. By this way, mutual coupling between two neighboring patches is reduced and doesnot require an intricate fabrication process. In [18], the array elements built on the metamaterial substrate which has the reduction in size, less mutual coupling and an improvement in channel capacity. Due to the copper losses in the unit cells efficiency is still lower in the metamaterial substrate. In [19] SRR and 1-D EBG structures were acting as a reflector and wave trap. The two antennas with 0.19λo spacing reveals the mutual coupling of less than –30 dB from 2.43 to 2.54 GHz.In [20], two cross printed dipole antennas that are placed perpendicularly on a ground plane and are excited by two microstrip baluns. In order to broaden the impedance bandwidth, the CSRRs are etched on the patch at symmetrical position. The microstrip balun and CSRR resonators imprinted in the patch possess a CSRR based transmission line. At the frequency band from 1 to 2 GHz, the measured port isolation is better than 25 dB. In [21], two probe fed patch having one row and two rows of Folded Split Ring Resonators (FSRR) on the ground plane operating at 5.2 GHz are discussed and is shown in Figure10 (a) and Figure 10(b). The single row of FSRR and two rows of FSRR implementation has the isolation of about –45 dB and –56 dB and is shown in Figure 10(c).

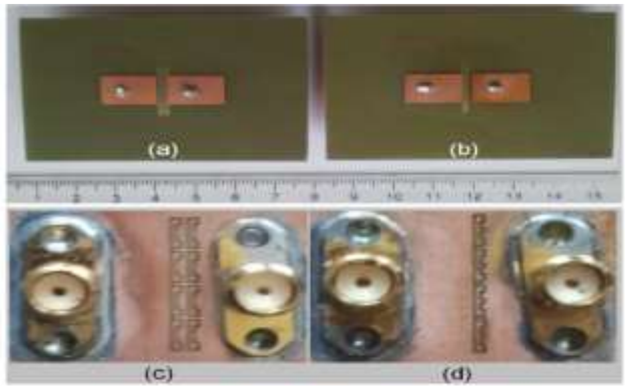


(a)

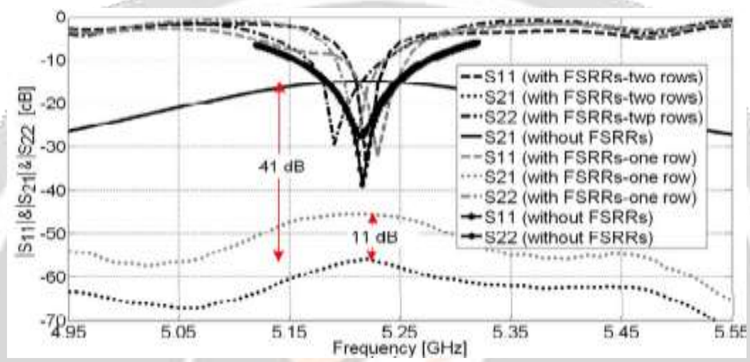


(b) (c)

(a)



(b)



(c)

Fig-10: (a) Geometry of antenna. (b) Fabricated antenna prototype. (c) Measured S parameters.

8.CONCLUSIONS:

This paper presents the detailed study and comparison of various techniques to reduce the mutual coupling in MIMO antenna which is proposed by the different authors. The various method to reduce the mutual coupling such as Defected Ground Structure, Decoupling Network, Parasitic Elements, Neutralization Lines and Metamaterials has been studied. These each method described above has its own advantages and disadvantages in term of complexity, cost, fabrication technique and mode of operation. The researcher had also tried to improve capacity of system, bit error rate, gain, and diversity of the MIMO antenna system. Further the stated MIMO antenna can be used for single, dual and multiband applications. Mutual coupling degrades the system performance in terms of pattern diversity and hence mutual coupling reduction is a vast and an interesting area of research which has direct application for next generation wireless, i.e., 5G and beyond.

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