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Review on Isolation Techniques in MIMO Antenna System

Rhea Nath[1], Pramod Singh[2]

[1] *Electronic Communication, M.Tech Student*
Meerut Institute of Engineering and Technology, UP Technology University (India)
[2] *Associate Professor, Meerut Institute of Engineering Technology (India)*

ABSTRACT

MIMO technology involves multipath antenna elements both at the transmitter and the receiver ends for capacity enhancement in multipath channels. The designing of MIMO antenna with an objective to achieve high isolation and reduced mutual coupling is indeed a challenging task. To achieve a powerful MIMO antenna, the mutual coupling between the antenna elements should be at the minimal. This paper presents a brief discussion and also comparison over various techniques pertaining to enhancement of isolation between the antennas so as to reduce mutual coupling between the antenna elements.

Key words: Mutual Coupling, MIMO antennas, Isolation, Defected Ground Structure, Decoupling Network, Parasitic Elements, Neutralization Lines, Meta Materials.

I INTRODUCTION

MIMO has become a current trend in wireless communication system for the achievement of high bandwidth efficiencies and huge data rate. It requires arrays of antenna at both the terminals of receiver and transmitter. For transmission of date in an efficient way, MIMO system make use of spatial multiplex technique. MIMO communication technology, as a practical method, has received much recognition to significantly enhance wireless channel capacity without requiring any extra power or spectrum in rich scattering atmosphere. The possession of several antenna components in MIMO system is much more important than a SISO system in terms of channel enhancing capacity and reduction in transmitted power. Thus, MIMO antenna could draw considerable attention for their capability to overcome the drawback of, limited channel capacity of SISO antenna. MIMO technology is considered as one of the new paradigm in fourth generation wireless communication standard that leads to enhance the capacity and increase in data rate by use of MIMO antenna array at both the terminals of receiver and transmitter. For small devices, a typical MIMO antenna array should have specific specifications like compact structure, good radiation pattern, high radiation efficiency, low envelop correlation, high isolation between the antenna elements, design of antenna with this high performance with added requirement of multiband behavior is a major challenge. To understand an effective MIMO system, it is indispensable to have an adequate number of uncorrelated antenna at both transmitter and receiver ends. This arrangement bring forth a drawback regarding antenna size and the isolation achieved between the adjacent antenna elements that can affect the overall diversity performance of the MIMO systems. In this MIMO communication system, the less capacity efficiency that antenna will suffer, the greater the mutual coupling between the antenna elements is. This strong coupling between the antenna elements, obviously degrade the system performance. The antenna elements having space less than 0.5ʎ have higher mutual coupling. The occurrence of mutual coupling decreases the radiation pattern and, accordingly, enhance the co-channel interference and alter the input the characteristic of the antenna. The technique pertaining to isolation enhancement and integrated to overcome the strong mutual coupling.

II.LITERATURE SURVEY

In this paper, decoupling network isolation has been used in 7.5GHz frequency with an isolation < - 58dB. The shape of the isolation network is of two directional coupler. Advantage: construction is simple, coupler provides large coupling coefficient that helps in rescinding the direct coupling caused by the antenna elements. Disadvantage: Transmission line requires extra space [22]. In this paper, decoupling network isolation has been used in frequency range from 2.45GHz and 5.25GHz with an isolation < -20dB .The shape of the isolation network is strip like Monopole. Advantages: ECC with dual band decoupling network was reduced to 0.01 and 0.19. Disadvantages: ECC without dual band decoupling network was 0.12 and 0.29 [23].In this paper, parasitic elements isolation is been used in 4.5GHz frequency with isolation -37.2dB. The shape of the isolation network is like a rectangular parasitic tape .Advantages: avoids etching the slot on the ground or in the dielectric without significant increase in antenna height .Disadvantages: Optimization for the dimensions and location of the conducting tape has to be done carefully. [24].In this paper, parasitic elements isolation is been used in6GHz frequency with isolation -36dB. The shape of the isolation network is slots loaded in the conventional mushroom EBG structure .Advantages: provides very good isolation, correlation co- efficient is nearly zero, good diversity gain .Disadvantages : with the inclusion of EGB structures, the resonant frequency of the antenna is shifted from 5.8GHz to 5.5GHz.[25].In this paper, defected ground plane structures isolation is been used in 1.8GHz frequency with isolation <-10dB. The shape of the isolation network is H shaped DGS (20mmx5.4mm).Advantage: compact, low cost. Disadvantages: little distortion in the radiation profile due to H shaped DGS.[26]. In this paper, defected ground plane structure isolation is been used in 3.35GHZ and 4.5GHz frequency with isolation in -33dB and -27dB .The shape of isolation network is co-centered circular split ring slots . Advantages: ECC is very low, good spatial diversity Disadvantages: proper selection of radii of the slots to control the stop- band frequencies. [27]. In this paper, neutralization lines isolation is been used in 1.7 – 2.76GHz frequency with isolation of < -15dB .The shape of isolation network is neutralization line. Advantages: Good impedance matching, good antenna diversity with diversity gain of nearly 10 dB, low correlation less than 0.5. Disadvantages: Lower frequency band has wider bandwidth when compared to upper frequency band. [28]. In this paper, neutralization lines isolation technique is been used in 2.4 GHz frequency with isolation of < -19dB .The shape of the isolation network is neutralization line . Advantage: ECC less than 0.006. Disadvantages:

Occupies very little board space for neutralization line. [29]. In this paper, Meta materials isolation technique is been used in 2.4GHz with isolation > - 37dB. The shape of isolation network is open slot spilt ring resonator (OSSRR). Advantages: OSSRR is less complex and has reduced electric length than CSRR, sharp filtering characteristics, high isolation. Disadvantages: when resonators are displaced horizontally from the centre of the ground plane , the resonator moves away from either of the antenna and reduction in mutual coupling cannot be observed , no standard design procedure. [30]. In this paper, Meta materials isolation technique is been used in 5.2GHz with isolation – 56dB. The shape of isolation network is folded SRR. Advantages: less space, high performance, non-Complex structure, low design complexity. Disadvantages: reduction in bandwidth due to substrate losses, backward radiation, increasing the distance between the antennas, the performance of FSRR is degraded, no standard design procedure. [31]

III TECHNIQUES TO IMPROVE ISOLATION IN MIMO ANTENNA SYSTEMS.

When antenna are placed closely at a distance less than $\frac{\lambda}{4}$, there appear a high mutual between the antenna elements. By placing the antenna, maintaining some separation between them. A variety of isolation techniques has to be integrated between the MIMO elements like, DGS, Decoupling Network, Parasitic Elements, Neutralization Lines, Mata-materials, etc., in order to reduce mutual coupling. To have a huge amount of reduction in mutual coupling, the size, dimension, shape, position of isolation antenna structure is to be optimized. A number of studies have been for the improvement of the isolation characteristic of MIMO antenna array. Diverse techniques in regard to reduction of mutual coupling on which studies were conducted are furnished below:

IV DEFECTIVE GROUND STRUCTURE (DGS)

The current produced on the ground plane coupled to the adjacent antenna elements caused high coupling between them. With the modification of the ground plane structure, the mutual coupling between the antennas can be lessen. The simple ground modification plan or DGS has been introduced in an attempt to provide a band stop effect primarily to suppress the flow of ground between the antenna elements. The DGS can be introduced by inserting the slits to suppress the field current in ground plane. The mutual coupling can be minimized by etching slots and slits on the ground plane. By establishing the DGS under the patch element, [4] the mutual coupling the ports of two rectangular patches can be reduced. The design consists of two circular split ring slots that are carved on the ground plane, each of which matches to the resonating frequency of the patches. Because of the resonated slots of two split rigs, to stop bands are inserted. By suitably choosing the dimension of radii of the circular split rings, the necessary band stop filter and stop band characteristic is achieved at 3.35 GHz and 4.5 GHz. The coupling coefficient achieved is – 33 dB at 3.35 GHz and -27dB at 3.35 GHz. To improve the isolation characteristic at LTE and WiMAX bands, a structure with symmetric slots and joined shorting lines are used in an attempt to decrease the interaction between the 2-printed dual band PIFAs, with a structure of symmetric slots.The proposed MIMO antenna comprising of 2-

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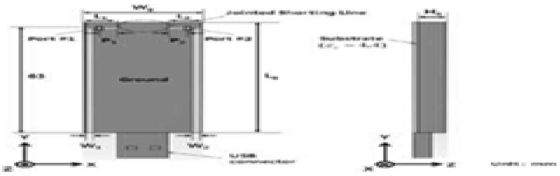
printed dual band PIFAs with symmetrically slotted structure and by precisely adjusting the electric length of current flow between the ports, the isolation enhancement can be achieved. flow between the ports. While measuring the first antenna, port-1 is agitated and port-2 is terminated by a 50 ohm load. In a similar way the S-parameter for antenna-2 is measured. In figure 1 & 2 the geometric and fabricated dual band MIMO antenna using symmetric slotted structure are respectively shown. In figure 3 the simulation and measured characteristic of the proposed MIMO antenna has been shown. From the measured value, the 6dB return loss bandwidth is 4.66 percent (2.5 GHz to 2.62 GHz) for M-WiMAX bands. Furthermore, the measured isolation value is more than 20dB over the LTE band 13 (746 – 787 MHz) and for M-WiMAX band the isolation value is more than 15dB (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

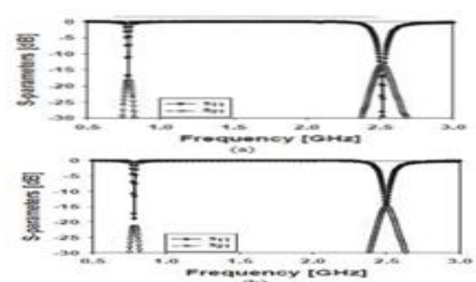


Fig-3: The proposed MIMO antenna: S-parameter characteristics (a) Simulated S-parameter characteristics and (b) Measured S-parameter characteristics

V DECOUPLING NETWORK

Mutual coupling between the antenna elements in the array is nothing but the electromagnetic interaction. To reduce the mutual coupling the decoupling network technique is used [5], [6]. By providing negative coupling in order to decouple the inputs ports between the neighbouring antennas, the coupling between the neighbouring antenna can be

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lessen. Budge elements together with distributed elements have been used the isolation between the neighbouring antennas. Advantage of using decoupling network is chiefly due to spatial efficiency. A T-shaped strip for shorting purpose is used to decrease mutual coupling in the 3-antenna MIMO system for WLAN operation [5]. In order to reduce mutual coupling between the radiating ports via suppression of surface wave propagation, a tree like structure with some branches were introduced. Two simple coupled-fed PIFAs were used [7] for LTE 700/WLAN operating band with the use of decoupling structure, -10dB obtained for lower band (704 – 960 MHz) and -15dB is obtained for higher band (1710 – 2170 MHz). This tree like structure consists of adjacent transmission line with both the terminals short-circuited to the ground plane and capacitor set in at the middle of the line. A digitated decoupling structure for UWB antenna in floating form provides wideband characteristic of about 20dB [8]. The stubs position on the ground plane of radiator are accountable for attaining wideband characteristic. In [9], the decoupling network that is made of two directional couplers, helps to obtain indirect coupling. To reduce mutual coupling between the antenna elements, slots were made into the inter-elements gap. The MIMO antenna array consists of two symmetric multi branch monopoles placed back to back to each other. Fig. 5 & Fig. 5 respectively shows the geometric and fabricated proposed MIMO antenna. In an attempt to minimize the mutual coupling, a stub connected to the ground plane via shorting pin and a strip metal line connected to two monopoles are introduced. Fig.6 shows the measurement of S-parameter of the antenna by an Agilent N5230A. The measured return loss of 10dB could cover the needed band.

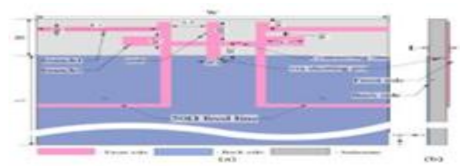

Fig- 4: The proposed MIMO antenna array(configuration): (a) top view and (b) side view

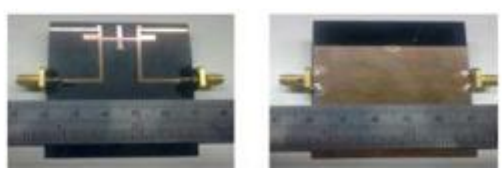

Fig-5:Proposed MIMO antenna array: (a) top view and (b) back view

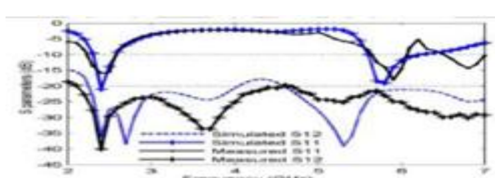

Fig-6: The proposed antenna :S -parameter characteristics

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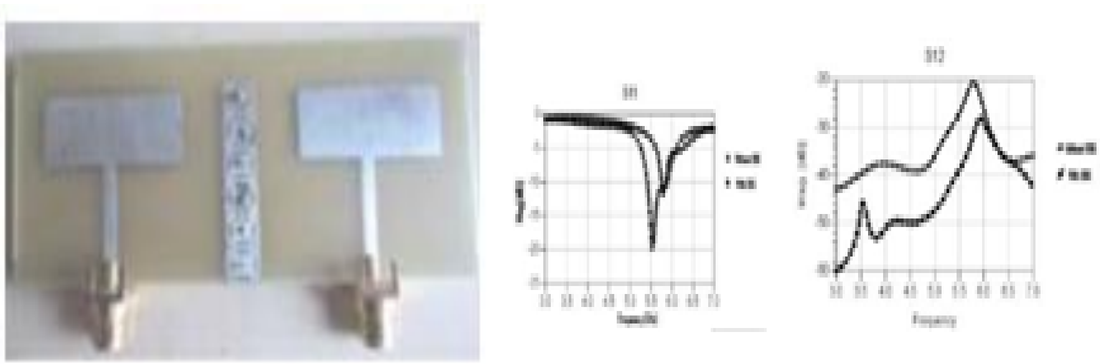
VI PARASITIC ELEMENTS

One more method to reduce mutual coupling between the two neigbbouring MIMO antenna elements is the use of parasitic elements between the two adjacent MIMO antenna elements to enhance its efficiency, isolation and correlation coefficient. Parasitic elements are not essentially connected to the antennas. These elements are used for cessation of some coupled field current with the creation of an opposite coupling field, hence, the resultant affect of the coupling on the said antenna get minimized. An opposite coupling field produced by the parasitic elements decreases the original coupling field hereby reduces the overall coupling on the concerned antenna. For the purpose of reducing mutual coupling a ground stub of 'T' like shape along with the slot structure is formed between the two square monopole antennas. The stub here improves the matching characteristic antenna and the slot placed within it would reflect the radiation from the antenna elements and hence, improve the isolation. The parasitic element may be of a resonate type, floating or a shorted stub. In WLAN band, a stop band is crated with the strip in the ground plane to suppress the interference. The electromagnetic band gap structures are either metallic or dielectric elements that are arranged in a periodic fashion that exhibits one or more prohibited frequency band. This periodic EBG structure are also known as photonic band gap structure. The EBG structures are very bulky and are also more complicated even though they are used to reduce mutual coupling. The introduction of mushroom EBG structure between the antenna elements is to act as a parasitic element to support either Transverse Electric (TE) or Transverse Magnetic (TM) waves acts as band-notch filter [10]. A mushroom EBG structure may be treated as per the parallel LC resonant circuit. The capacitance is commenced from the gap and induction concerned from the current along the adjacent cell. Thus, the surface waves are forbidden to propagate and thereby reduce mutual coupling between the antenna elements. Fig. 7(a) shows the mushroom EBG structure loaded with slots between the monopole antenna to decrease mutual coupling between the rectangular patch antenna elements. An isolation of 3dB is achieved as shows in Fig.7 (b).

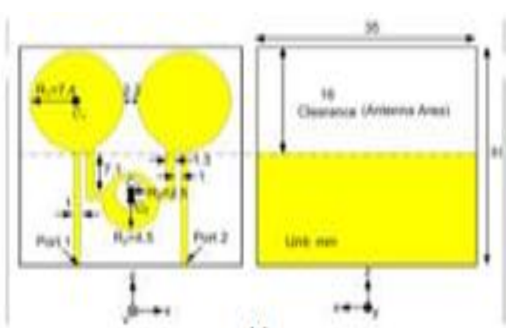


(a) (b)

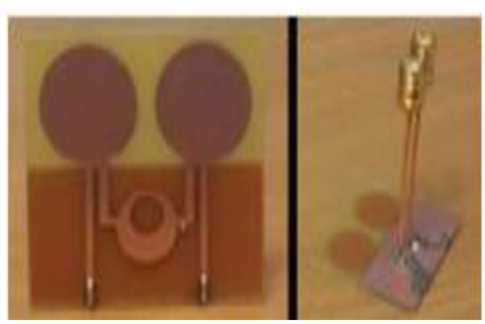
Fig- 7 :(a) Geometry of antenna. (b) Measured S11 and S12 parameters

VII NEUTRALIZATION LINE

By using NL, the isolation between the antenna elements can be improved. This is possible because of the current of the antenna elements is neutralized. The current at the input elements has been taken at a specific location when impedance is minimum and the current is maximum and thereafter by choosing the appropriate length for the NL its phase is revised. By feeding this revised current to the neighbouring antenna the coupled current can be decreased. In [11], with the insertion of NL between two antennas, certain current is introduced on the neutralization lines and then creates an additional EM field to cease the mutual coupling. By use of adjourning strip lines that can terminate the reactive coupling between the antenna elements. This technique is known as Neutralization Technique [12]. In [13], two antenna elements of F-like shape are symmetrically arranged in which NL are inserted from the top of the PCB. Each of the element of antenna is attached to the ground plane via the branch called grounded branch. This grounded branch is observed as parasitic monopole. A NL placed between the two antenna elements and is also connected with the key ground plane maintaining a gap to the two grounded branches of dual antenna is well established. It provides an isolation which is less than -15dB (1.7 – 2.76 GHz bands). In [14], to obtain a high isolation between the signal ports, a MIMO antenna structure is offered with the NL technique. Each antenna element is monopole, short-lived and thus gap between them is only about 0.1225λ at 2.45 GHz. For an MIMO structure with a size of only 0.16λ x 0.32λ_0 at 2.45 GHz, the isolation is better than 15dB and at an operating frequency band, the antenna gain is better than 2dB. In [15], a NL is connected and inter-leaved between the two antenna monopole on the substrate which are at distance of 22mm as in fig. 8(a) & 8(b)). The constituent of this NL are two metal strips and a circular disc. In order to suppress the coupling current on the ground plane, this circular disc has a decoupling current path of different length. A slot of circular disc has decoupling current paths of different lengths. A slot of circular shape made on monopole antenna decreases he optimal decoupling frequencies to 5 GHz. A huge capacitance is set in by engaging wide band NL at the top of the ground plane. Due to the connection of NL to the two antenna elements its quality factor develops which in turn deceases the bandwidth. Still it envelops a UWB MIMO bandwidth range of 3.1 – 5 GHz with an isolation of above 22 dB, as shown in fig.8(c).



(a)



(b)

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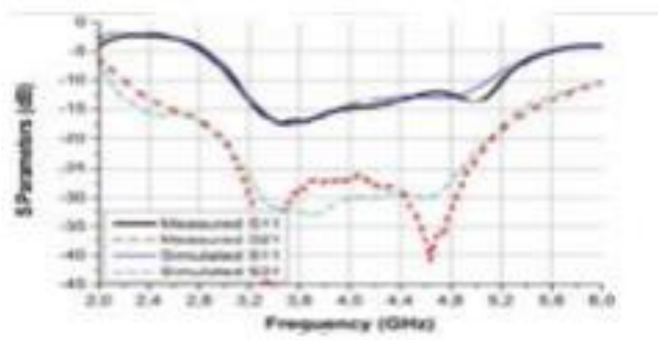


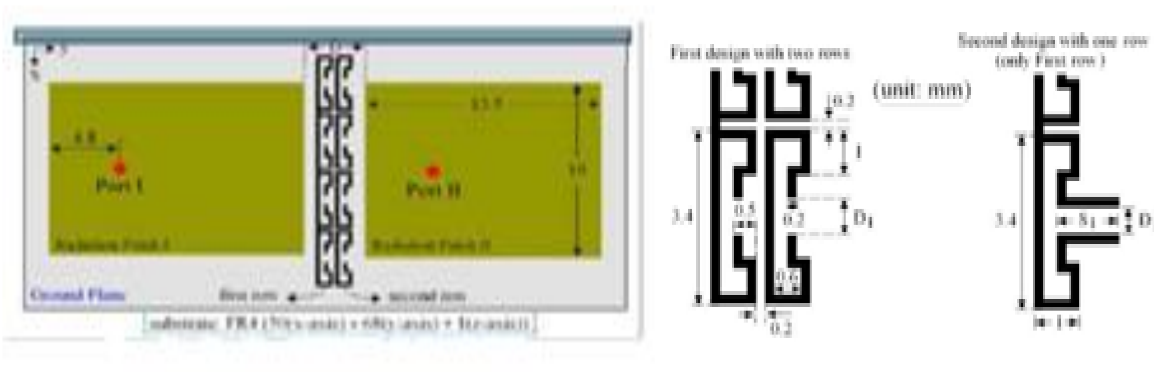
(c)

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

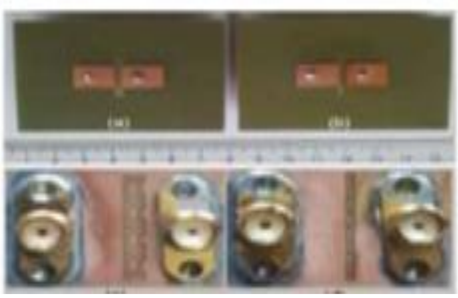
VIII META MATERIALS

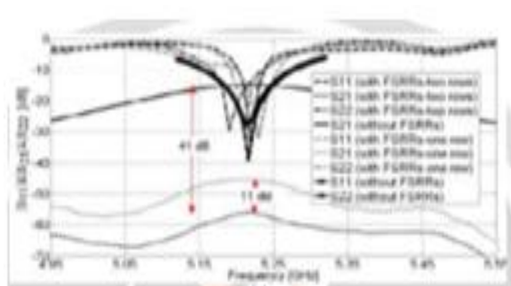
Meta materials describes such materials having the properties not available in the native . These meta materials posses negative permittivity or permeability or both. Meta materials antenna are broadly classified into two categories; (i) MTM based antennas; (ii) MTM inspired antennas

MTM based antenna : MTM based antennas are those antennas that makes use of substrate like ENG (Epsilon Negative),MNG (μ –negative) or DNG (Double –negative) substrate MTM inspired antenna are those type of antenna that only uses the MTM units cell like SRR (Split Ring Resonator) , CSRR (Complementary Split Ring Resonator) . In [16], in order to completely restrain the EM coupling between narrowly spaced high profile monopole antenna elements, Single Negative Magnetic (MNG), Single Negative Magnetic (MNG) is evolved. The MTM basic structure is the Splits Ring Resonator (SRR) & Complementary Split Ring Resonator (CSRR) or the use of Capacitive Loaded Loop (CLL). With the use of SRR, the EM field adjacent antenna can be blocked provided the external magnetic field is acting normally to the resonant rings [17]. The Meta materials with wave guided is employed to decoupled closely packed Microstrip patch antennas. By this means, mutual coupling between two nearby patches is reduced and it does not necessarily required a complicated fabrication process. In [18],the array elements constructed on the meta materials substrate is reduced in size, poor mutual coupling and enhancement in channel capacity . Channel efficient is still lower in meta materials substrate due to copper loss in the unit cell . In [19] ,SRR and ID – EBG , structure were performing as a reflector and wave trap. The two antennas with $0.19\lambda_0$ spacing divulge mutual coupling of less than -30dB from 2.43 GHz to 2.54 GHz. In [20], two cross printed dipole antenna are placed normally on the ground plane and are agitated by two Microstrip baluns. The CSRRs are engraved on the patch at symmetrical position, two widen the impedance bandwidth. Both the Microstrip balun and CSRR resonant are printed in the patch possess a transmission line based on CSRR. The isolation measured between the ports is better than 25dB at a frequency band of 1 – 2GHz. In [21], in fig. 10(a) & 10(b) shows two probe fed patch consisting of one row and two rows of Folded Split Ring Resonator (FSRRs) etched on the ground plane at an operating frequency of 5.2 GHz argued. As shown in 10(c), both the single row and the double rows of FSRRs has he isolation of about – 45dB and -56dB respectively.



(a)





(b) (c)

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

IX CONCLUSION

This paper presents lengthy study on various techniques and then comparison to reduce the mutual coupling in MIMO antennas as is proposed by different antennas. The diverse methods such as DGS, decoupling Network, Parasitic Elements, Neutralization Lines and Meta-materials for reduction in mutual coupling and is studied in detail. Each such method illustrated above has both advantages and disadvantages in terms of cost, complexity, fabrication technique and mode of operation. In order to improve the system capacity, gain, bit error rate and diversity of MIMO antenna system.

Moreover, the said MIMO antenna can be used for single, dual and multiband applications. The degradation in the system performance in terms of antenna diversity is mainly due to mutual coupling, hence, the reduction in mutual coupling is a wide area of interest for research which impart a direct application in generation to come in wireless system i.e. fifth generation and its beyond.

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