**I J C T A**, 9(13) 2016, pp. 6309-6314


# Reconfigurable MIMO Antenna Design with High Isolation using Metasurface

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**ABSTRACT**

In this paper, a frequency reconfigurable multiple-input-multiple-output (MIMO) antenna has been described. The idea of the design is to form reconfigurable MIMO antenna by the development of two-port antenna that are identical to each other and pin diodes are used to achieve the frequency reconfigurability. The design of the canonical element consists of compact folded slots with one pin diode placed on both the elements for the frequency reconfigurability and the field cancelation to improve isolation can be done by placing a coupling metasurface. In addition, the mutual coupling between the elements is reduced by properly designing the two-port antenna and the coupling metasurface. Based on the PIN diode switching state, the antenna is capable of operating at two different frequency ranges and in both combinations the mutual couplings between ports exhibit better than -10 dB isolation. The canonical element size is 30x15 $mm^2$ radiates at 2.6 GHz and 3.5 GHz. The antenna performance is obtained in terms of impedance bandwidth and mutual coupling.

***Keywords:*** Multiple-Input-Multiple-Output, Mutual coupling, Metasurface, Pin diodes

## I. INTRODUCTION

Multi Input Multi Output (MIMO) antenna in wireless communication will face reduced performance because of the mutual coupling between them. This is because when the antennas are close to each other they start to interact between them. The performance between them can be degraded in two ways, one by increasing the mutual coupling and other by increasing the return loss. There is a huge demand for frequency reconfigurable antenna now in wireless communication. Various parameters of the antenna such as bandwidth, radiation pattern, gain and polarization can be adjusted and altered at different environments by reconfigurable antenna. The other advantages of the reconfigurable antenna is, it offers small size and the radiation pattern is almost same for all the operating frequency bands and also the effects of jamming and co site interference can be reduced.

Different methods to reduce the mutual coupling when the antennas are close to each other have proposed by several authors. Some the most delegate methods for printed antennas are using decoupling networks[1], electromagnetic band-gap (EBG) [2], slot cutting [3], neutralization line technique [4], defected ground plane structure (DGS) [5]and parasitic element between the antennas [6]. In [1] a reactive element is connected between the two antennas to reduce the coupling. This network consists of two stages, one is matching network and other is decoupling network. Due to these additional networks there will be additional increase in cost. In [2], a ground plane pattern is used which increases the size of structure and also the formations are very large and bulky. That is why it cannot be implemented when ease of implementation is needed. In [3] to improve the isolation slot cutting technique has been used. But in this technique to improve isolation there is no general solution. In [4] neutralization technique was used which connects a line between the two ports. The DGS [5] uses ground plane modification was used to suppress the band-stop effect. In [6] a parasitic element is used which needs additional layer, for the metallized holes to be grounded.

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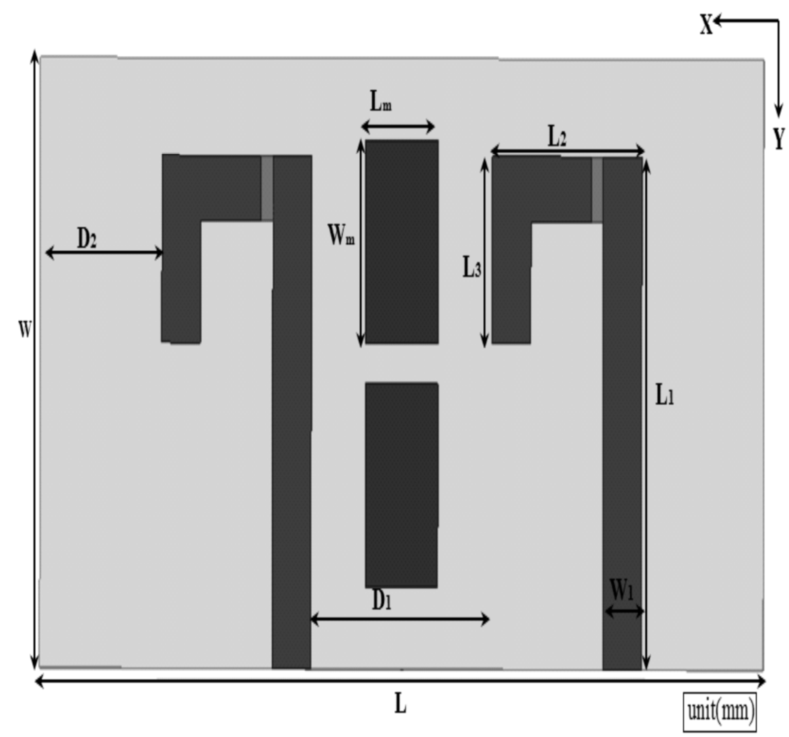
In [7], by using PIN diode switches in two printed dipoles for Multi Input and Multi Output a reconfigurable antenna array has obtained. In [8], a planar frequency reconfigurable micro strip loop antennas are used for the applications of Long Term Evolution (LTE) and Digital Television (DTV). Even though a single antenna is used for both the applications, the size of the antenna is large.

In this paper, an effective structure is proposed to reduce the size of antenna when it is radiating at low frequencies and to reduce mutual coupling when these two antennas are placed close to each other. This structure also produces the reconfigurability at two different frequencies with better mutual coupling. Here, a two-port antenna is used to form MIMO antenna where one antenna is identical to the other antenna that is, the dimensions of both the antennas are same. The operating bandwidth of the antenna is fully covered by the coupling reduction bandwidth. The metasurface can be easily fabricated together with the printed antennas without any extra cost. Since we are using FR4-epoxy substrate the cost of the structure is low. This research mainly includes folded antenna structure where the length of the slot is folded after a certain length to reduce the size of the antenna. This can be mainly used in the field of MIMO technology, hand held device applications, LTE, biomedical applications and radar applications where, in many cases, uses two-element antenna and needs isolation is as high as possible between transmit and receive antenna.




| | | | |
|---|---|---|---|
| **W** | **15** | **L** | **30** |
| **$D_1$** | **7.5** | **$D_2$** | **5.05** |
| **$W_1$** | **1.6** | **$L_2$** | **6.2** |
| **$L_1$** | **11** | **$L_3$** | **3** |
| **$W_m$** | **5** | **$L_m$** | **3** |

**Figure 1: Dimensions and Schematic of two-port antenna**

## II. STRUCTURE OF THE RECONFIGURABLE TWO-PORT ANTENNA

### (A) Antenna Design

The configuration of the MIMO antenna is shown in fig.1. The antenna is placed on the FR-4 epoxy substrate with relative permittivity of 4.4 and the thickness of the substrate is 1.6 mm. The folded slot consists of two vertical arms of length $L_1$and $L_3$ and one horizontal arm $L_2$. The slot width is same (=1.6 mm) along its length. The dimensions of both the slots are same to provide an identical structure. The distance between these two slots is $D_1$and the distance of the antenna from the substrate is $D_2$. The coaxial probe feed is located at the edge of vertical slot $L_1$ from outside of the substrate. In handset design a probe feed is mostly used. The effective length of the folded slot is half wavelength and this will control the antenna's frequency band excitation which is centered at 2.6 GHz. All the dimensions of the design are given in the table of fig. 1.

When more than one antenna are used and are placed next to each other, they couple to each other through the media present in between them that may be the substrate and air layer and the air half-space. The coupling through the air-superstrate layers is obtained by surface waves. The coupling through air half-space means the coupling due to direct slot-to-slot near field. These two couplings may dominate the performance depending in the location and dimension of the antenna.

By properly adding an extra indirect coupling path, the direct mutual coupling between the two antennas can be canceled out. This is because the indirect signal that is coming from extra coupling path will oppose the signal passing directly from one slot to another slot. The inserted structure should not spoil the radiation properties.

The isolation between the two slots can be increased by placing an array (2x1) of metasurface in between the two slots, where the size of unit cell of metasurface is $L_m x W_m$ $mm^2$.This metasurface will prevent destructive effects on the radiation properties of MIMO antenna.

### (B) Pin diode analysis

PIN diodes can be used as switching elements. In this proposed design frequency re-configurability is obtained by using PIN diodes as switches. The switch is placed on both the slots at the end of the length $L_1$ where the proposed antenna has been folded. The size of each individual switch is 0.5x1.6 $mm^2$. When both the switches are ON the antenna will be allowed to pass current throughout its length and hence it radiates at 2.6 GHz. As well, when both the switches are OFF then the proposed MIMO antenna radiating frequency will be shifted to 3.5 GHz, this is because the switch will stop the flow of current at that particular length and hence the length of the antenna will be reduced which results in its frequency shift. Without changing the antenna dimensions, the antenna resonates at two different frequencies by using PIN diode.

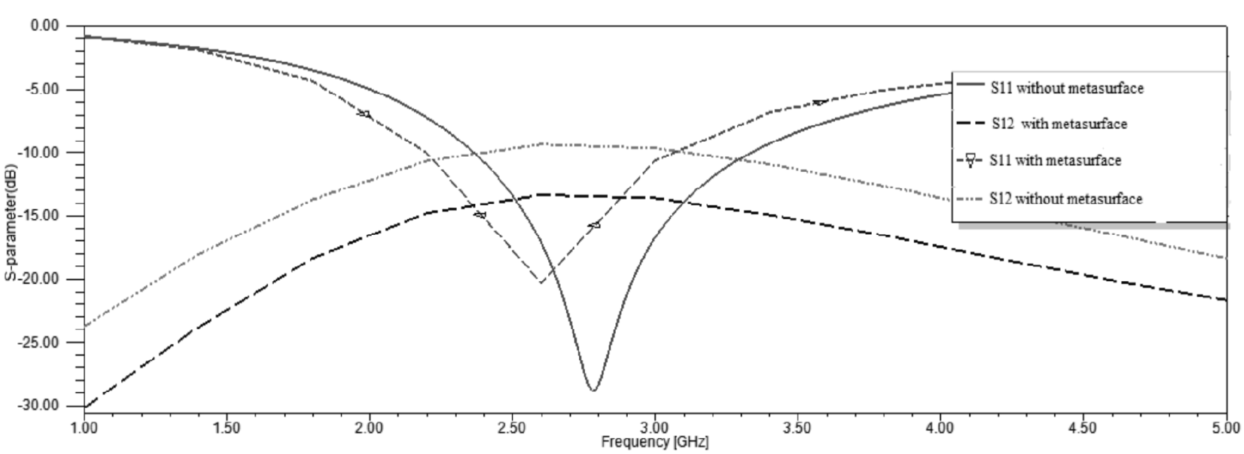



**Figure 2: Mutual coupling and return loss of the antenna with and without metasurface**

## III. RESULTS AND DISCUSSION

Two structures of antenna are designed and simulated, one with only two antennas which are placed next to each other and one with array of metasurface placed in between these two antennas.

Fig. 2. shows the simulated S-parameters of the antenna structure. The return loss of the individual antenna is not affected after inserting the metasurface and antennas together. The coupling between the two antennas is reduced greatly, particularly in the operating frequency at 2.6 GHz. The $S_{12}$ that is mutual coupling for the structure without metasurface is -9.31 dB, as shown in the fig. 2. After placing metasurface the coupling is considerably improved to -13.36 dB. So, after placing metasurface there is improvement of minimum 4 dB. This results proves the performance of the proposed technique is good.

The return loss ($S_{11}$) and mutual coupling ($S_{12}$) of the antenna design with and without switches has explained in fig.3. The return loss at both the frequency bands is less than -10 dB. The mutual coupling between the antennas at both the frequency bands is less than -10 dB as shown in the fig. 3.

The radiation patterns are shown in the fig.4. and fig.5. The Gain of the proposed antenna with and without metasurface are 8.2 dB and 6.5 dB in x -z plane and it will be 9dB and 8.6 dB in x-y plane. The antenna radiates omnidirectionally. This feature mainly applied in handset devices where omnidirectional antennas are highly required.

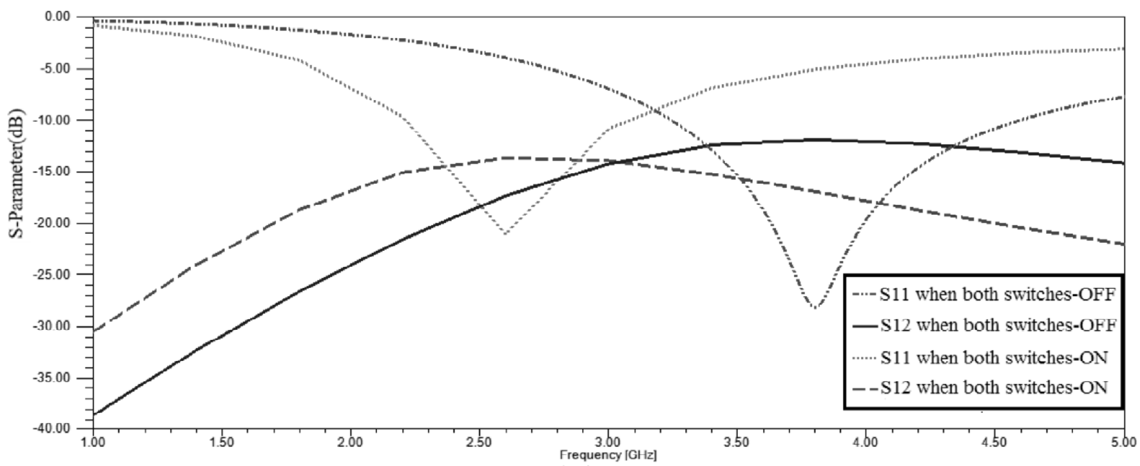



**Figure 3: Mutual coupling and return loss when both the switches are switched ON and OFF in the presence of metasurface**

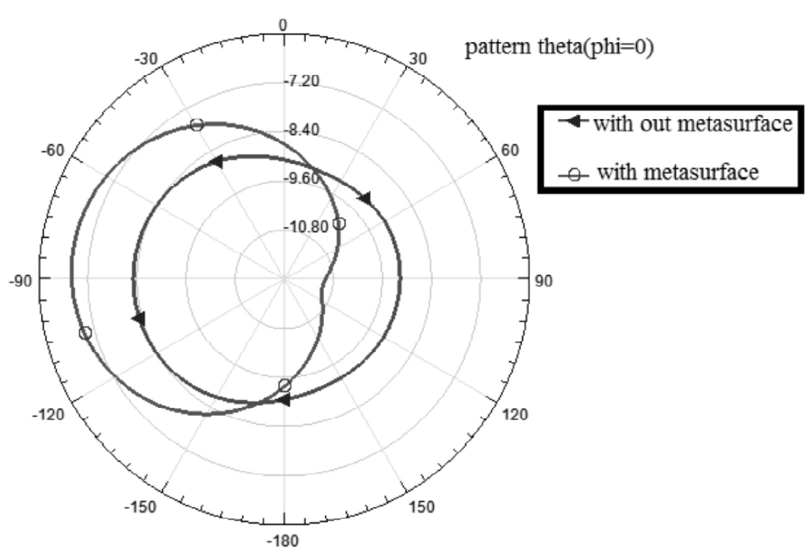



**Figure 4: Effect of metasurface on the radiation pattern when phi=0**

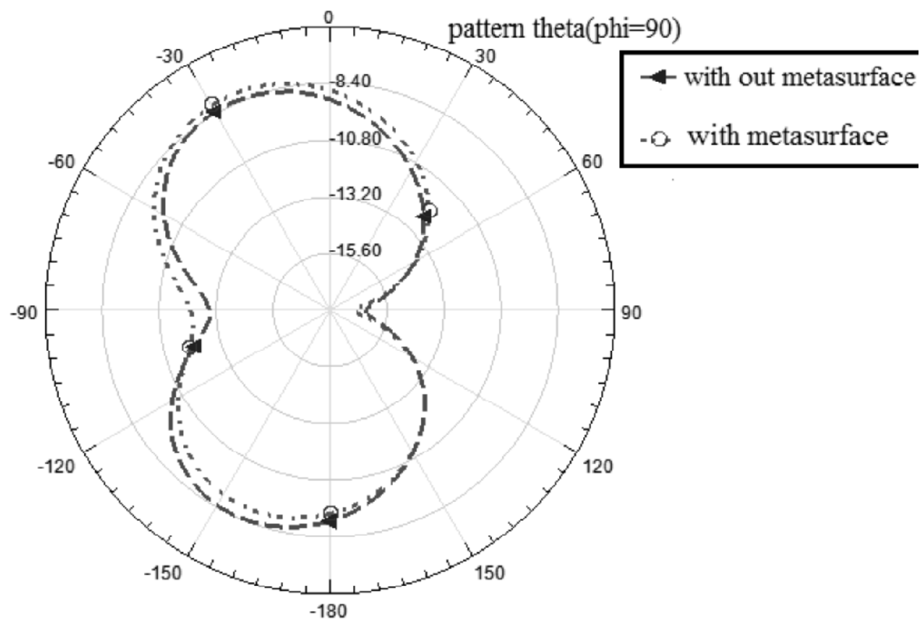



**Figure 5: Effect of metasurface on the radiation pattern when phi=90**

## IV. CONCLUSION

In this paper, a simple and highly effective frequency reconfigurable MIMO antenna for wireless communication with reduced coupling between them has been proposed. The basic idea of the design is development of two- port antenna where the second antenna is the replica of first antenna to form MIMO antenna. The antenna element consists of folded slots for the radiating elements and the field cancellation to achieve high isolation is done by coupling metasurface which is placed in between them. In addition the frequency reconfigurability is obtained by placing single switch on both the antennas each at a particular length. The coupling between antenna elements is reduced by properly designing the coupling metasurface and the two-port antenna. The antenna radiates at 2.6 GHz and 3.5 GHz depending on different switching conditions.

The mutual coupling between these two ports is better than -10dB at both the frequency bands. The performance of the antenna is good and this structure has low-cost features. The proposed frequency reconfigurable MIMO antenna is well suited for handset devices.

In future, the experimental measurement will be compared with the simulated results.

## ACKNOWLEDGMENT

This work was supported by SRM University, Chennai, India.

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