A Survey Report on Isolation Techniques for Printed MIMO Antenna Systems

Poorna Pathak, Sunil Kumar Singh

Abstract: ***Wireless communication has become an essential part of our day to day life. Printed antennas are leading technology for these wireless systems. With the ever growing demand of higher data rate and larger channel capacity, Multiple Input Multiple Output (MIMO) technology find its place among various existing wireless technologies. Like other technologies this also has limitations due to system size and space related issues. Fortunately researchers are successfully find way to address these problems. Lot of intense research work is done and lot more is yet to be done. This survey is mainly aimed towards summarizing various isolation techniques used in MIMO systems. To the best of author's knowledge this kind surveys are very few and more need to be carried out. The focus of present survey is on categorization of various isolation techniques.***

Index Terms: Channel Capacity, Decoupling Structures, Isolation, Multiple Input Multiple Output, Mutual Coupling, Wireless Communication.

I. INTRODUCTION

Although Ultra Wide Band (UWB) systems are deployed and providing high data rate transmission, they are not sufficient for upcoming demand of higher channel capacity. The wireless standards such as existing 4G and upcoming 5G demand even more on channel capacity. Since transmission bandwidth and power levels cannot be increased within present international spectrum allocation scenario which is below 6GHz. That is why a new technology which can promise higher data rate transmission within existing bandwidths is highly in demand. Apart from that, existing UWB systems also suffer from multipath fading effects. Let in a wireless system we have M transmitters and N receiver antennas. Ref. [1] gives the general channel capacity equation as,

$$C = BW \log_2\left(\det\left(I_N + \frac{P_T}{\sigma^2} HH^H\right)\right) \quad (1)$$

Where, C stands for channel capacity, BW is channel bandwidth, P_T represents equally distributed input power among the element, while σ^2 represents noise power and I_N and H are symbols for an NxN identity matrix and a complex channel matrix respectively.

It is clear from this equation that increase in band width or Signal to Noise Ratio (SNR) will result in increased channel capacity 'C', but as we have mentioned that the spectrum and power levels which are practically being used cannot be increased as is set by various government agencies as well as various leading operators, which leaves only two options viz. increasing M and/or N to have higher channel capacity C. This is the motivating force behind development of MIMO technology. MIMO stands for Multiple Input Multiple Output system and is based on using multiple antennas to transmit the signal and multiple antennas at receiver side, with different fading characteristics [2]. This is inspired by an old concept of spatial multiplexing, which began in late 1950s, intended to increase capacity of telephone relay links. Initially it used cross polarized antennas, among them one was horizontally polarized and another one was vertically polarized. This was the natural way of providing isolation and placing antennas λ/2 distance apart was also the effective one. But devices are getting smaller and smaller day by day and so space available for antenna elements is also shrinking which makes it impractical to provide enough separation between antenna elements to reduce mutual coupling. So it is needed to carry out a survey on various decoupling techniques used for MIMO technologies. The author found that there are negligible surveys on this topic, available in open literature. This survey is an effort towards the fulfillment of the demand.

II. ISOLATION IMPROVEMENT CONCEPT AND TECHNIQUES

Most of the printed antennas have the drawback of propagation of surface waves in antenna substrate [3]. These surface waves cause mutual coupling which has serious effect on radiation efficiency and channel capacity of individual antenna element as well as on MIMO configuration of antennas [4]. The most simple yet powerful way to mitigate mutual coupling is to place antenna elements with a sufficient inter element separation i.e. >λ/2, but this may lead to increase in grating lobes and if we keep the separation less than that, it will cause coupling. One more technique for the same is to place antennas perpendicular to each other, this is an effective method for linearly polarized antennas but this also need space. Placing individual antenna elements with a larger separation can only be done at transmitter side because a sufficient space is available there, but same is not the case at receiver side as most of them are mobile devices. So various techniques are reported to reduce mutual coupling as well as separation between antennas in MIMO system which are summarized in subsequent sections.

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A. Decoupling Structures

Decoupling Structures are used to cancel mutual coupling by providing a negative coupling at the input ports of the individual antenna elements of MIMO antenna system. Decoupling structures can be constructed using lumped elements or distributed one or using both of them. Decoupling networks usually have large sizes for lower frequencies due to the size of transmission line needed. Decoupling structures made of lumped elements realized using hybrid coupler resolves the problem space availability for lower frequency (i.e. <1GHz) in [5]. For Ultra Wide Band, a floating parasitic digitated decoupling network provides isolation about 20dB over a wide bandwidth [6]. Investigation on other structures is summarized in the table 2A.

TABLE 2A

Ref.	Freq. (GHz)	Isolation	Remark
[7]	7.5	< -58dB	Uses directional couplers.
[8]	2.45 and 5.25	< -20dB	Makes use of strip Monopole.
[9]	0.704-0.960 and 1.71-2.17	-10dB and -15dB	Provide tunable isolation bandwidth of 260MHz.

B. Defected ground structures

Coupling between adjacent antenna elements which caused by ground currents can be reduced by applying modifications to the ground plane [10]. Ground plane modifications such as cutting slits or other shapes, work as band stop filter for the coupling fields generated by ground currents. [11], [12], [13], and [14]. Most commonly the defected ground structures are placed beneath the transmission line which reduces the effect of electromagnetic fields around the defect. These structures make the ground complicated. Summary of different MIMO systems using defected ground structures is given in table 2B.

TABLE 2B

Ref.	Freq. (GHz)	Isolation	Remark
[15]	1.8	< -10dB	H shaped DGS, compact but not efficient enough.
[16]	3.35 and 4.5	-33 and -27 dB	Co centered circular split ring slots, good spatial diversity.
[17]	2.7 and 3.95	-18 and -21 dB	Cutting slits in ground, compact design.

C. Parasitic elements

These are the elements which are placed near antenna elements or between two elements, in case of MIMO antenna systems to minimize coupling. They also create opposite coupling fields between antenna elements to counter the coupling fields between antennas. Parasitic elements are not actually connected to antenna elements, they are placed near them. They are advantageous as they can be designed for various purposes such as to control bandwidth along with decoupling [18]. They can be composed of resonators or stubs with both floating and/or shorted arrangements. Some of the works in MIMO utilizing parasitic elements are listed in Table 2C.

TABLE 2C

Ref.	Freq. (GHz)	Isolation	Remark
[19]	3.1 to 10	>23dB	Used impedance resonators with ground modifications
[20]	4.5	-37.2dB	Used rectangular parasitic tape so it avoids etching slots on ground plane.
[21]	6	-36dB	Good isolation and diversity gain achieved using slots in EBG.

D. Neutralization lines

Neutralization lines are also effective in providing isolation. In neutralization technique current taken from one element is fed to other element with reversed phase using a transmission line of suitable length to minimize the coupled currents with second element [22]. The complication in this technique is, to select a proper location of maximum current to be picked up and to manage proper length of neutralization line to reverse the phase of that current with in limited space available. It takes very detailed analysis of current distribution and associated phase on antenna. Also these line are suitable for narrow band antennas, they are not as effective for wide bandwidth. Neutralization lines are not always straight lines; they can sometimes look like decoupling structures and can act as both a decoupling network and a neutralization line. Some latest implementation work is summarized here in the table 2D.

TABLE 2D

Ref.	Freq. (GHz)	Isolation	Remark
[23]	1.7-2.76	< -15dB	Diversity gain near 10dB
[24]	2.4	< -19dB	Compact
[25]	3.1 to 5	< -22dB	Bandwidth and efficiency slightly reduced

E. Met materials

Metamaterials are artificial material composed of tiny unit cells made of ordinary material and arranged in specific manner to synthesize negative material properties such as negative permittivity or negative permeability or both, depending on need. They may be planar such as Electromagnetic Band Gap (EBG) material or non planar. They can also be classified as Epsilon Negative (ENG), Mu Negative (MNG) or Double Negative (DNG) [26]. Lot of work has been done in the field of metamaterials due to their capabilities.

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There exists a band gap in the frequency response of metamaterial which acts as band stop filter, which can eliminate the coupling between elements of MIMO system and so they are considered a candidate for isolation enhancement. Some of the considerable work in listed in table 2E.

TABLE 2E

Ref.	Freq. (GHz)	Isolation	Remark
[27]	1 to 2	> -25dB	Upto 18% size reduction
[28]	2.4	> -37dB	Open slot split ring resonator (OSSRR) used
[29]	5.2	-56dB	Compact and high performance but Increase in substrate loss

III. CONCLUSION

Based on the survey conducted for MIMO isolation techniques we conclude that metamaterial not only provide high isolation but also serves better for antenna size reduction. Other good methods are decoupling networks and defected ground structures as compared to neutralization line or parasitic elements. We tried to summarize as much as possible isolation techniques used in MIMO systems. This is not still over and the field has much more to be discovered. There are lot of the techniques which are not categorized yet such as joining ports or providing polarization diversity by simply tilting the beam of antenna, ground plane modifications are also effective and lot of other techniques. We started our talk by basic concept of MIMO and summarized various techniques. This is a little effort and lot more need to do in this area of isolation enhancement.

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