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A Comparative Study of Reduction in Mutual Coupling in Microstrip MIMO Antenna

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***Abstract*: Multiple-Input Multiple-Output (MIMO) antenna systems have attracted appreciable interest as an efficient method of rising reliableness and increasing the data rate in wireless mobile communications. MIMO antennas can enable to produce high speed and prime quality transmission involving larger data transfer in wealthy multipath environments. MIMO antennas for wireless applications need extremely economical antenna design that has sufficient spatial de-correlation that challenges for designing in small device. So as to attain a high isolation, good diversity and multiplexing performance are needed. Primary aim of MIMO antenna design is to cut back mutual coupling between antenna components.**

Mutual coupling is an inevitable development in multi antenna systems, typically reducing the system performance. Various works have targeted on the reduction of this effect. The aim is maintaining the mutual coupling suppressing structure as easy as doable whereas having a high amount of mutual coupling reduction. Varieties of works are done on the suppression of mutual coupling within the recent years. Here we discussed reduction in MC with the help of resonators and shows different procedure projected for reducing the value of mutual coupling among antenna components.

Introduction

Microstrip patch Antenna is a low profile, conformable to planner and non-planner surfaces, uncomplicated and economical to construct via contemporary printed circuit tools. It is a narrow band, wide-beam antenna. It can be grown on a flat plane. In general the patch is in the rectangular type in addition it is also available in spherical, cylindrical or in other shapes. The sheet on which it is grown, which is of metal, is called “ground plane”. The length of the patch is half of the wavelength i.e. “λ/2”. The foremost disadvantage of this antenna is their inefficiency along with very narrow bandwidth, low power, high Q, poor diversity, low gain. To rise above these problems multiple patches are designed on a same ground plane on receiver as well as on transmitting end, this structure of design is known as MIMO (that is Multiple Input Multiple Output). To increase the capacity of radio links MIMO technology is used. In MIMO technology multiple transmit with receive antennas are used en route for make use of multipath propagation (fig. 1).

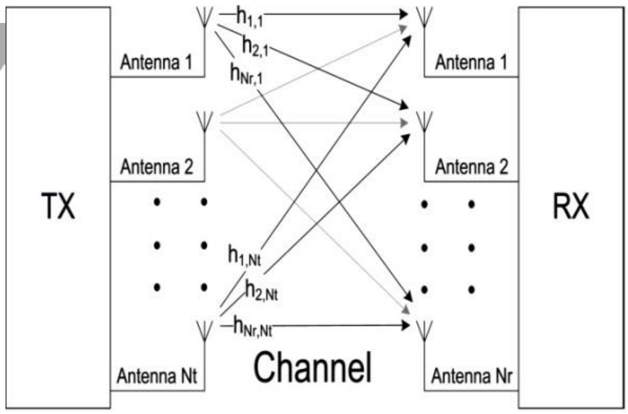

Fig.1 MIMO system

The schema of MIMO antennas exist for high data rate as well as it counteracts the effect of fading during signal propagation through various environments. By using MIMO antenna system the probability of reception and reliability increases [1]. The main advantage of MIMO antenna system is higher data rate which is accomplished by without increase in the transmission power or bandwidth [2].

The main weakness of MIMO antenna is mutual coupling (MC) between the near antenna elements due to this the antenna factors are decreased [3]. In recent years there are many studies are proposed for reducing the mutual coupling between the antenna elements. This paper presents analysis on different MIMO antenna technologies used for reducing the mutual coupling.

Reducing mutual coupling (MC) in MIMO antenna system

In microsrtip patch antenna when we are using multiple patches on a single plane to form MIMO antenna, the space between these patches are very narrow it is mostly of $\lambda/4$ order, then there is more chance of having MC. MC in antenna illustrates energy absorbed by one antenna's receiver when a further nearby antenna is operating. In the transmitting mode energy that should be radiated away is absorbed by nearby antenna in the similar way in receiving mode energy that could have been captured by one antenna is instead absorbed by a nearby antenna. It causes the antenna factors to be decrease and hence the efficiency of the antenna is reduced at very significant level. In past few years there are so much work is proposed to reduce MC between the closely spaced patches of antenna. Here we discussed reduction in MC and hence once the MC is reduced the antenna factors are also increases.

In [4] a completely unique structure based on complementary split-ring resonators (SRRs) was introduced to reduce the MC between 2 microstrip antennas that radiate within the same frequency band. The unit cell was consisting of 2 complementary SRR inclusions connected by a further slot. This modification improves the rejection response in terms of information measure and suppression. Complementary split-ring resonator (CSRR) structures were used for harmonic rejection and filtering [5]. Fig 2 shows the antenna structure with CSRR. There was 10-dB reduction in the MC between 2 patch antennas.

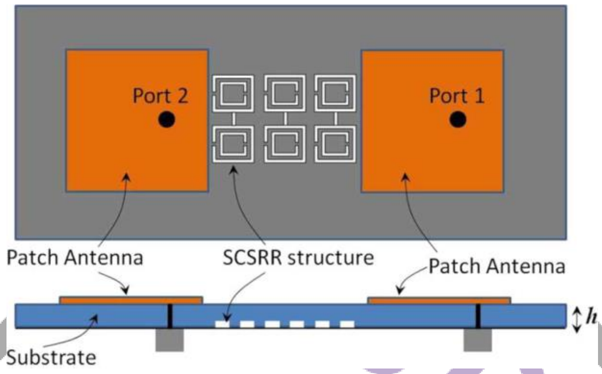

Fig. 2 Top and side views for the two patch antennas with the SCSRR etched on the ground plane

In [6] an cost-effective technique to reduce the MC among two 5.2 GHz probe-fed patch antennas in an array layout's explanation was given. 2 entirely different designs of folded split-ring resonators (FSRRs) etched into the ground plane were used intended for reduction of the MC (shown in fg. 3). The result shows 30 dB reductions within the MC between 2 antennas.

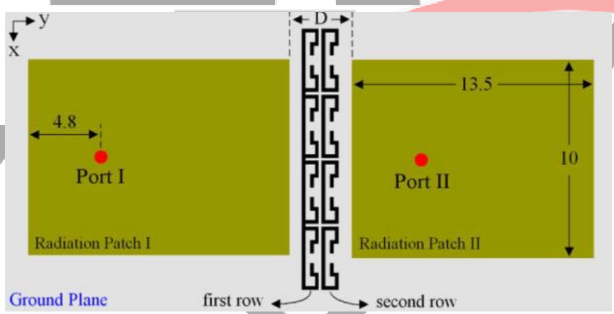

Fig. 3 Geometry of the patch antenna array along with the FSRR in the ground plane.

In [7] a structure was given to reduce MC between antenna components. The structure was a u-shaped microstrip line section inserted between the coupled components. The coupling reduction information measure fully covers the operational information measure of the antennas, and therefore the structure is devoted to linear polarization. The antenna was a 2.44-GHz probe-fed linearly polarized patch component (as shown in fig. 4). By using u-shaped microstrip line 6 dB reductions in MC.

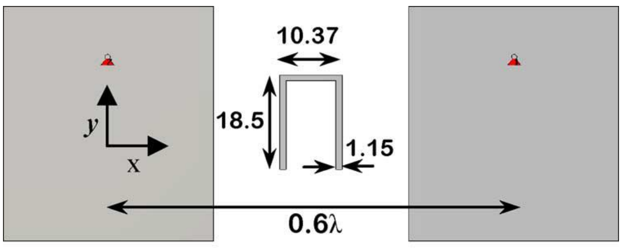

Fig.4 Antenna structure with indicated dimensions in millimeters. The triangle represents the feed point.

In [8] E-shaped microstrip patch antenna has been used at a centre frequency of 3.94 GHz. The antenna includes a return loss more than 25 dB within the frequency band between 3.88 GHz and 3.98 GHz and therefore the maximum gain of the array is higher than 7 dBi among the frequency band. A straightforward I- shaped resonator in between two E-shaped microstrip antenna components separated by 0.45? to reduces the MC in patch array of antennas. The MC has been reduced by 30 dB by the introduction of this easy I-shaped resonator on a similar plane of the microstrip radiator as shown in fig. 5.

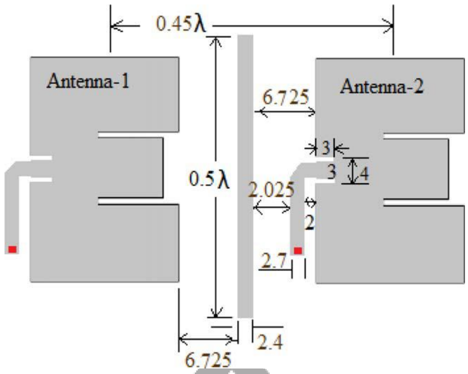

Fig.5 Antenna structure with I-shaped resonator

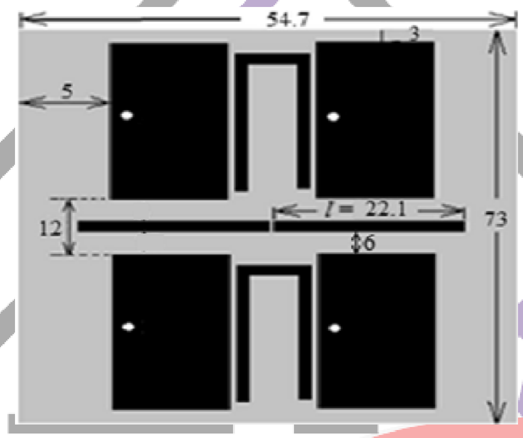

Fig. 6 Schematic diagram of 4-element MIMO antenna structure (dimensions are in mm)

The trouble due to MC between antenna elements is complex to solve with baseband algorithm and signal processing [9]. In [10] a rectangular shaped antenna incorporated with four microstrip resonators intended for MC suppression. The schematic diagram, of 4-element MIMO antenna configuration incorporated through an inverted U-shaped resonator and line resonators, is illustrated in fig. 6. In [10] the proposed design reduces MC by more than 44 dB between horizontal antenna elements and 35 dB between vertical elements at 5.25 GHz frequency.

In [11] the antenna structure was design to reduce MC between 2 patch antennas. The structure was prevents the propagation of space waves additionally to the surface waves on the substrate of a microstrip antenna. Therefore, higher reduction in MC was obtained.

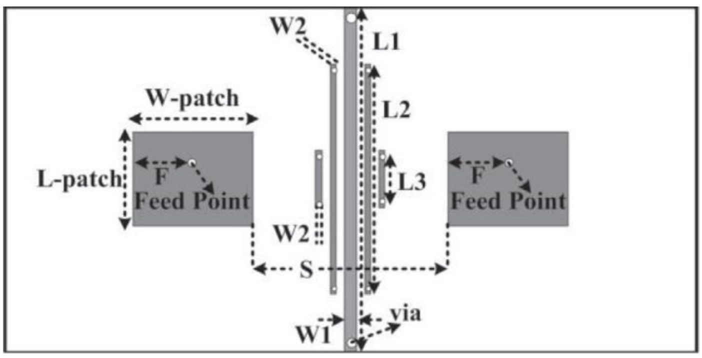

Fig. 7 Geometry of the microstrip antenna

The geometry of 2 rectangular microstrip patch antenna components with the parasitic strips and vias operate at center frequency of 4.32 GHz is shown in Fig. 7. The antenna was consists of 2 rectangular slots etched into the ground plane in conjunction with 5 rectangular narrow strips of various lengths placed in between the 2 patches. The parasitic components in the form of strips were placed parallel to the direction of the electric field radiated by the antenna components. The layout of the parasitic components was almost like an inter-digital filters. This geometry achieves 41 dB reductions in MC.
In [12] A MIMO WLAN band-notched antenna with prominent inter-element isolation was projected. The projected MIMO system was of two monopole antennas, each composed of a slotted radiating patch with a stepped ground plane (Fig. 8). The well-established slots and the ground plane steps were sensibly located to accomplish the desired wide band functionality along with WLAN band-notched comprehension.
Furthermore, to reduce the MC among the ingredient monopole antennas as well as to get better isolation, a parasitic element was positioned sandwiched between the antennas on the backside of substrate. By prudent tuning of the arrangement along with size of the parasitic element, high isolation was accomplished which is essential for MIMO communication systems. The qualities of projected MIMO antenna were Wide bandwidth, compact size, and band-notched characteristic.

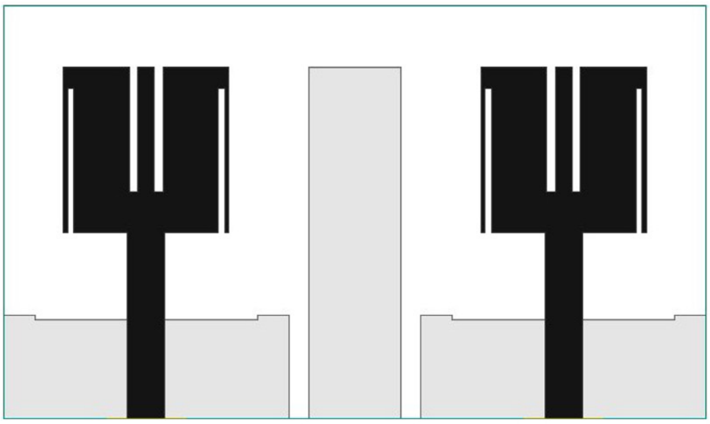

Fig. 8 projected MIMO antenna design

In [13] a wideband four-element MIMO antenna for 5G purpose was projected. The solitary antenna consist of a rectangular patch element with an inverted F-shaped slot, a chicken neck shaped feed line along with a slotted ground plate (Fig. 9).

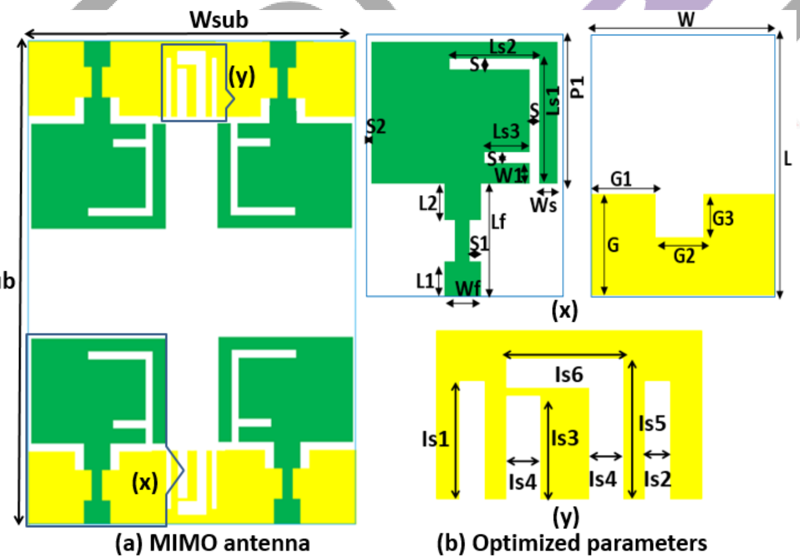

Fig. 9 proposed antenna design

The projected MIMO system was capable to accomplish wide bandwidth with the aim to covers three 5G bands (28/37/39 GHz). The antenna possesses enhanced isolation of less than -20 dB for the entire involved band. The envelope correlation coefficient was below 0.002 for the whole bandwidth. The antenna had high gain of more than 5.28 dBi and its radiation pattern was Omni-directional. These results make the projected antenna suitable for accommodating 5G MIMO wireless applications.

Conclusion

Many investigators have contributed towards the improvement of channel capacity, Bit Error Rate, diversity and gain of the multi element antennas for MIMO systems. However there are still plenty of opportunities for the researchers to work on various reduction techniques in MC. In this review paper various MC reduction methods based on resonators are discussed. Along with the above discussed methods there was also having other methods for reducing the MC like defected ground structures, electronic band gap structures, with the use of meta material etc. Various methods that have been discussed above are summarized in Table 1.

Table 1. Comparison of above discussed methods

S.No.	Paper title	Frequency	Achieved reduction in MC
1	Mutual coupling reduction between microstrip patch antennas using slotted-complementary split-ring resonators	5 GHz	10 dB
2	Mutual coupling reduction between very closely spaced patch antennas using low-profile folded split-ring resonators	5.2 GHz	30 dB
3	Mutual coupling reduction between planar antenna by using a simple microstrip U-section	2.44 GHz	6 dB
4	Reduction of mutual coupling between E-shaped microstrip antenna array by using a simple microstrip I-section	3.94 GHz	30 dB
5	A compact 4-channel microstrip MIMO antenna with reduced mutual coupling	5.25 GHz	44 dB
6	High mutual coupling reduction between microstrip patch antennas using novel structure	4.32 GHz	41 dB
7	High inter-element isolation and WLAN filtering mechanism: A compact MIMO antenna scheme	5.5 GHz	Significant reduction
8	A Four-element Compact Wideband MIMO Antenna for 5G Applications	28/37/39 GHz	20 dB

From the review of MC reduction techniques for MIMO antenna, it is observed that better result was achieved in "A compact 4-channel microstrip MIMO antenna with reduced mutual coupling". Resonators are suppresses the MC at very great level and resonators are easy to use as well as they are having no inherent loss and high radiation efficiency and they can also operated on microwave frequencies. Thus the use of resonator for reducing the MC in MIMO antenna becomes effective.

MC degrades the system performance in terms of pattern diversity and hence MC 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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