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Reduction of Isolation in MIMO Antenna Using Rupee Shaped Structure

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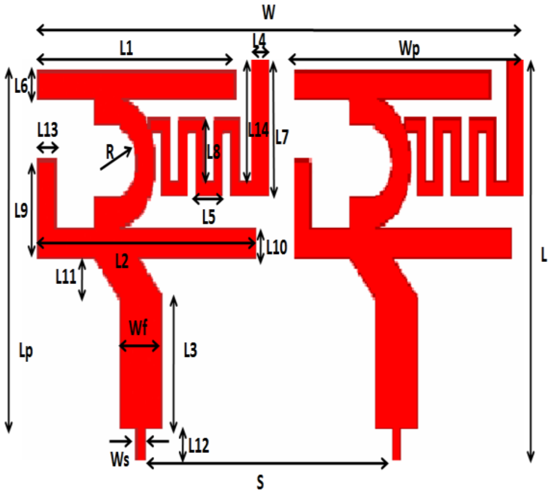
Abstract: A novel concise Rupee shaped micro strip patch antenna with CPW (Co-planar Waveguide Feed) is designed, which is used for Multiple Input Multiple Output (MIMO) systems. The described two element MIMO system reproduces at a dual band of 4.696 GHz and 7.723 GHz with an enhanced impedance bandwidth of 33.33% and a minimized mutual coupling of –35.3 dB. These results are better when compared to a normal E shaped, H shaped, U shaped patch antennas plotted with identical size and thickness, obtained without using any further decoupling methods. A 2×2 MIMO system employing the Rupee shaped patch antennas is analyzed using computational electromagnetic ray tracing software for an indoor environment. The described antenna is a good choice for MIMO systems operating for several Ultra Wide Band (UWB) applications.

Key words: *Rupee shaped patch antenna; Multiple Input Multiple Output (MIMO); Impedance bandwidth; Mutual coupling;*

1. Introduction

Multiple Input Multiple Output (MIMO) technology is the most promising choice for present 3G and 4G wireless communications for obtaining larger data rates and spectral efficiencies. The improvement in channel capacity with increasing the number of antennas at both transmitters and receivers was first verified by Foschini [1]. This work has started many researchers to explore on different areas of MIMO systems like signal processing, channel estimation, data encoding, receiver design, and antenna design. Among all these areas, antenna design plays a major role for exceeding the data rates. However presently a little work is done in the area of antennas regarding to the MIMO systems to improve the performance of MIMO parameters. The major requirements of MIMO systems are that the antennas must provide diverse reception at smaller spacing between the antennas in order to reduce the mutual coupling. When the antennas are closely placed, the electromagnetic waves of different antennas interfere with each other resulting in signal loss and interference between them. The parameter that describes this interference between the antennas is mutual coupling and the main goal of any antenna design for a wireless MIMO system is to reduce this mutual coupling. The effect of mutual coupling on capacity of MIMO wireless channels is studied in [2]. The main source for reducing the mutual coupling applied different types of techniques is studied in [3, 4]. There are various techniques for minimizing this mutual coupling like, using Electromagnetic Band Gap structures (EBG's) [5], Defected Ground Structure (DGS) [6], using parasitic elements [7] and neutralization technique etc. However, in all these concepts the reduction is achieved with complexity of the structures. In the present paper, a high bandwidth and good isolation between the antennas is achieved without using any complex structures, but by taking a simple four slot patch antenna and meander lines (Rupee shaped). The unique shape of the antenna gives an improved impedance bandwidth of 33.33% and an isolation of 35.3 dB. The described two element MIMO system resonates at a dual band of 4.969 GHz and 7.723 GHz, which can be used for several Ultra Wide Band (UWB) and WiMAX applications. In the present wireless communications, the patch antennas are fabricated with various designs and shapes. The most widely studied antennas are E shaped patch antennas [8], H shaped patch antennas [9], U slotted patch antennas [10], *etc*... Among all these antennas, E shaped patch antenna is proved to be the better one in terms of impedance bandwidth and mutual coupling. In the present paper, a novel Rupee shaped patch antenna is designed and the results indicate its superiority compared to all the above mentioned antennas.

2. Antenna Design



II.

Fig. 1 Proposed Rupee shaped patch antenna

Table 1: Dimensions of the rupee shapes MIMO antenna

Symbol	Dimension (mm)	Symbol	Dimension (mm)
L	40	L5	2.5
W	60	L6	2
W_f	5	L7	4
W_s	3	L8	3
R	10	L9	3.5
L1	30	L10	3.4
L2	32	L11	2.5
L3	6	L12	2
L4	2	L13	1.5
L_p	25	L14	3
W_p	25	S	30

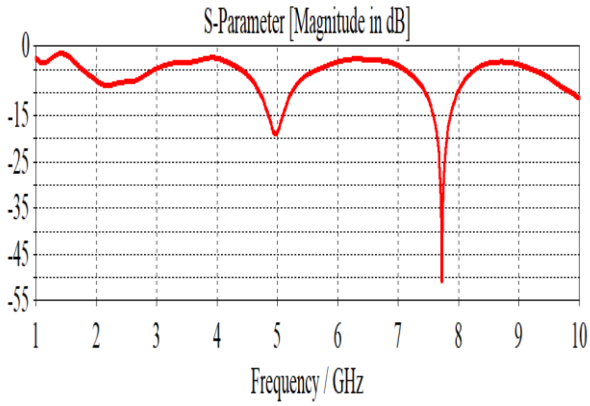


Fig. 2 Return loss of proposed antenna

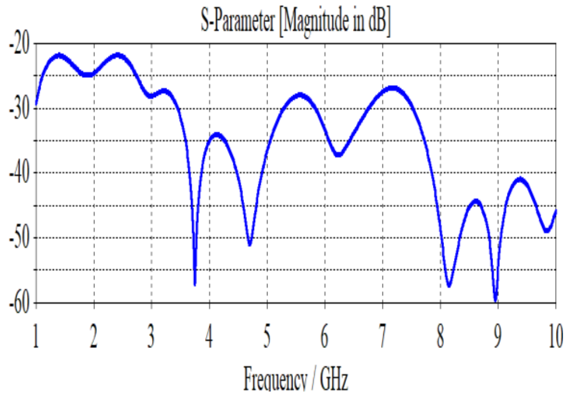


Fig. 3 Mutual coupling of proposed antenna

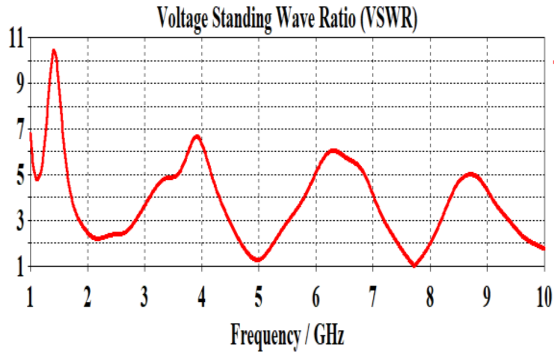


Fig. 4 VSWR of proposed antenna

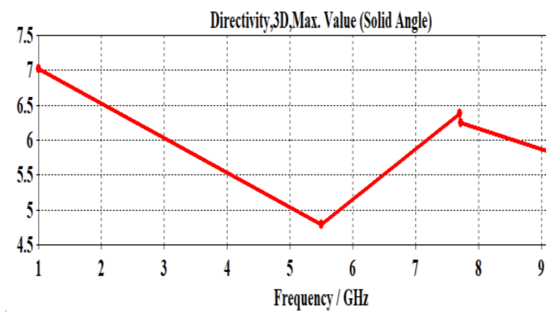


Fig. 5 Directivity of proposed antenna

The desired resonant properties of the Rupee antenna array have been obtained and optimized by designing the antenna structure with the aid of the Computer Simulation Technology (CST), based on the Finite - Difference Time- Domain (FDTD) principle. Fig.2 shows the simulated results of return loss and Fig. 3 shows mutual coupling in dB. The system resonates at a dual band of frequencies 4.969 GHz and 7.723 GHz. The –10 dB impedance bandwidth obtained between the frequencies ranges 8.0 – 7.3 GHz is 33.33%. This bandwidth is very high compared to a normal E shaped patch antenna discussed in [11], which gives a bandwidth of 14% designed with same size (approximately) and air as the substrate. The mutual coupling (S_{21}) is also found to be very low and the isolation obtained at the operating frequency range is 35.3 dB, where as in [11] the obtained isolation is 34.23 dB. In [12], the authors achieved the bandwidth enhancement using distributed inductive capacitive (LC) networks for an E shaped patch antenna and in the present method; the bandwidth and isolation are improved without using any additional decoupling methods. From Fig. 2, it can be observed that the Rupee antenna gives good return loss characteristics and higher bandwidth compared to other patch antennas. Similarly, Fig. 3 shows the good isolation characteristics of Rupee antenna compared to all other above mentioned patch antennas. The impedance bandwidth and mutual coupling comparisons of all the antennas are given in Table.1 and from the Table, it can be observed that the proposed Rupee antenna gives excellent band-width and isolation compared to E shaped, H shaped, and U shaped patch antennas. The correlation coefficient values are very low at the resonant frequencies. The obtained radiation patterns of the developed two element MIMO system using the Rupee shaped patch antenna are shown in Fig. 6.

$$\rho = \frac{\left|S^*_{11}S_{12} + S^*_{21}S_{22}\right|^2}{\left(1-\left|S_{11}\right|^2-\left|S_{21}\right|^2\right)\left(1-\left|S_{22}\right|^2-\left|S_{12}\right|^2\right)} \quad (1)$$

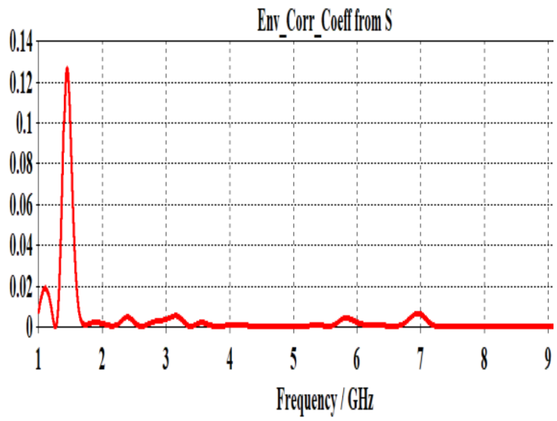


Fig.6 Envelope correlation coefficient (ECC)

where, ρ represents the correlation coefficient; S_{11}, S_{22} represent the return loss of both the antennas respectively in the array; S_{12} represent the mutual coupling between the two antennas with energy from port of antenna 2 to port of antenna 1; S_{21} represent the mutual coupling between the two antennas with energy from port of antenna 1 to port of antenna 2; S_{11}^*, S_{21}^* represent the complex conjugates of S_{11}, S_{21}. Another important parameter describing the amount of isolation between the antennas is correlation coefficient, which can be calculated using the Eq. (1). The correlation coefficient vs. frequency plot is shown in Fig. 6. It can be observed that in order to find out the one of the MIMO parameter involves to decide the use of antenna is evaluated using the parameter of ECC. Here comparison of different antenna shapes with respect to their proposed antenna improves the better performance in terms of all the parameters mentioned in the present design. The proposed antenna involves the usage of improved bandwidth in the frequency range C-band applications producing larger bandwidths

Table 2: Bandwidth and mutual coupling

Antenna type	Bandwidth (%)	S_{12} (dB)
Rupee shaped	33.33	35.3
E Shaped antenna	14	25
H Shaped antenna	4	23
U Shaped antenna	5	23

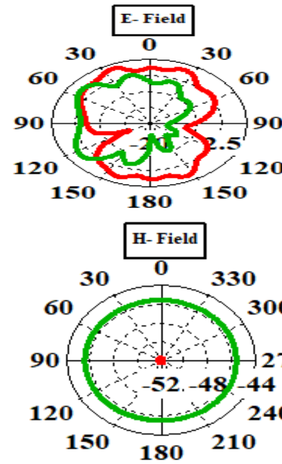


Fig. 7 Radiation Pattern at 4.969 GHz

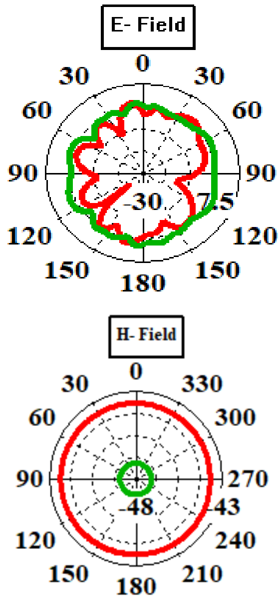


Fig. 8 Radiation Pattern at 7.723 GHz

The radiation patterns of the described antenna is bidirectional in E-plane and omnidirectional radiation pattern in H-field. In order to find the radiation pattern of the antenna port 1 is excited and port 2 is terminated with characteristic impedance (50 Ω).

IV. Conclusions

In this paper, a novel Rupee shaped patch antenna is proposed and a two element MIMO array is developed by using it. The proposed MIMO antenna array resonates at a dual band of frequencies 4.969 GHz and 7.723 GHz with an improved impedance bandwidth of 33.33% and a reduced mutual coupling of –35.3 dB. These characteristics are well suited for many 4G, Bio Medical, Wi-Fi, WiMAX, WLAN applications. As the proposed antenna exhibits excellent return loss and isolation characteristics compared to an E shaped, H shaped, and U shaped patch antenna, it has a good scope of usage in many wireless MIMO applications.

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