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A Modified Back to Back E-Shaped Patch Antenna for 4G MIMO Communications

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ABSTRACT

The present work deals with design of a modified back to back E-shaped patch antenna with improved bandwidth and isolation characteristics. The proposed antenna resonates at 14.16 GHz & 15.47 GHz frequencies for VSWR < 1.34, giving an impedance bandwidth of 20%. A 2×2 MIMO is developed by using the proposed antenna with a reduced mutual coupling of -37 dB. The results for various antenna parameters like radiation pattern, gain, return loss, mutual coupling, and bandwidth are furnished in this paper.

Keywords: *Modified Back to Back E-shaped patch antenna, MIMO (Multiple Input Multiple Output) systems, Impedance bandwidth, Mutual coupling.*

1. INTRODUCTION

MIMO (Multiple Input Multiple Output) systems are proved to achieve higher data rates by deploying multiple antennas at both the transmitter and receiver instead of a single antenna at the respective locations without using additional bandwidth or an increase in the respective power [1]. MIMO systems are very much suitable for the present and emerging communication systems like Wi-Fi, 3G and 4G etc. However, when multiple antennas are involved at closer spacing the technical challenges are more pronounced compared to a SISO (Single Input Single Output) system.

Hence, the basic aim of MIMO antenna design is to minimize the correlation between the multiple signals [2]. The parameter that describes the correlation between the received signals in highly diversified environments is mutual coupling, which deteriorates the performance of the communication system. By calculating the mutual coupling, one can analyze the electromagnetic field interactions that exist between the elements of a MIMO system. Higher mutual coupling reduces the antenna efficiency and thus minimizes the system channel capacity. The impact of mutual coupling on the capacity of MIMO systems is studied in [3].

The mutual coupling mainly depends on the distance between the elements of an antenna array. By increasing the distance between the elements of the antennas, the mutual coupling can be reduced. However, the distance between the antennas cannot be maintained too large, since MIMO systems have their major applications in Mobile terminals, laptops, and WLAN Access Points Wireless communications [4]. Patch antennas are very much compatible with MIMO systems because they are easier to fabricate and inexpensive, low in weight, planar or conformal layout. Patch antennas can be designed in any desired shape and this flexibility in patch antenna design makes it preferable for modern wireless communications. However, the patch antennas suffer from narrow bandwidth, which limits their application in modern communication systems like MIMO systems.

In the present work, a modified back to back E shaped patch antenna MIMO system is proposed with improved bandwidth and reduced mutual coupling compared to the antenna discussed in [5].The designed system resonates at 14.16 GHz and 15.47 GHz frequencies for VSWR≤1.34.The measured mutual coupling between the antenna elements is small and is less than -37dB. In section 2, the proposed antenna geometry is presented and in Section 3 the two element MIMO array system is presented with simulation results.

2. ANTENNA DESIGN

The primary objective of the antennas used in MIMO systems is to support the large data rates without increase in transmitter power and it can be achieved only when the antennas are having more impedance bandwidth. The bandwidth of microstrip antennas is however, narrow and it can be improved by using various methods like using air substrate, reducing the ground plane, introducing parasitic element either in coplanar or stack configuration, changing the shape of the patch etc. In the present paper the last method is adopted for improving the bandwidth of the antenna.

The back to back E-shaped patch antenna shown in Fig.1 has been designed using EM simulator based on Finite Element Methods (FEM). The proposed antenna is designed by incorporating additional slots to a normal E shaped patch discussed in [6] and by connecting them back to back for achieving higher bandwidths. The Modified back to back E-shaped antenna was designed with the following dimensions on a ground plane of area 27.2x30 mm^2.

L=17.2, W=20, Ls=5, W1=5.9, Wt= 1, Ws=6.2
(all dimensions are in mm)

The dimensions d_1 and d_2 of the patch in the proposed Back to Back E-shape patch antenna are taken as 2mm and 6mm respectively. A 50Ω co-axial probe of outer and inner radii as 2.2 mm and 0.65 mm respectively is used as the feed for the proposed antenna. For the design of this antenna, the substrate RT/duroid®5880 of thickness 3.2mm and with low permittivity (εr=2.2) value is chosen.

The proposed patch antenna gives an improved bandwidth of 20% compared to the antenna discussed in [6], which is only 7%. The improvement in bandwidth is achieved without changing the dimension of the above mentioned normal E shaped antenna. The reason for the improvement in the bandwidth is due to the additional slots incorporated at the top and bottom of the patch. The proposed antenna resonates at a dual band of 14.16GHz and 15.47 GHz as shown in Fig.2 and can be operated at both the frequencies with good return loss.

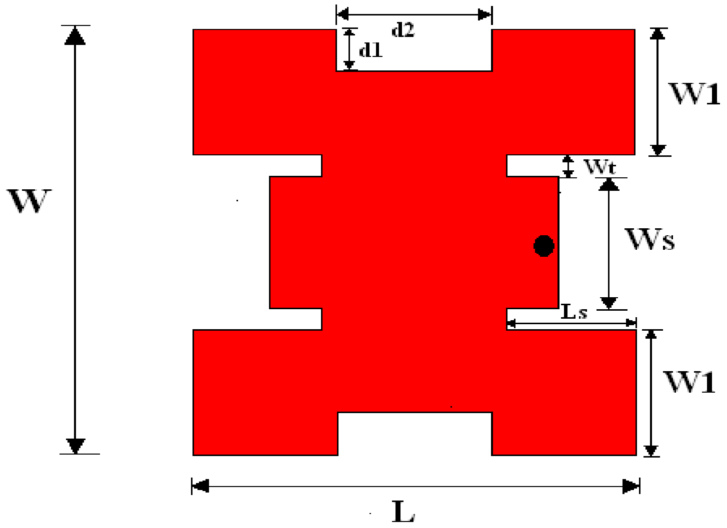


Fig.1 Modified Back to Back E shape patch antenna

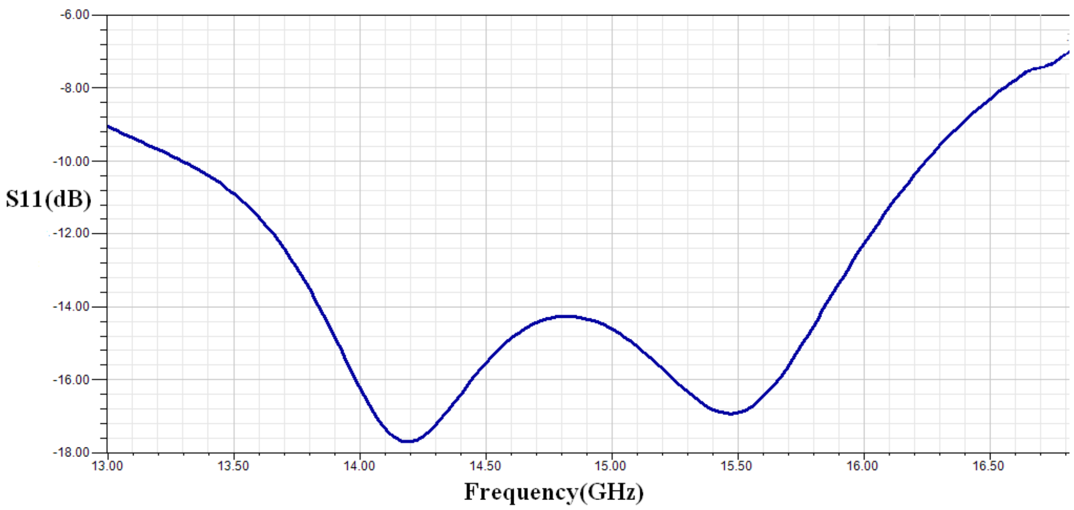


Fig 2. Return loss of the proposed antenna

3. TWO ELEMENT MIMO ARRAY

The main design criteria for MIMO system engineers in developing small electronic modules is reducing mutual coupling, which mainly arises due to the smaller spacing between the elements. However, when multiple antennas are involved at closer spacing, the design issues are more complicated compared to a SISO (Single Input Single Output) system. The reduction in mutual coupling can be achieved by properly choosing the shape of the antenna and without increasing the distance between the elements.

In the present paper, a 2×2 MIMO system is developed by using the proposed back to back E shaped patch antenna as shown in Fig.3. For the proposed MIMO system, the separation between the elements is taken as 10 mm. For the proposed MIMO array, the dimensions are taken same as that of the single modified Back to Back E-shape patch antenna mentioned in Section 2.The antennas are mounted on a substrate symmetrically with ε_r = 2.2, which in turn is mounted on a ground plane.

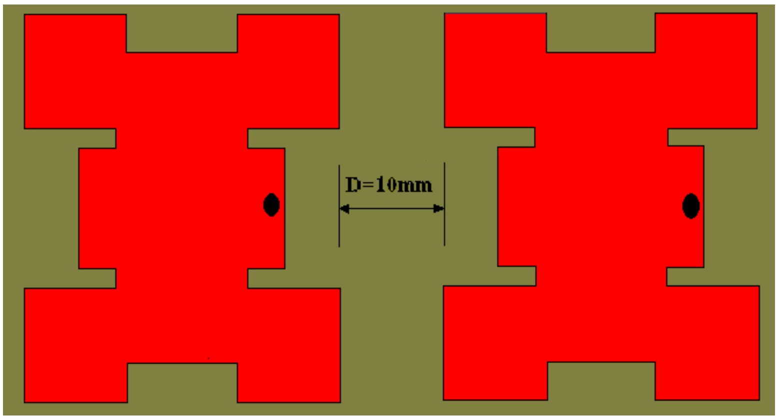


Fig 3. A 2x 2 MIMO systems using the proposed antenna

The return loss (S_{11}) and mutual coupling (S_{21}) of the developed 2×2 MIMO system are presented in the Fig 4. From the results, the proposed MIMO array exhibits a good return loss (S_{11}) and excellent isolation properties (S_{21}) at the resonant frequencies 14.1 GHz and 15.79GHz. The antenna gives the -10dB bandwidth of 3.1 GHz. At the resonant frequencies, the values of S_{11} are -15.5dB and -17.3dB respectively, which gives good impedance matching for the antenna.

The important parameter to be considered in the MIMO systems is mutual coupling S_{21} which is -37.8 dB and -23.3dB at 14.1GHz, 15.79 GHz respectively as shown in Fig 5. This mutual coupling is very low compared to the mutual coupling developed between two normal E shaped antennas discussed in [7], which are also separated by same 10 mm distance. This low value of mutual coupling suggests the proposed array system to be an efficient system in terms of isolation. The VSWR plot of the proposed MIMO array is presented in the Fig.5. The VSWR value is observed as 1.4 and 1.31 at the resonant frequencies 14.16GHz and 15.71GHz respectively, indicating improved matching condition. The radiation patterns of the proposed antenna at the two resonant frequencies are shown in Fig 6. The gain plot of proposed MIMO system is shown in the Fig. 7, which gives the peak gain of 7.73 dBi at resonant frequency 14.1GHz and 6.2dBi at 15.79GHz. The obtained gain is suitable for many of the mobile applications operating at UWB (Ultra Wide Band) frequency range.

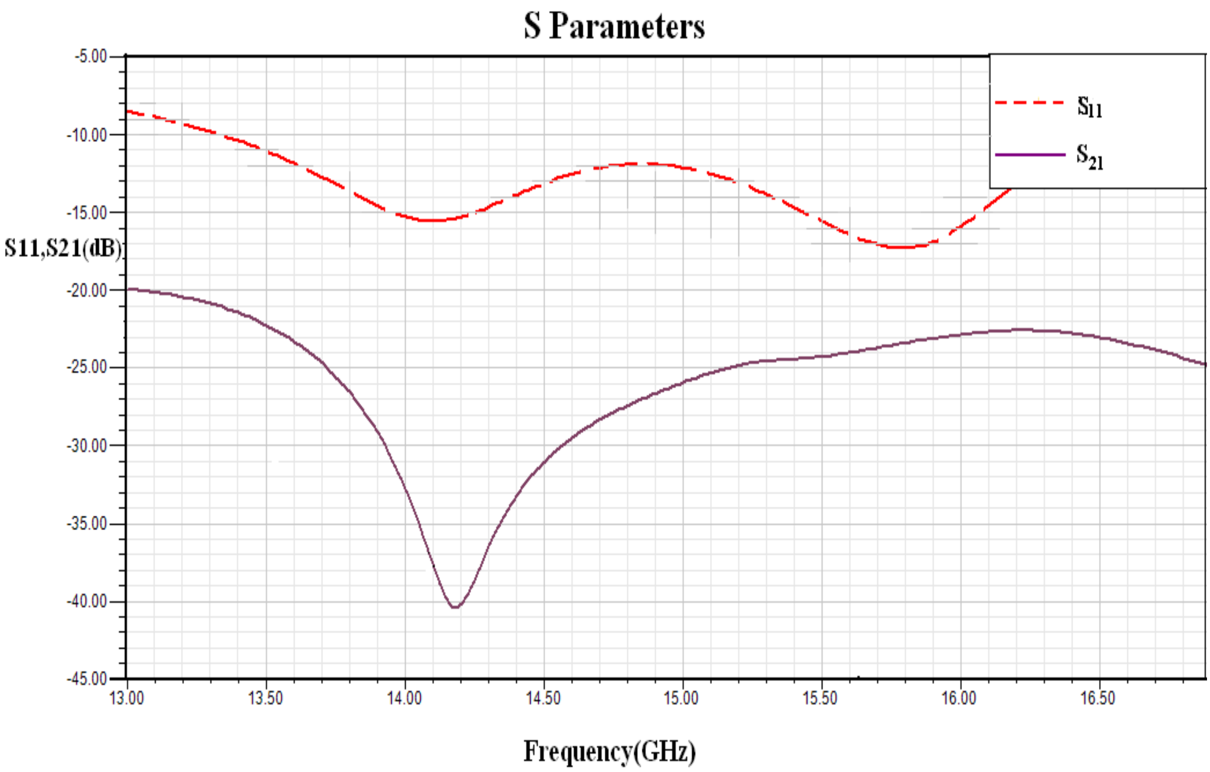


Fig 4. S Parameters for proposed MIMO system

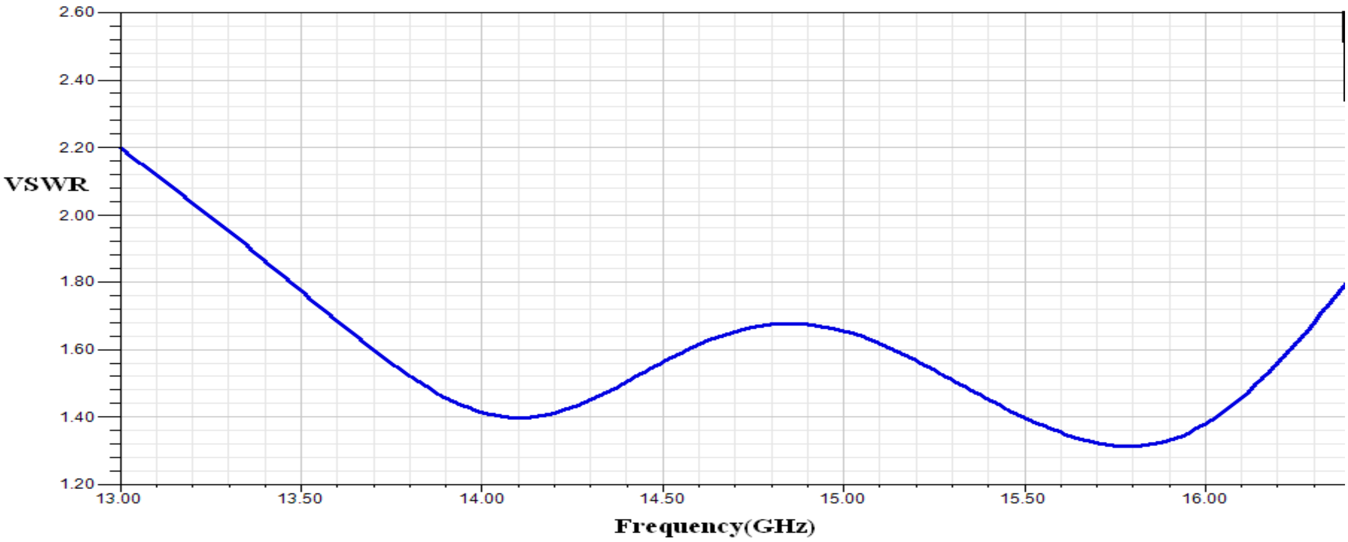
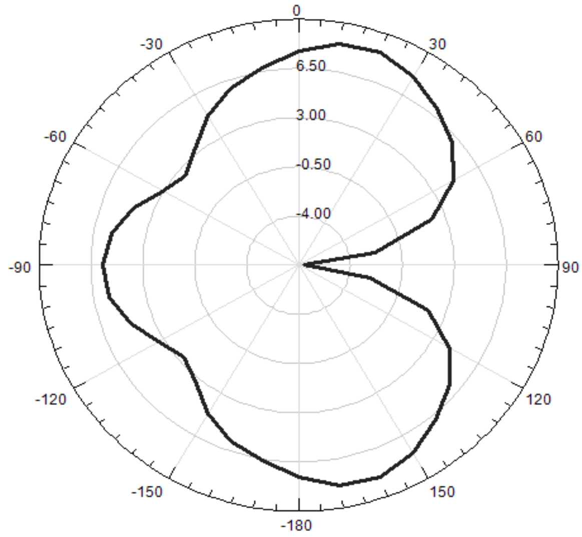
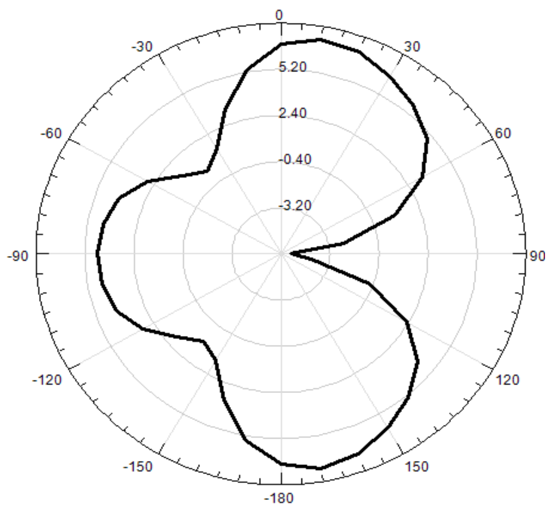


Fig 5. VSWR Plot



(a)



(b)

Fig.6 Radiation patterns for proposed MIMO Array at (a) 14.1GHz (b) 15.79GHz

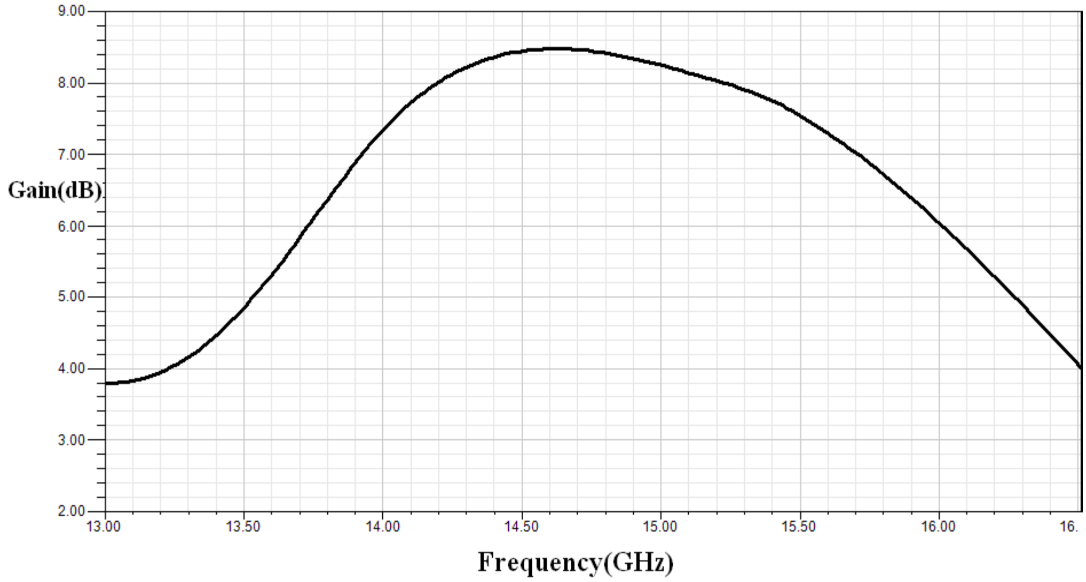


Fig.7 Gain plot of the 2×2 MIMO System

4. CONCLUSION

In this paper, 1x1 and 2x2 MIMO systems are developed using a Modified Back to Back E-shape patch antenna and S-parameters are analyzed. The proposed antenna array resonates at dual band, offering an improved impedance bandwidth of 20% with mutual coupling < -37dB. These characteristics are well suited for all 4G MIMO applications. The proposed study can be extended by employing more no. of antennas in MIMO system for improving the channel capacity of the MIMO systems.

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