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Metamaterial Inspired Patch Antenna for MIMO Application

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Abstract—*A step shape structure based on complementary split ring resonator (CSRR) patch antenna designed for MIMO (multiple input multiple output) application is presented. The proposed microstrip line fed MIMO antenna system provides WIMAX, Satellite and C-band applications covering 2.7, 4.09, 6.1 and 7 GHz. The metamaterial based MIMO array antenna is studied with various configurations of array and good performance is achieved with small element spacing. The dimension of the single element patch antenna is (25×38×1.6) mm^3 and simulated in Ansoft HFSS with FR4 substrate of $\mathcal{E}_r$=4.4.*

Keywords: *Multiple-input-multiple-output (MIMO), CSRR, envelope correlation coefficient, HFSS*

1. INTRODUCTION

The development of next generation wireless communication systems requires broadband and multiband devices for faster data transfers with miniaturization of handheld devices. Modern communication system attracted in wireless world because of their advantages, including high speed data rate, extremely low spectral power density, high precision, low cost and low complexity. These antenna modules are expected to provide good impedance matching, an enhanced gain and radiation pattern throughout the operating frequency bands. In order to achieve the performance indices, techniques such as loading of high permittivity dielectric substrate, slotting the patch, defected ground structure, shorting pin, inclusion of an amplifier type active circuitry, stacked configuration etc. have been used [1-2]. MTM is an innovative approach which achieves the demand and improves the performance of the antenna with exquisite material characteristics and ability to control and guide the electromagnetic wave propagation, naturally stemming from the respective controllability of their electric and magnetic properties. The SRR structure is of two concentric metallic rings with a split on opposite sides and CSRR is the negative image of SRR. These are electrically small LC resonant elements with high quality factor used as periodic structure of metamaterial and due to the resonance characteristics of the CSRR it attracted the attention of the frequency-selective structure designer [3-5]. Nowadays multiple-input-multiple-output (MIMO) technology has become an integral part of wireless systems and regarded as the next generation wireless service. This technology depends on the use of multiple antenna elements at the mobile terminal as well as the base station. To enhance channel capacity in multipath environments the MIMO system attracted much attention and which uses a plurality of antenna elements where each multipath rout can be treated as a separate channel occupying the same frequency band. In MIMO configuration antenna elements must be spatially separated in order to achieve the predicted high signal capacity. The mutual coupling between the antenna elements should be low enough or at distance of half a wavelength or more and high isolation makes uncorrelated signals among the antennas [6-8].

In this letter a compact quad band step shape patch antenna with CSRR loading for wireless application operating at 2.7, 4.1, 6.1 and 7 GHz is reported. Two element arrays of the proposed antenna with three different configurations for MIMO application operating at all four resonant frequencies are also analysed and provides good mutual coupling, envelop correlation and radiation pattern.

2. ANTENNA DESIGN AND SIMULATION RESULTS

The geometry of the proposed step shape patch antenna with defected ground plane is shown in fig. 1. FR4 substrate with thickness 1.6mm and $\mathcal{E}_r$= 4.4 is used to design the patch antenna. The area of the antenna is 25×38 mm^2 and fed with microstrip line fed. The parameters of the proposed antenna are L=38mm, w=25mm, L_g= 15mm, a= b= d =5mm. The configuration of the ground plane affects the characteristics of the antenna. We earlier mention that CSRR's are LC resonant elements at microwave range and used as periodic structure of metamaterial. Therefore we load CSRR at the ground plane to achieve the required goal.

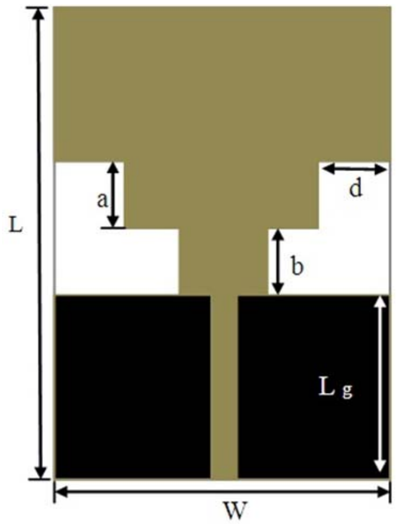


Fig. 1: Geometry of the proposed antenna

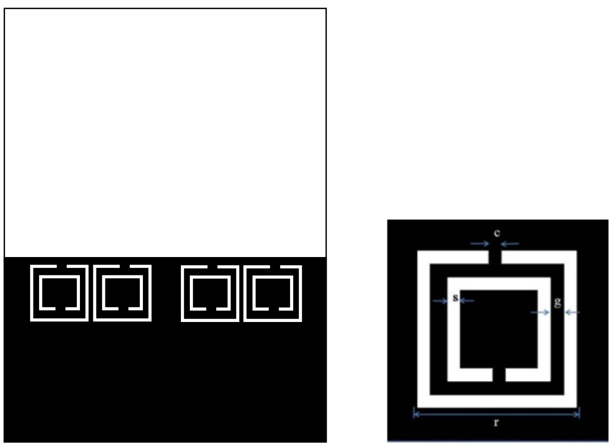


Fig. 2: Back view of the proposed antenna with CSRR and Zoomed view of CSRR

This is an optimal method to obtain a multiband with improved gain through the parameters with loading CSRR in the ground plane. Fig. 2 shows the prototype back view of the proposed metamaterial based proposed antenna. The dimension of the CSRR (fig.2) is r=5mm, c=s=g=0.2mm. Fig.3 shows the simulated reflection coefficient of the proposed antenna with metamaterial loading. Various parameters of the antenna can be adjusted in order to achieve all of this four frequency bands.

The simulated radiation patterns of the proposed patch antenna at all four operating frequencies in the E-plane and H-plane are shown in fig. 4. It has been seen that the radiation patterns of the metamaterial inspired patch antenna structure are stable at all operating frequencies and has a good omnidirectional pattern.

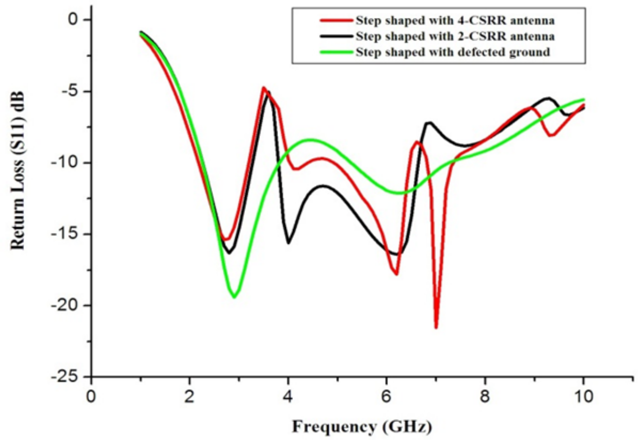


Fig. 3: Reflection coefficient of the proposed antenna

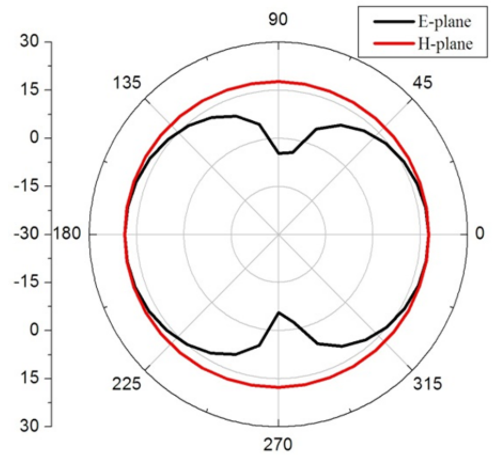


Fig. 4(a): E and H plane radiation pattern at 2.7GHz

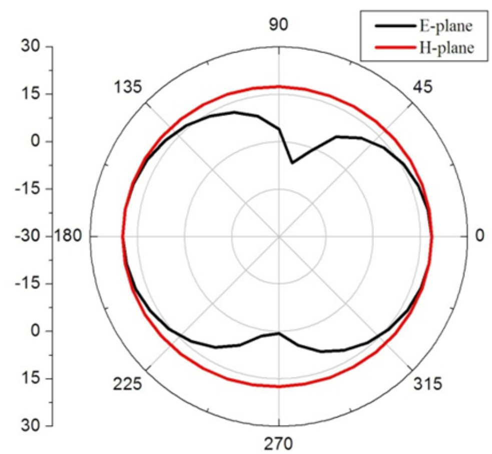


Fig. 4(b): E and H plane radiation pattern at 4.09GHz

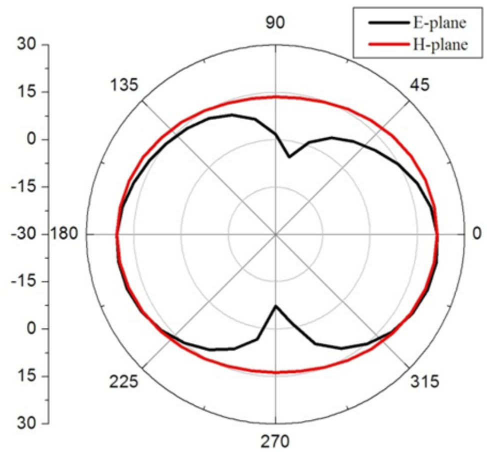


Figure 4(c) E and H plane radiation pattern at 6.1GHz

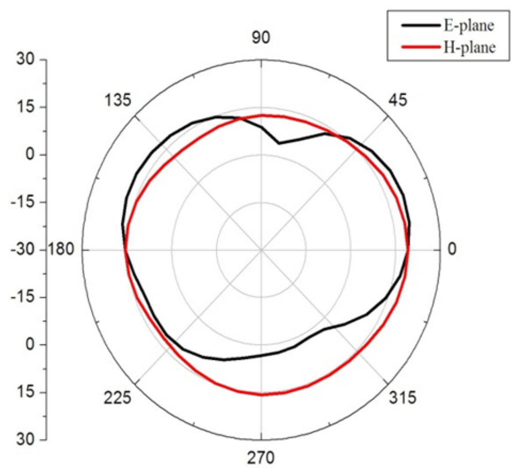


Fig. 4(d): E and H plane radiation pattern at 7GHz

3. ANTENNA ARRAY CONFIGURATION FOR MIMO APPLICATION

This proposed antenna element is now arrayed for MIMO application. The performance of an antenna array is based on mutual coupling, envelop correlation and radiation pattern. Fig. 5 represents the relevant simulated S-parameters of three possible configurations.

In each case the spacing between the array elements is set at 10mm. Due to change in position and polarization of the elements different mutual coupling is occurred. Lower mutual coupling is occurred when the antenna elements are orthogonal and parallel.

In order to study the system performance of the proposed antenna structures as MIMO application, the envelope correlation coefficient has been calculated. Under the assumption of uniform multipath environment, the coefficient of a two antenna system can be computed from the S-parameters is given by-

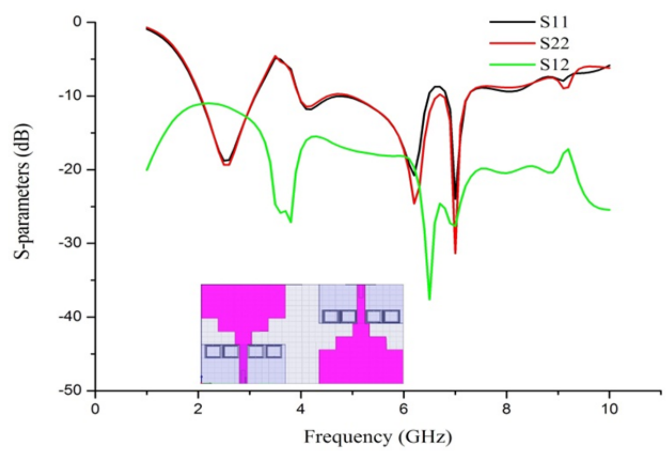
$$\boldsymbol{\rho_e} = \frac{|S_{11}^{*}S_{21} + S_{12}^{*}S_{22}|^2}{|(1 - |S_{11}|^2 - |S_{21}|^2)(1 - |S_{22}|^2 - |S_{12}|^2}$$

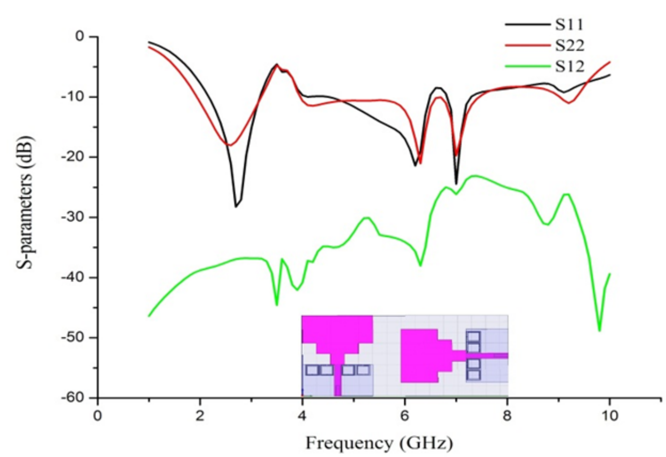
The practically acceptable envelop correlation coefficient for the antenna diversity is less than 0.5. The calculated envelop correlation from the proposed metamaterial inspired antenna array is less than 0.0027. Fig. 6 shows the Envelop correlation for the proposed two element antenna array. Although the array structure shown a good omnidirectional pattern similar to the single element which is not shown here. Table I shows the simulated peak gain of the antenna array structure.

Table 1: Peak gain of the array antenna

Frequency (GHz)	2.7	4.09	6.1	7
Peak gain (dBi)	1.57	2.75	4.6	3.1

The low envelope correlation, low mutual coupling with the omnidirectional radiation patterns confirm that the proposed metamaterial inspired patch antenna array is suitable for use in MIMO application.





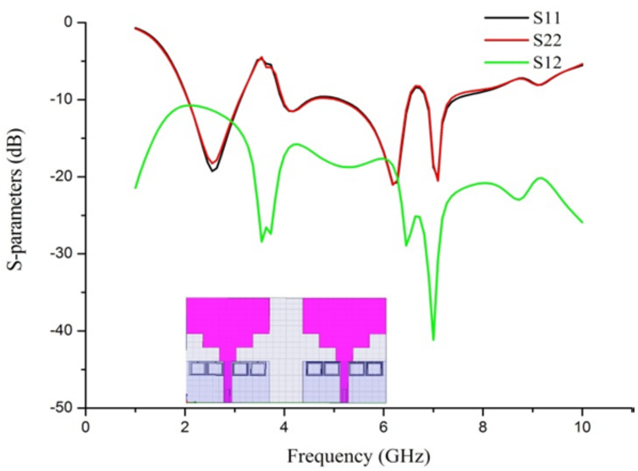


Fig. 5: Simulated S-parameters of the MIMO configured antenna

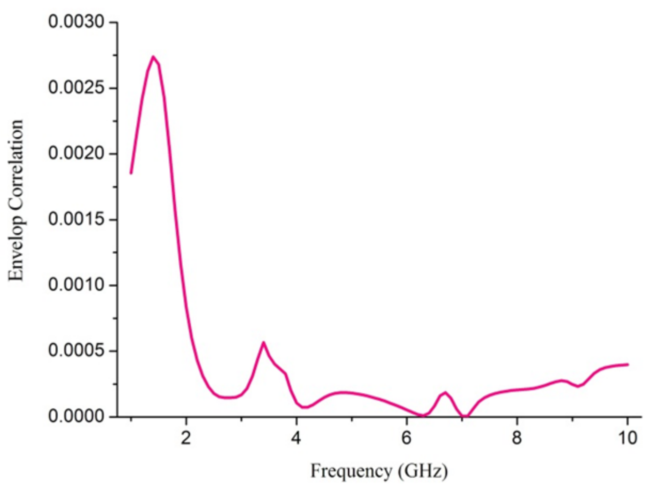


Fig. 6: Envelop correlation for the proposed two element antenna array

4. CONCLUSION

The characteristic of this proposed antenna are useful for WIMAX, Satellite and C-band applications in wireless communication systems. The combinations of metamaterial inspired patch antenna elements are suitable for MIMO application. The proposed MIMO antenna array gives envelop correlation lower than 0.0027, -12dB mutual coupling and good omnidirectional radiation pattern at all four operating frequencies.

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