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A 2x1 Dual-Band MIMO Antenna using Complementary Split Ring Resonator for Wireless Applications

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Abstract

This paper presents a compact 2x1 dual-band MIMO antenna with complementary split ring resonator proposed for wireless applications resonate at two different frequencies 2.58GHz and 5.71GHz. Radiating elements are linearly polarized. The proposed MIMO covers 2.30-2.84GHz and 5.54-5.82GHz frequency bands with low return loss especially at lower band 40.20dBi. The antenna is designed by introducing Complementary Split Ring Resonator (CSRR) between radiating elements and inverted L-slot on partial ground. The whole layout is designed over alow cost FR4 substratehaving dielectric constant εr = 4.3 with loss tangent 0.02. The size of proposed design is reduced to 29.16x34.39mm2.The gain at the 2.58 GHz resonant frequency is 1.16dBi and at 5.71GHz resonant frequency gain is 1.01dBi. The simulated result shows the Envelope Correlation Coefficient (ECC) of 0.01 and more than 10 dB of in –band isolation.Theproposed designed MIMO include the LTE and WLAN Band.

Keywords: *MIMO, CSRR, ECC, Partial Ground*

I. INTRODUCTION

For indoor and outdoor applications wireless communication is the fastest growing technology because of its large bandwidth, high data rate and reliability. The demand for MIMO comes into the picture because of the disadvantage of single- input, single-output (SISO) system occurs at the transmitter and receiver. The SISO over burdens demands of bandwidth for a communication system. Fourth and fifth generation of wireless application with MIMO makes the communication system reliable. MIMO systems have a specialty of increase in maximum rate, reliability and coverage of current wireless communications, link improvement, without additional bandwidth (frequency spectrum saving) or transmit power. To provide a good quality of services, MIMO technology is the best candidate or channel solution for non-line of sight (NLOS) communication [1]. In the case of MIMO, an array of the antenna is used. This array helps to improve channel characteristics for transmission. MIMO technology leads to enhancing the performance of wireless communication systems with an increase in the channel capacity at the same time reducing the adverse effect due to of multipath fading. MIMO technology utilizes multipath to increase the throughput of the channel with each pair of antennas that is introduced into the system.

The antenna using split-ring resonator (SRR)gives negative dielectric constant. CSRR is the complementary structure of the SRR. Different shapes are available in form of SRR and CSRR. The field analysis of SRR and CSRR finds out by applying Babinet'sPrinciple [1]. CSRR and SRR is the Meta-material inspired structure. CSRR is used to provide small size in the overall system. CSRR helps in preventing the current between each port so the isolation automatically improves. SRR and CSRR provide better isolation but results in narrowband operation. CSRR reduces the SAR (specific absorption rate) making it suitable for human interaction [1].

To overcome the disadvantage of narrowband

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operation partial ground technique back radiation of the antenna due to the suppression of surface wave diffraction from the edges of the full micro-strip antenna ground plane.

In this paper, we propose 2x1dual band MIMO antenna design using partial ground with L-slot and CSRR that is used to improve the whole system performance. The partial ground is used to enhance the bandwidth of the antenna. To overcome the disadvantage of large size here complementary split ring resonator (CSRR) in the proposed MIMO antenna. Antenna feed line consists of 50 Ω, micro-strip transmission lines. In our design, a 1x1 MIMO antenna is proposed with more than 23 dB of isolation between radiating elements. The designed MIMO covers 2.58 GHz and 5.71GHz, the S and C band giving very low return loss.

Here the proposed 2x1 dual band MIMO antenna is optimized using particle swarm organization for wireless applications. The particle swarm optimization (PSO) used with min-max algorithm was set to achieve the best design goals for required frequency operating band, compactness and for desired antenna parameters. The proposed 2-port antenna system with 50 Ω ports is designed using computer simulation tool (CST Microwave Studio 2015) version 12.0 and fabricated on a lower costFR4 dielectric substrate (thickness of 1.524 mm, the permittivity of 4.3, and loss tangent of 0.025) of dimension 29.16×34.39 mm2. The recommended design behind the selection of the propound radiator element is the minimum return loss, low mutual coupling (high port to port isolation), compact size, higher gain and required bandwidth for wireless applications.

Table 1. Optimizedvaluesof considered parameters (mm).

Parameter	*wg*	*lg*	*Sw*	*sl*	*fw*
Value	29.16	19.96	29.15	34.39	3.57
Parameter	*f l*	*pl*	*r1*	*m*	*x*
Value	23.54	11.71	5.48	.41	5.11
Parameter	*Y*	*Z*	*A*	*b*	*c*
Value	2.70	.33	12.94	18.63	18.31

A linearly polarized dual-band MIMO antenna resonate at 2.58GHz and 5.71GHz frequencies are connected to both ends of the partial ground to reduce mutual coupling between radiators. By introducing the CSRR in the middle of the radiator patch, it increases in isolation and gain. The perfect dimensions are accomplished here while setting the min-max algorithm with a ±10% variation in set values. The suitable parameters for best result were obtained after 1553 iterations and are shown in Table 1. The schematic view of the simulated MIMO antenna is shown in Fig. 1.

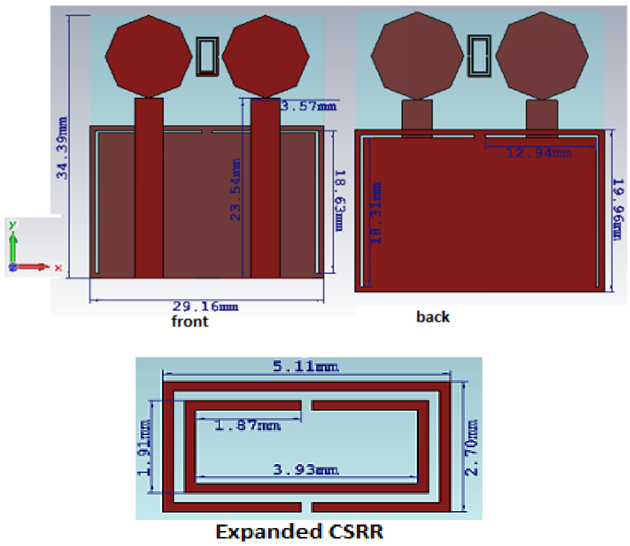

Figure 1. Schematic view of the proposed 2X1MIMO antenna

II. Simulation Results

To get minimum return loss and low mutual coupling between the radiators, the antenna parameters are optimized. The resultant simulated S parameters for return loss and isolation are shown in fig. 2. The dual-band proposed antenna covers bandwidth from 2.30-2.84GHz and 5.54-5.82GHz frequency bands with VSWR<2. The simulated

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isolation between the ports is 20dB in first band and 14dB in second band.

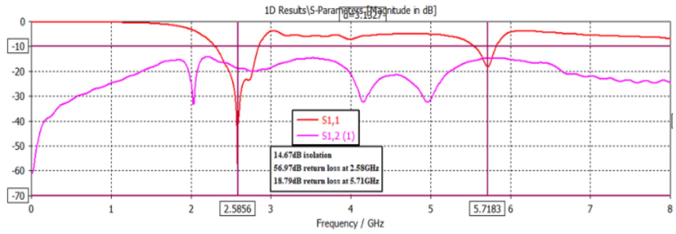


Figure 2. S parameter of the proposed 2X1 MIMO antenna

A comparison between the proposed ground and partial ground is shown in fig.3, which confine the effectiveness of partial ground. With full ground, the proposed MIMO does not give any desired band but shows high isolation for required bands. It does not show any application in WLAN/Wi-MAX/LTE bands. On the other hand, the proposed partial ground with inverted L-slot shows the desired frequency bands and shows more than 10dB isolation between the port1 and port2. The proposed ground helps in size reduction, less return loss and low mutual coupling in comparison with the conventional ground. CSRR also helps in reduce mutual coupling and improve the degrading factors of antenna performance. Inverted L-slot is responsible for the 5.71GHz peak resonant frequency.

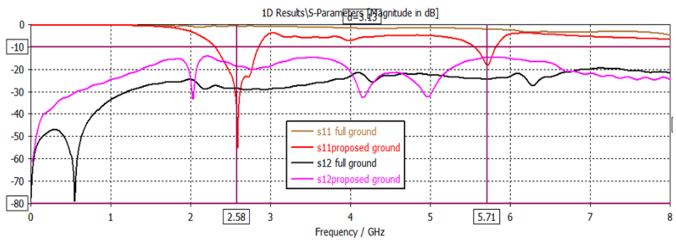
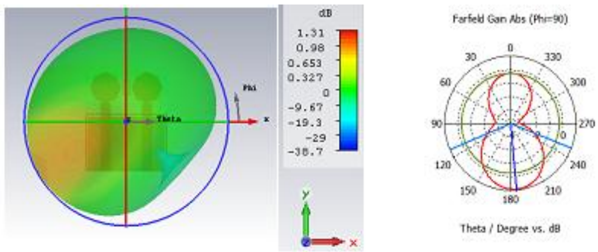


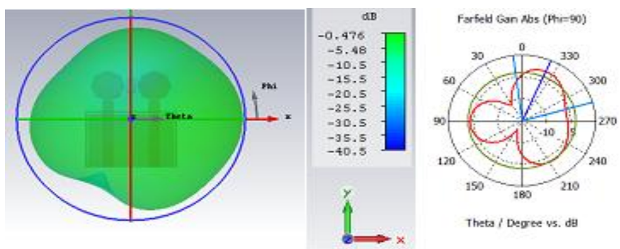
Figure 3. Comparison of S parameters with full and proposed ground

The diversity behaviour and radiation pattern of the proposed 1x1 MIMO antenna are reported here in terms of gain, 2D-3D radiation patterns, and ECC. The simulated 2D and 3D radiation patterns of the proposed MIMO antenna are shown in fig.4 at 2.58GHz frequency and fig.5 at the 5.71GHz frequency. At resonant frequencies, it gives overall 1.31dB gain and good radiation efficiency at the overall system is 54%. Radiation patterns are used to confine the overall diversity performance of the designed structure. ECC is also used as an addressing factor of the diversity performance instead of individual S parameters. S12 is insufficient to disclose all the information about mutual coupling. The simulated value of ECC in the -10 dB impedance band is less than 0. 01 and is shown in fig.6 at both the resonant frequencies. The ECC is very valuable because it involves all the S parameters of the designed MIMO antenna. The lower value of ECC justified the meaning of lower correlation between antenna elements and vice versa. In both the frequency bands the value of ECC is lower than 0.5, which is also the faithful requirement for 4G applications. By the ECC the decorrelation property of antenna has been exhibited and has very less value than the limit set by international telecommunication union (ITU) [5].



(a) 3D radiation pattern (b) 2D radiation pattern

Figure 4. Radiation pattern at 2.58GHz resonant frequency



(a) 3D radiation pattern (b) 2Dradiation pattern

Figure 5. Radiation pattern at 5.71GHz resonant frequency

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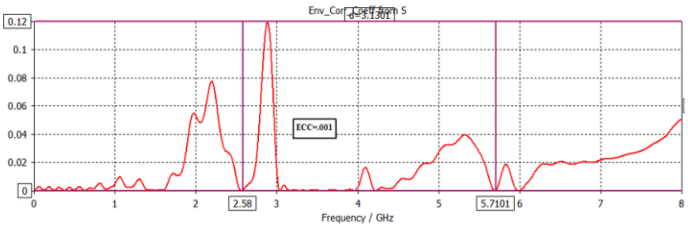

Figure 6. Simulated ECC of proposed MIMO antenna

The surface current distribution of the proposed antenna is shown in fig.7 and fig.8. When current is drawn, there are voltage losses; equally, the current density may not be uniformly distributed on the electrode surfaces. As per observation the high amount of surface current is shown at the middle part of both the antenna, where the partial ground ends. At the lower frequency bands of the S parameters S12 and S14, its effect can be observed. Fig.9 shows the VSWR of the proposed MIMO antenna, and the simulated VSWR is less than 2 at the existing frequency bands.

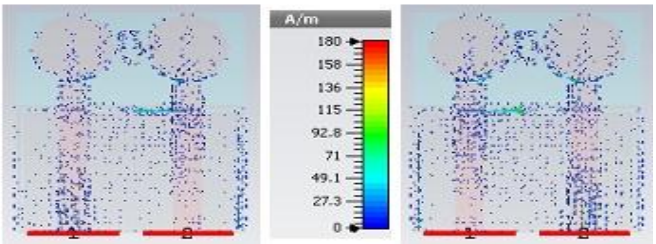

Figure 7. Surface current distribution at 2.58GHz resonant frequency

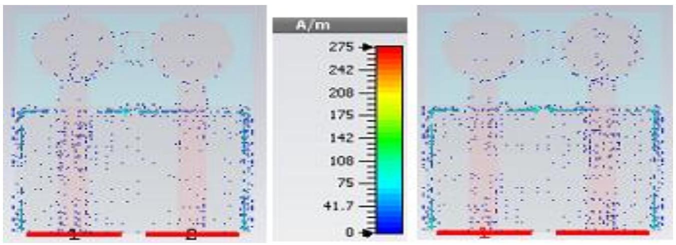

Figure 8. Surface current distribution at 5.71GHz resonant frequency

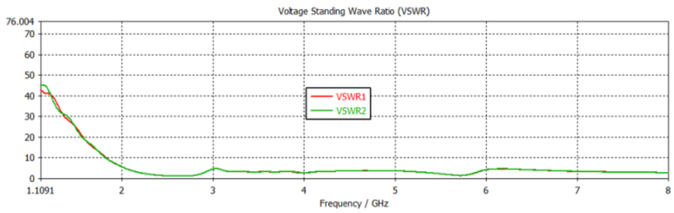

Figure 9. VSWR of the proposed 2X1 MIMO antenna

III. Conclusion

A very compact dual-band MIMO antenna is designed with CSRR, a partial ground technique with perfect boundary conditions is presented in this letter. This letter shows high isolation, compactness, and good radiation efficiency. Using S parameters and far-field patterns the result are verified. The ECC of the antenna is within the acceptable threshold limits, which is demanded to upgrade the data rate through spatial multiplexing in wireless communication channels. ON the basis of simulated results the proposed antenna can be a potential candidate for desired applications in the practical handheld device.

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