Design and Analysis of Four-Port MIMO Antenna with Dual-Band Rejection Characteristics

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Abstract— The combination of (ultra-wideband) UWB and multi input-multi-output (MIMO) significantly improves the date rate transmission capacity, spectrum efficiency and overall quality of the communication link in comparison to single antenna systems. The proposed MIMO antenna is comprised of four identical elliptical shaped monopole radiators that are placed orthogonal to each other. A second order Koch fractal geometry is applied at the edges of the ground patch to minimize the overall ize of the ground plane without changing its peripheral dimension and without compromising the lower frequency response. Further, in order to eliminate the undesired resonant bands (3.5 and 5.5 GHz) from UWB, an elliptical complementary split ring resonator (CSRR) is introduced in the monopole radiator. In order to reduce the inert-element coupling in the proposed MIMO antenna, a different approach (of slotted edge substrate) is used as a substitute of traditional decoupling stub/elements. In the entire operating band of 3 to 13.5 GHz, inter-element isolation more than 22 dB and envelope correlation coefficient (ECC) less than 0.008 are obtained. The measured parameters of the fabricated prototype antenna are found to be satisfied with the simulated results.

Keywords: Envelop correlation coefficient (ECC); Complementary split ring resonator (CSRR); Multiple Input Multiple Output (MIMO); Koch fractal

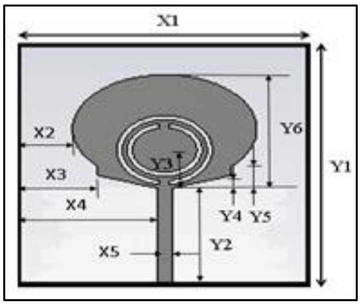
I. INTRODUCTION

In the present world, due to rapid growth in communication there is need to improve the transmission of data over wireless media so as to achieve the demand of fast and feasible communication. To meet the above, it is required to have better and input throughput, date rates, BER and quality of signals received at the receiving end of the systems. The antenna that can attain all the parameter values at optimum level is MIMO antenna. MIMO stands for multiple- input multiple- output, where multiple refers to multiple antennas used simultaneously for transmission and reception. One primary reason to use multiple antennas is to improve link quality and reliability, diversity, throughput between the transmitter and receiver, or both. MIMO gives the best diversity gain of the signals. MIMO technique can increase the capability and reliability without additional power or spectrum. To achieve good performance and compact structure, good isolation between closely spaced antennas is required for MIMO communication systems. Ultra Wide Band(UWB) technology has drawn considerable attention due to its merits of low complexity, low power consumption, capability of high data rate, low interference, good time domain resolution and reduction of severe multipath fading effects. UWB communication system makes use of huge frequency bands and various commercial gadgets share band within the UWB spectrum which affects the performance of portable UWB terminals. It becomes essential to eliminate the interfering bands. UWB MIMO antenna exhibiting single/multiple band rejection characteristics have been seen in the last few years. The permitted power spectral density of UWB signal is rather limited to avoid interference with other systems.

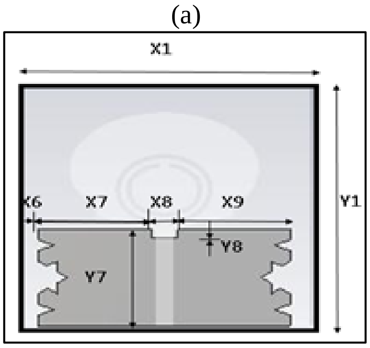
The most challenging task while designing MIMO antenna is to overcome the limitations of space. It is difficult to place the large number of radiating elements within limited space. Designing an antenna for quad port MIMO system is more complex, because it has to deal with higher value of ECC and mutual coupling. So, we must make sure that the isolation between the radiating elements is increased. In this design, each element is configured around a highly eccentric electrical patch loaded with Complementary Split Ring Resonator (CSRR) and a defected ground structure is added. The rigorous simulation related to the antenna designing and optimizations are performed on CST Studio Suite software platform.

II. ANTENNA DESIGN

The proposed MIMO antenna is comprised of four identical elliptical shaped monopole radiators placed orthogonally to each other. Also aa second order Koch fractal geometry is applied on the edges of the ground planes of the radiating elements which is an added feature in this design. An elliptical Complementary Split Ring Resonator (CSRR) is introduced on the monopole radiator which helps in eliminating the undesired bands from UWB. In order to reduce the inter-element coupling, a different approach of slotted edge substrate is used as a substitute of traditional decoupling elements. A perpendicular slot of dimensions X11 x Y9 is cut from the lower edge of the dielectric substrate in order to obtain very good inter-element isolation and ECC.



(a)



(b)

Fig. 1: Single antenna a) Front view b) Back View

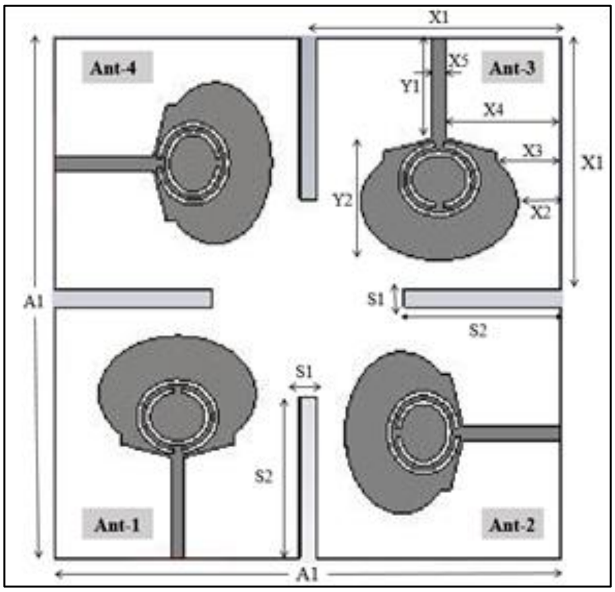


Fig. 2: Proposed design of Four port MIMO antenna

Dimension	Value (mm)	Dimension	Value (mm)
A1	58	X8	2.5
S1	2	X9	10.75
S2	18	Y1	28
X1	28	Y2	11.25
X2	5	Y3	4.25
X3	7.5	Y4	1.5
X4	13.25	Y5	2.65
X5	1.53	Y6	13.35
X6	2	Y7	11.25
X7	10.75	Y8	1

Table 1: Dimensions of the proposed antenna

III. RESULTS AND DISCUSSION

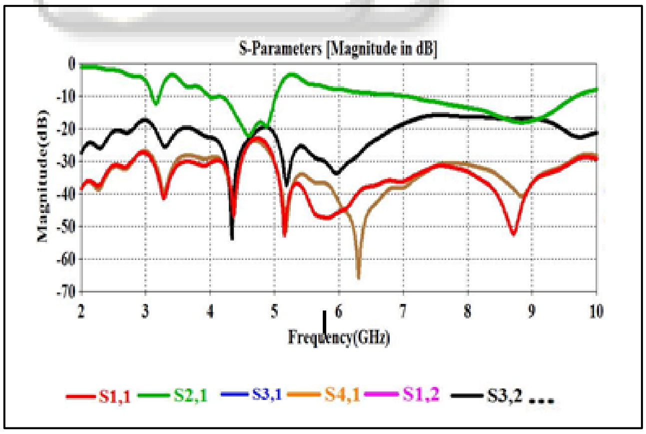


Fig. 3: S-Parameters of MIMO Antenna

S-Parameters gives the relation between input and output ports (or terminals). This figure shows the simulated and measured reflection coefficients at different antenna ports. Here S11 is measured at port1 by terminating the other ports in MIMO antenna. The same procedure is followed for the remaining ports (S22, S33, S44). The Centre frequencies of three notch bands are 3.15 GHz, 4.952 GHz and 8.8492 GHz.

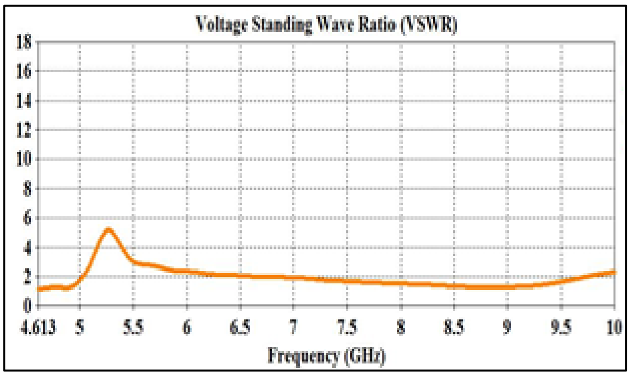


Fig. 4: VSWR of MIMO Antenna

VSWR stands for Voltage Standing Wave Ratio, also referred as Standing Wave Ratio (SWR) is the function of reflection coefficients, which describes the power reflected from the antenna. For better performance the VSWR should be 0-2.

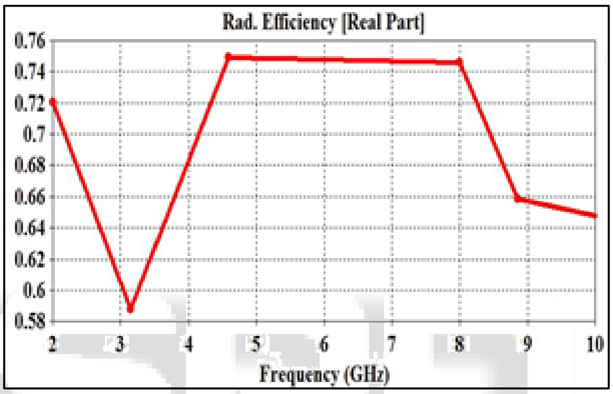


Fig. 5: Efficiency of MIMO Antenna

Antenna efficiency is most often used to mean Radiation Efficiency. It is the measure of the electrical efficiency with which a radio antenna converts the radio-frequency power accepted at its ports into radiated power. Here the desired radiation efficiency is 75% from 4.5 GHz to 8 GHz.

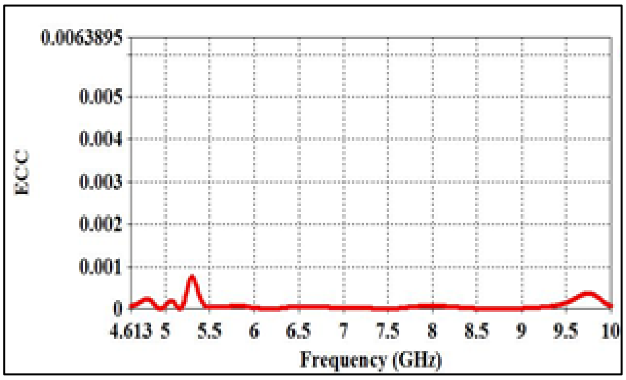


Fig. 6: ECC of MIMO antenna

The (Envelope Correlation Coefficient) ECC for a four-port MIMO system (N=4) between antenna elements is expressed as below

$$\rho_e = \frac{|S^*_{11} S_{12} + S^*_{21} S_{22} + S^*_{13} S_{32} + S^*_{14} S_{42}|^2}{(1 - |S_{11}|^2 - |S_{21}|^2 - |S_{31}|^2 - |S_{41}|^2)(1 - |S_{12}|^2 - |S_{22}|^2 - |S_{32}|^2 - |S_{42}|^2)}$$

The ECC is less than 0.002 within the resonating UWB which assures that the MIMO antenna has good diversity performance.

The Diversity Gain(DG) signifies the increment in the quality of signal due to the introduction of diversity scheme in MIMO systems and here it can be observed that apparent diversity gain is more than 9.99dB in the desired frequency range as shown in fig.7.

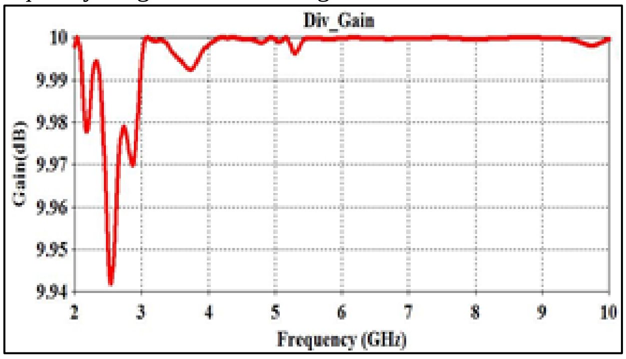
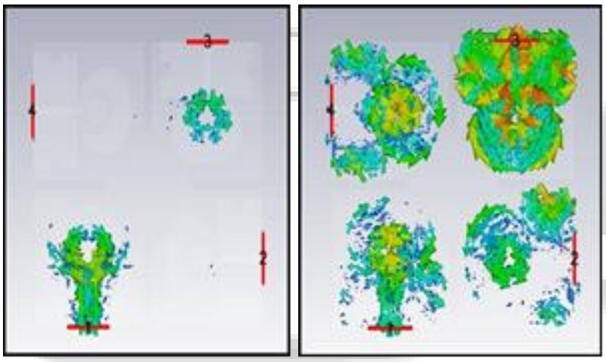


Fig. 7: Diversity Gain of MIMO antenna

Frequency(GHz)	ECC	ADG
3.15	<0.002	10
4.952	<0.002	10
8.8952	<0.002	10

Table 2: Performance parameters of the Design

A. Surface Currents:

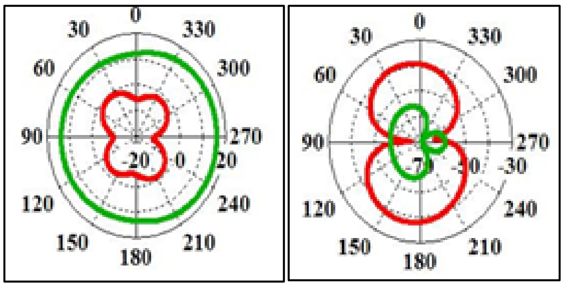


(a) (b)

Fig. 7: Surface current distribution in proposed MIMO antenna (a) Port 1 excitation at 3.15 GHz (b) Port 3 excitation at 8.8452 GHz

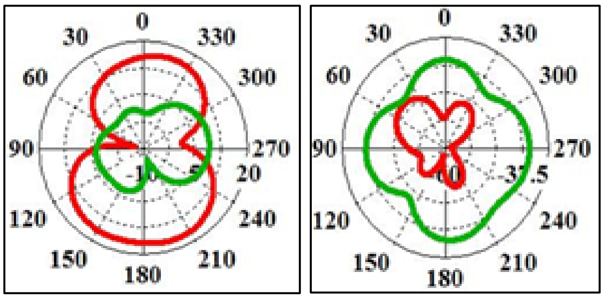
The above figures represent the current distribution in MIMO antenna at interfering bands 3.15 GHz and 8.8952 GHz. The maximum current is concentrated near the respective slot of CSRR at chosen frequency. The outer slot of CSRR eliminates the lower band, inner slot eliminates the upper band of unwanted frequencies.

B. Radiation Patterns:



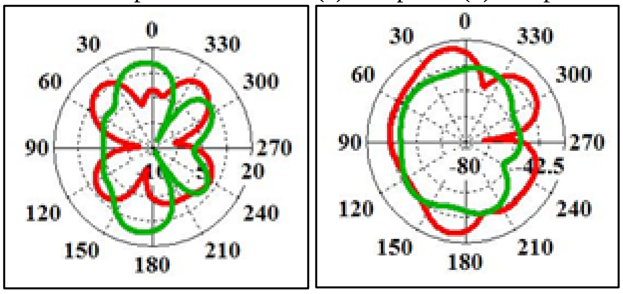
(a) (b)

Fig. 8: Radiation Patterns of the Proposed antenna at 3.15 GHz with port 1 excitation (a) XZ-plane (b) YZ-plane



(a) (b)

Fig. 9: Radiation Patterns of the Proposed antenna at 4.952 GHz with port 2 excitation (a) XZ-plane (b) YZ-plane



(a) (b)

Fig. 10: Radiation Patterns of the Proposed antenna at 8.8492 GHz with port 3 excitation (a) XZ-plane (b) YZ-plane

In this design the radiation pattern refers to the directional (angular) dependence of the strength of the radio waves from the antenna. The simulated radiation patterns of the proposed MIMO antenna in the XZ and YZ planes at 3.15 GHz, 4.952 GHz and 8.8952 GHz frequencies are shown in the figures.

IV. CONCLUSION

In this paper, a Four-port MIMO antenna is proposed with four elliptically shaped antenna elements placed orthogonal to each other where each element is fed by microstirp feedline mechanism. An elliptical CSRR is introduced in the radiating element for achieving dual-band rejection characteristics. In order to provide better isolation between the radiating elements a slotted edge substrate. The performance parameters such as ECC, Efficiency and DG for this MIMO design proved that this could be a suitable substitute for the modern UWB based MIMO applications.

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