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Research Paper

MIMO Antenna Design for ISM Band Applications.

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Abstract: This paper presents the design of a multiple input multiple output (MIMO) antenna for Industrial, Scientific and Medical (ISM) band applications at 2.4 GHz. Polarization diversity of the two antennas is used to design independent and uncorrelated signals on each antenna. The antennas are designed and simulated in CST microwave studio with a return loss < -10 dB and two antennas are combined as a single system forming a MIMO array of two antennas. The low mutual coupling and low envelop correlation coefficient made it a good choice for MIMO system and also provide an increased data rate.

Key Words: MIMO, ISM, mutual coupling, envelop correlation, CST, Flame retardant-4(FR-4)

1. Introduction

The significance of MIMO technology is increasing in wireless communications due to its high data rate **[1]** and link range without an extra band width or transmission power and spectrum **[2],[3].**Using MIMO an additional path can be used to increase the link capacity **[4].**MIMO technology can improve data rate and transmission quality. When more antenna elements are established in a small area which cause mutual coupling and thus degrade the diversity performance **[5].** Mutual coupling mainly depends on distance between the antenna array elements. But in real time the distance between antenna elements cannot be increased beyond a certain limit, which obstructs the spatial diversity to achieve expected spectral efficiencies and transmission quality. The alternate solution to achieve compactness in MIMO system design is the use of pattern diversity **[6], [7],** multimode diversity **[8]** and polarization diversity **[9]** in conjunction with space diversity. In polarization diversity channel capacity can be increased by reducing the space between antenna elements **[10].**

In This paper a simple rectangular micro strip antenna is designed with a considerable return loss for 2.4 GHz. This antenna is further used to design a 1*1 *MIMO* system. In this work orthogonal polarization concept is applied to the proposed two port patch antenna to obtain better results in relation to return loss and mutual coupling. The orthogonality of two distinct polarizations develops independent and uncorrelated on each antenna and thus leads to a full rank MIMO channel which provides improved channel capacity. This paper is organized as follows. Section 2 describes the design of a single antenna, section 3 explains the design of a MIMO array and section 4 concludes the analysis of the paper.

2. Single Antenna Design

The proposed antenna is designed on *FR-4* substrate having $\in_r = 4.4, tan\delta = 0.02$and thickness of 1.5mm and simulated in the range of 1 to 3 GHz. The top patch of substrate is fed by a micro strip line having a width of 3mm.The bottom patch of substrate is a ground plane. Antenna design parameters are given in table-1. The proposed antenna is simulated by CST microwave studio.

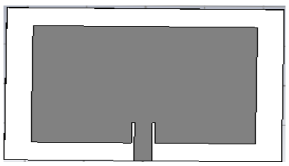

Figure -1: Single antenna design

Table -1: Antenna Design Parameters

Ground and substrate	L_0 =47.04 mm	W_0 =38.48 mm
Patch	L_1 =38.04 mm	W_1 =29.48 mm
Inset feed	L_2 =5.2 mm	W_2 =1 mm
substrate height	H=1.5 mm	
height of the ground	0.02 mm	
height of the patch	0.02 mm	

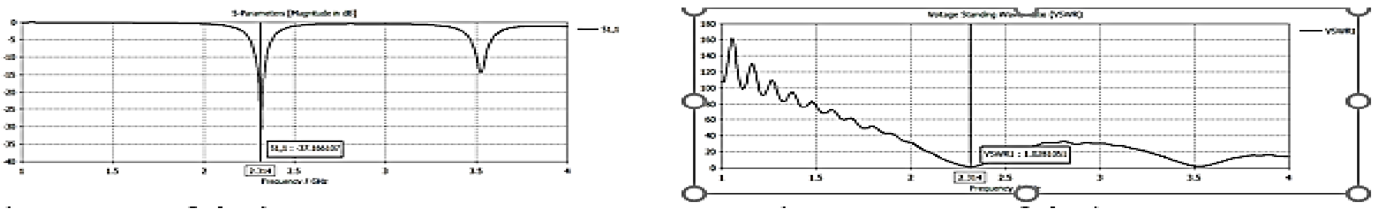

Figure - 2: S_{11} and VSWR of single antenna

Figure 2 shows that the return loss of the proposed single antenna is -37.176 and *VSWR* is 1.02(figure 3) in the entire operating frequency band. From figure 4 it is observed that the gain of the single antenna is 1.982 dB and directivity is 5.75dBi.Radiation pattern of the proposed antenna is shown in the figure 5.

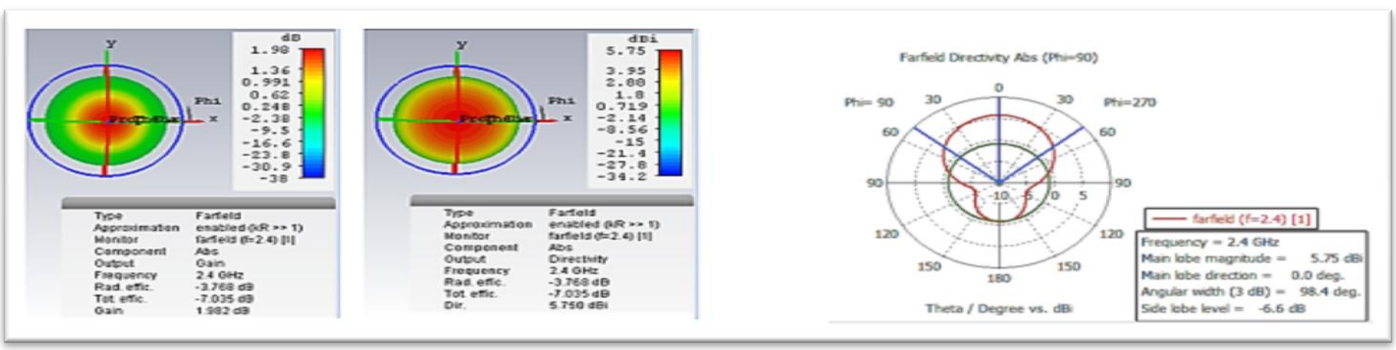

Figure -3: Gain, Directivity and radiation pattern of single antenna.

3. MIMO antenna array design

In MIMO system design mutual coupling play a key role .Mutual coupling can be mitigated by the use of polarization diversity. In this paper orthogonal polarization technique is used to mitigate the effect of mutual coupling. Orthogonality of two distinct polarizations constructs independent and uncorrelated signals on each antenna. In the proposed antenna to achieve orthogonal polarization, one antenna is rotated by 90^0 with respect to another antenna as shown in the figure 4.The separation between the antennas is 18.75mm (0.15λ).The antennas in the array have the same dimension as discussed in section 2.

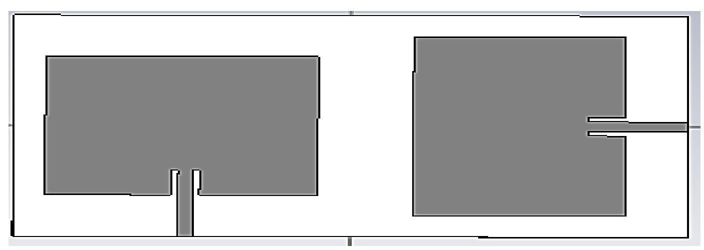

Figure - 4: MIMO antenna design

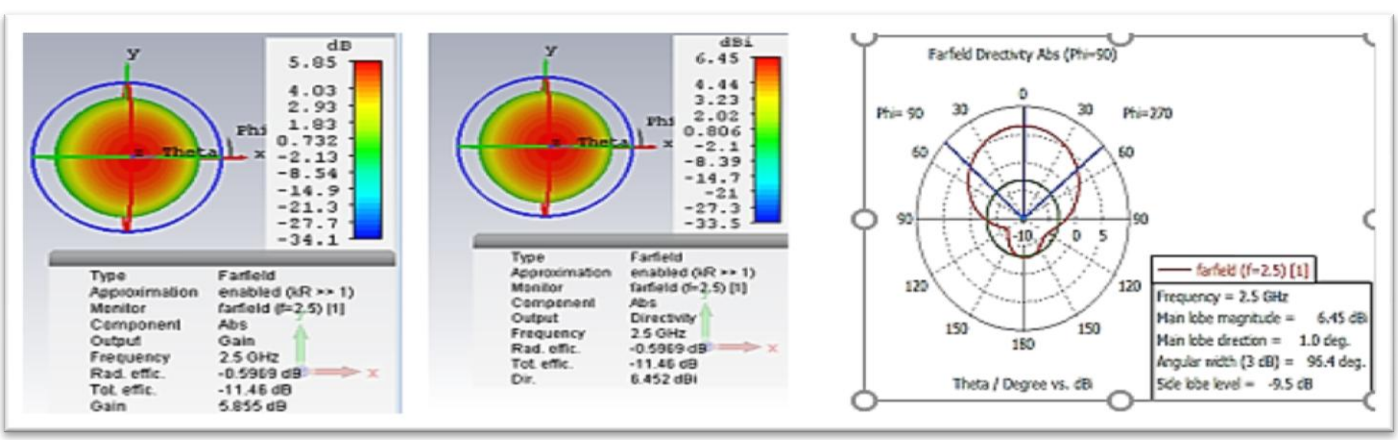

Figure -5: Gain, directivity and radiation pattern of horizontal antenna (1)

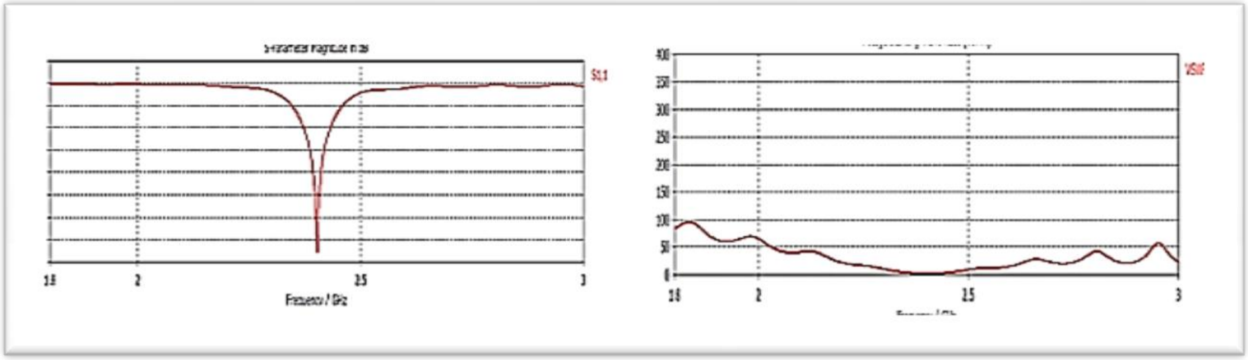

Figure - 6: S_{11} and VSWR of horizontal antenna (1)

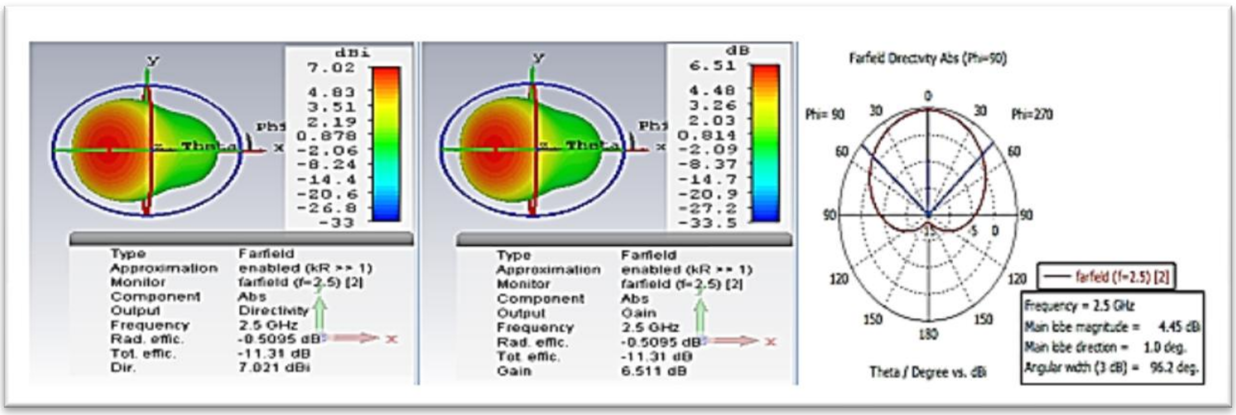

Figure - 7: Directivity, gain and radiation pattern of vertical antenna (2)

Simulation outputs in figure 6 and figure 8 shows that S_{11}<-10dB, s_{22}<-10dB, vswr1=1.23 and vswr2=1.08 FOR 2.4GHz *ISM* band frequency. Figure 9 indicates that S_{12}<-15dB and S_{21}<-15dB ,that is ,the two antennas are independent of each other and the value of mutual coupling between two antennas is very low .We further computed correlation coefficient and diversity gain (DG) using S parameters as expressed in equation 1.

$$\rho = \frac{|S_{11}+S_{12}+S_{21}+S_{22}|^2}{(1-|S_{11}|^2-|S_{21}|^2)(1-|S_{22}|^2-|S_{12}|^2)} \qquad (1)$$

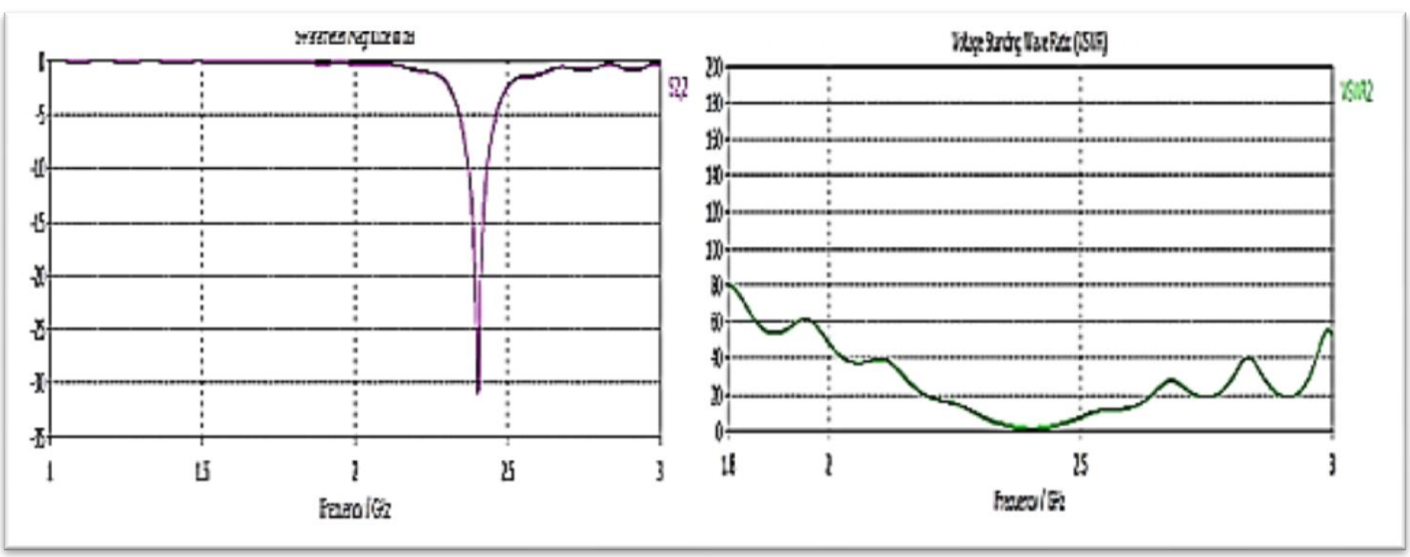

Figure - 8: S_{11} and VSWR of vertical antenna (2)

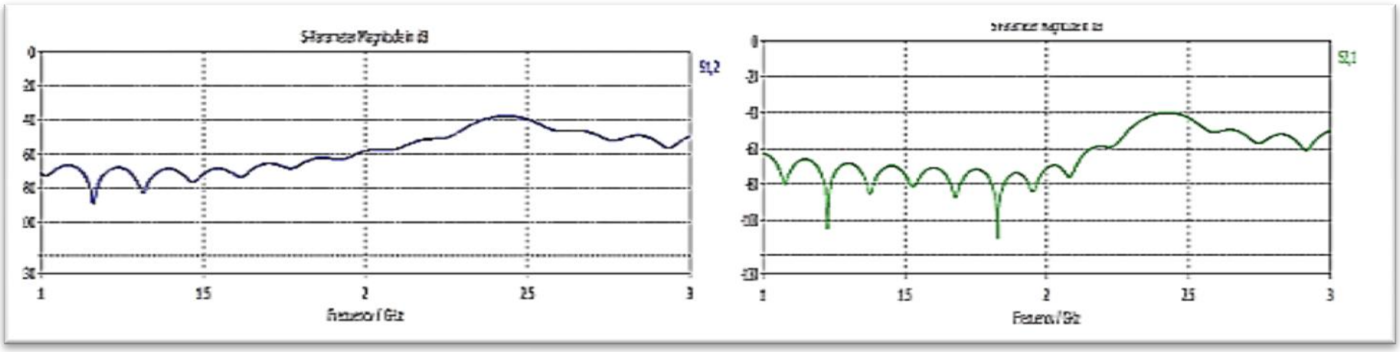

Figure - 9: S_{12} and S_{21} of proposed antenna

From figure 10 it is observed that the correlation coefficient is very low for the ISM band frequency 2.4 GHg.Correlation coefficient should be < 0.1 for *MIMO* antenna .Diversity gain (DG) represents the rise in signal to noise ratio due to diversity scheme and is expressed as in equation 2.Diversity gain is 9.9 dB and it is acceptable in terms of diversity.

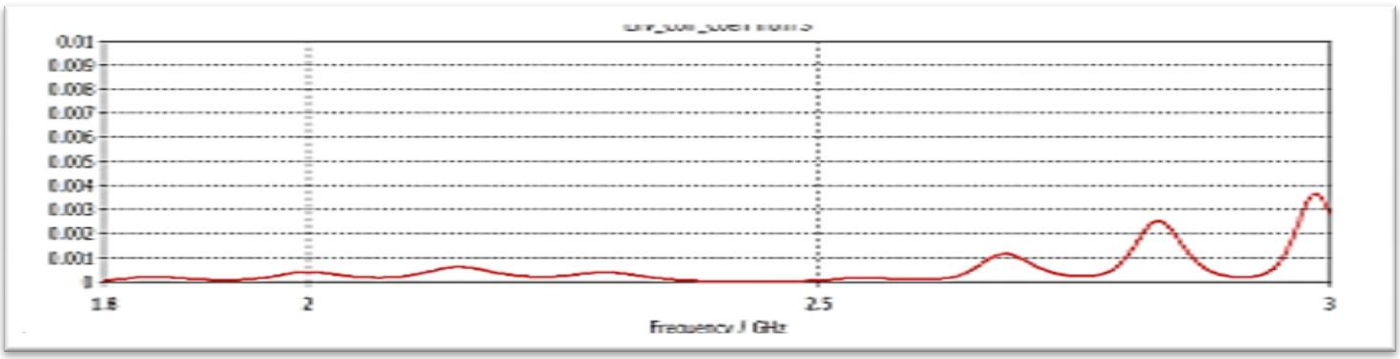

Figure - 10: Envelop correlation coefficient of proposed antenna.

4. Conclusion

This paper presents the design of a 1×1 *MIMO* array antenna for ISM band applications. Orthogonal polarization technique is used to mitigate the effect of mutual coupling and further to increase channel capacity. From simulation results it is obvious that various parameters of *MIMO* system are operating independent to each other ,which is the basic requirement of *MIMO* system design .The radiation pattern, gain and envelop correlation were also measured and were found to be suitable for ISM band applications.

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