ISOLATION ENHANCEMENT IN TWO PORT MIMO SYSTEM USING PARALLEL COUPLED LINES

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Abstract

In this paper, we implemented a parallel line coupled resonator for isolation enhancement in multiple-input-multiple-output (MIMO) antenna system for WLAN application. The edge-to-edge spacing between antenna elements is 3.8mm ($0.072\boldsymbol{\lambda}_o$, $\boldsymbol{\lambda}_o$ is the free space wavelength at 5.7GHz).The decoupling structure consists of parallel coupled resonator structure acting as band reject filter that helps to nullify the near coupled field between antenna system.The parametric study is done to optimize the length of coupled resonator so as to obtain high isolation between antenna elements at resonating frequency. The simulated efficiency remains above 88% along with envelope correlation coefficient (ECC) value lower than 0.03, making the design practicable for MIMO WLAN application.
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1. Introduction

The multiple-input-multiple-output (MIMO) design utilizing microstrip patch antenna design are popular in compact, low profile and high data rate wireless communication system [1]. Due to increase in number of antenna terminal on user platform, there is requirement of low mutual coupling between antenna terminals for better performance of antenna. Also Several MIMO antenna design has been reported in previous literature specifically focused to reduce the interelement coupling in MIMO system using various design techniques such as neutralization lines [2], split ring resonators (SRRs) [3], coupled polarization transformer [4], modified serpentine structure [5], and various metamaterial based decoupling structures [6-7], etc. All these designs have limitation of large spacing between antenna elements. To achieve compact edge-to-edge spacing with reduced isolation and suitable gain, MIMO system with parallel coupled resonator line (PCLR) has been reported as decoupling structure [8].
In this paper, using this proposed technique, the isolation between the closely spaced antenna elements (with edge-to-edge separation of $0.072\boldsymbol{\lambda}_o$; $\boldsymbol{\lambda}_o$ is free space wavelength at 5.7GHz) is obtained above 19dB, thereby increasing the isolation by 10dB.The paper is further organized as follows. Section 2, presents the design configuration of antenna system along with decoupling structure. In section 3, simulation results are discussed and finally, section 4 resents the conclusion along with a comparative study of proposed antenna with previous literatures in the context of using PCLR for mutual coupling reduction.

2. MIMO antenna design

The geometry of the proposed antenna is shown in Figure.1 that illustrates the design parameters of proposed MIMO antenna and PCLR decoupling structure printed on RT/Duroid 5870 (ϵ_r = 2.33, tan δ =0.0012) of height 1.57mm. The proposed antenna composed of two identical rectangle patch elements whose individual dimensions ($L_p \times W_p$) 18x16mm^2 are calculated and parametrically optimized so that it resonates at 5.7GHz with edge-to-edge separation (D) of 3.8mm ($0.072\boldsymbol{\lambda}_o$, $\boldsymbol{\lambda}_o$ is the free space wavelength at 5.7GHz) for the best performance of antenna. Each antenna element is excited using coaxial feed with an offset distance of 4mm from center of the patch to obtain 50ohm impedance matching.
The decoupling PCLR structure consists of four pairs of coupled line in close separation of '*b*' from each other. The PCLR consists of two section with each section consists of two pairs of coupled line in it and separation between each pair of section is '*g*' as shown in Figure.1 (b). The width of the line '*a*' and length 'L' has been optimized for best isolation performance of antenna. The optimized dimensions of antenna and PCLR are as follows: L=57, W=32, L_p=18, W_p=16, L_{PCLR}=22, d=2.64, *a=0.20, b=0.18, c=0.10 and g=0.33*(All Units in: mm).

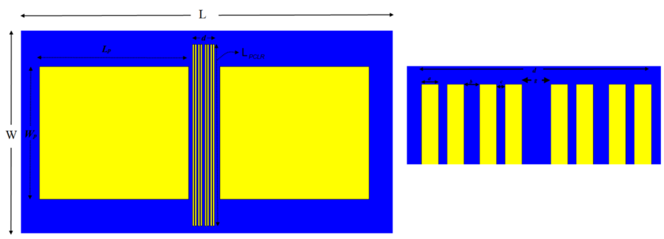

Figure.1 (a) Proposed MIMO antenna with Parallel coupled resonator lines (b) PCLR detailed dimension *a=0.20, b=0.18, c=0.10, d=2.64 and g=0.33* (Units in: mm)

3. Results and Discussion

Figure.2 shows the simulated S-parameter of system when antenna 1 is excited with and without the PCLR lines. With PCLR, there is a shift in resonance frequency to higher side due to close proximity of PCLR with antenna radiating side and there is an isolation improvement of 10dB obtained over the operating frequency band. The simulated impedance bandwidth of 3.6% (5.69-5.9GHz, 0.21GHz) centered at 5.75GHz is observed. The results show 10dB (-9 to -19) dB isolation improvement at resonant frequency. The simulated result implies that the proposed antenna meet the impedance bandwidth along with isolation requirement suitable for 5.8GHz WLAN applications. The simulated 2-D radiation pattern of the antenna in both yz-plane (E-plane) and xz-plane (H-plane) are shown in Figure.3 at 5.75GHz. Both E and H plane radiation pattern peak are in broadside direction. The addition of PCLR decoupling structure does not affect the radiation characteristics of the MIMO system. Fig.4 shows the current distribution of the proposed antenna in order to validate the effect of decoupling structure on the reduction of mutual coupling. It can be seen from the analysis that in absence of PCLR when antenna 1(top-left side) is excited and other antenna elements is matched with 50Ω load, the surface current is distributed over the entire area of antenna 2 (right side). With PCLR structure placed between antennas, the current from antenna 1 is concentrated largely on the decoupling structure, where the currents are traversing in opposite direction to that of antenna excited. These anti parallel current paths cancel the near coupled field between antenna elements. The same is true when other antenna elements are excited with proper matched load condition.

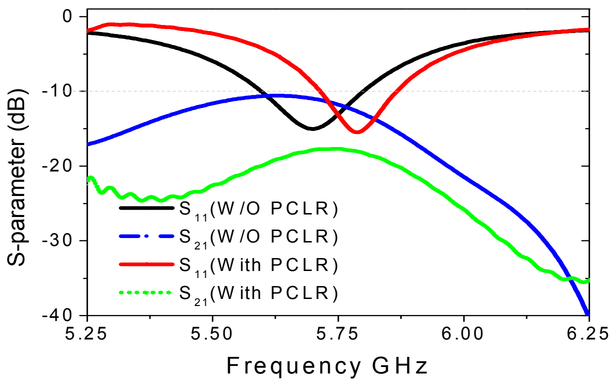

Figure.2. Simulated S-parameter of Proposed MIMO antenna with and without (W/O) PCLR

The diversity performance of MIMO system is defined in terms of Envelope correlation coefficient (ECC), which provides the degree of signal correlation between each antenna elements. To measure the diversity performance of antenna, it is important to have lower value of ECC <0.5, which can be calculated from far field patterns of the individual antennas [1] or from S-parameter [5]. ECC determined from S-parameter, assuming antenna is placed in uniform scattering environment, can be written and calculated as:

$$ECC, \rho_e = \frac{\left|S_{ii}^{*}S_{ij} + S_{ji}^{*}S_{jj}\right|^2}{\left(1-\left|S_{ij}\right|^2-\left|S_{ji}\right|^2\right)\left(1-\left|S_{jj}\right|^2-\left|S_{ij}\right|^2\right)} \qquad (1)$$

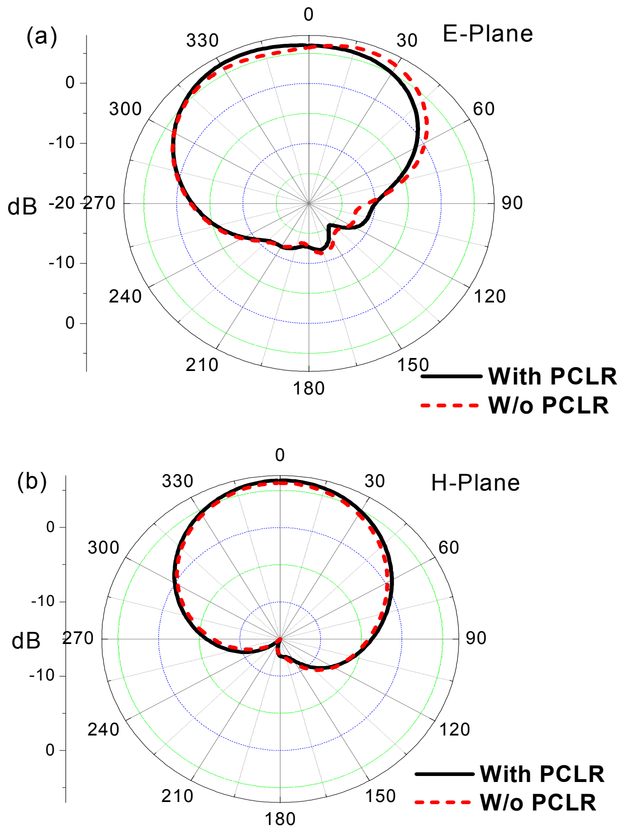

Figure.3 Simulated far field radiation patterns of two port MIMO antenna with and without PCLR (a) E-Plane and (b) H-Plane

The simulated ECCs is shown in Fig.5. It is observed that under operating band the measured ECC is well below 0.05 which indicates better performance of MIMO system as it is below the acceptable limit of 0.5. The performance of the proposed MIMO antenna are compared with earlier designs in terms of size, isolation techniques, isolation improvement and edge-to-edge spacing between antenna elements along with simulated gain and efficiency and is summarized in Table.1. It shows that the proposed design offer a narrow edge-to-edge spacing between the radiating elements and better antenna efficiency for MIMO design.

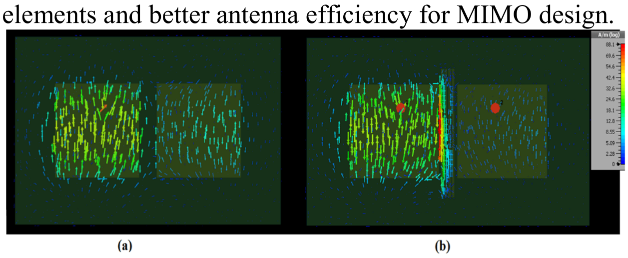

Figure.4. Surface current distribution (a) Without (b) With PCLR

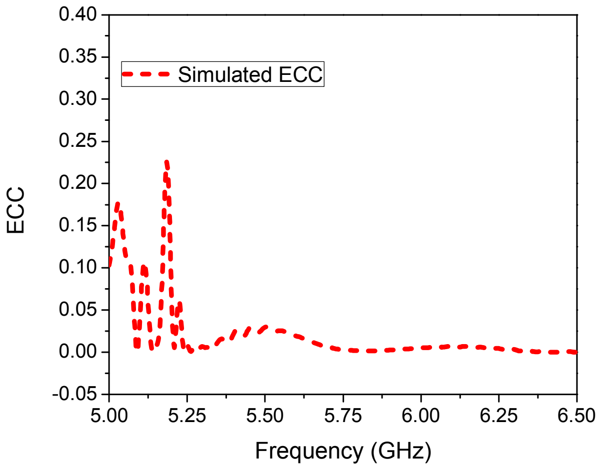

Figure.5. Simulated ECC of the proposed antenna

4. Conclusion

In this paper, an efficient use of parallel coupled lines resonator for low mutual coupling in MIMO antenna is presented. The design offers a small edge-to-edge spacing of $0.072\lambda_o$ with isolation level well below 19dB between antenna elements along with significant gain over desired frequency band. The antenna covers 5.69-5.9GHz frequency band with simulated ECC values less than 0.05 making the design suitable for 5.8GHz WLAN application. The presented design is compared to existing literatures and the result shows an improved efficiency and spacing between antenna elements using proposed design technique.

5. References

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Table.1. Comparison between proposed designs with other MIMO antenna system

Ref	**Patch Size (mm^3) & Substrate ($\mathcal{E}_r$)**	**Isolation Reduction Technique**	**Center frequency f_o (GHz)**	**Edge to edge spacing (mm)**	**Isolation (dB)**	**Isolation Enhancement (dB)**	**Simulated Efficiency (%)**	**Inter element spacing (mm)**
[4]	35x35x3.18 (6)	Coupled Polarisation Transformer	2.27	-----	-30	15	-----	70 (0.53 λ_o)
[5]	30x29.52x1.6 FR-4 (4.3)	Modified serpentine structure	2.45	6 (0.05λ_o)	-34	34	------	36 (0.3λ_o)
[9]	------- FR-4 (4.6)	Polarization conversion isolator	5.8	4.6 (0.092λ_o)	-22.3	22.3	< 70	20.5 (0.39λ_o)
Proposed Design	18x16x1.57 RT5870 (2.33)	Parallel coupled resonator	5.7	3.8 (0.072λ_o)	-19	10	>84	19 (0.36 λ_o)