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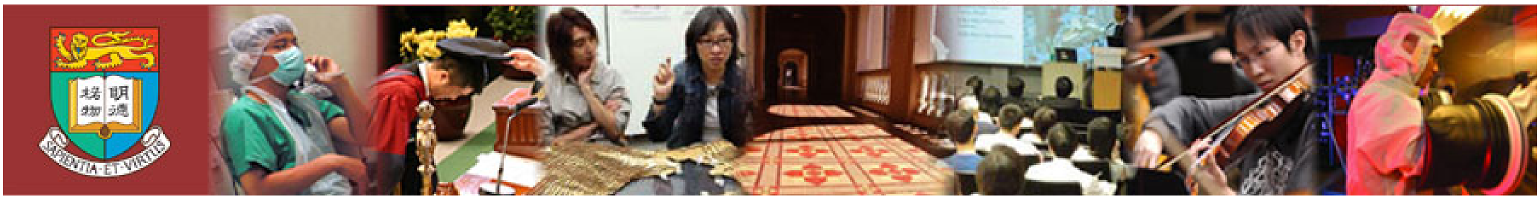

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Isolation improvement using CMRC for MIMO antennas

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***Abstract*—In this paper, a compact microstrip resonant cell (CMRC) is proposed to improve isolation of antenna elements in the design of multiple-input multiple-output (MIMO) antennas. The MIMO antenna used for studies consists of two symmetrical L-shaped planar inverted-F antenna (PIFA) elements placed at a distance of 16.2 mm on a printed-circuit board (PCB). A single-layer CMRC is etched on the PCB between the PIFA elements to improve isolation between them. Computer simulation is used to study and design the MIMO antenna. Results show that the CMRC can increase isolation between the two PIFA elements by 10 dB in the 2.4-GHz WLAN band. The envelope correlation coefficient (ECC) is about 0.0005 to 0.0035 over the frequency band.**

***Index Terms*—MIMO antenna, compact microstrip resonant cell (CMRC), isolation improvement, WLAN antenna.**

I. Introduction

An increasing number of mobile users are demanding for higher-speed internet services for their smart phones. Multiple-input multiple-output (MIMO) technology is one of the possible techniques to satisfy this demand as it can provide higher receive gains and network capacities, and hence faster data rates and better reliabilities [1]. As a result, many future communication systems such as the 4G LTE and high-speed WiFi systems have included the MIMO technology to the system specifications.

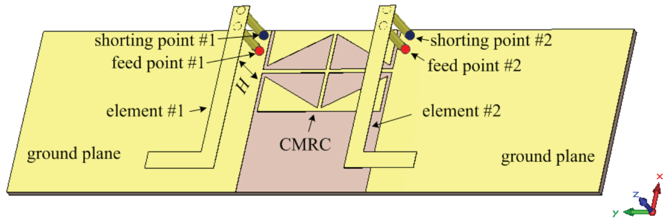
One of the major challenges to employ MIMO technology in mobile networks is to design the MIMO antennas to be installed in the very limited spaces of mobile devices without too much interference from or mutual coupling between the antenna elements. Different techniques such as using the Electromagnetic Band-Gap (EBG) structure, T-shaped or L-shaped ground branches, parasitic elements and slits have been proposed to increase isolation of antenna elements in the design of MIMO antennas [2-7]. In [2], an Electromagnetic Band-Gap (EBG) structure was used to reduce the surface current between the two antenna input ports and hence to increase isolation. In the MIMO antennas employing the T-shaped or L-shaped ground branches [3-4] and parasitic elements [5], isolation between antenna elements was increased by cancelling off the current on the non-excited antenna element using the current on the excited antenna element and ground branches or the parasitic elements. In [6-7], a slit was etched on the ground plane to force the surface current to flow along it. This increased the length of the current path on the ground plane and isolation between the antenna elements. Neutralization technique is also quite a commonly technique used. In [8], the induced current from the ground plane and the generated current path from the neutralization link on each MIMO antenna element were partly cancelled, which increased isolation between the antenna elements. Metamaterial can also be used to increase isolation between antenna elements of MIMO antenna using the properties of negative permittivity and negative permeability [9].

Compact microstrip-resonant cell (CMRC) is a type of microwave circuit which was initially developed in [10]. It has been widely applied in the designs of microwave filters [11], oscillators [12], low-noise amplifiers [13] and power amplifiers [14]. However, to the best knowledge of the authors, CMRC has never been studied to design MIMO antennas for wireless devices applications.

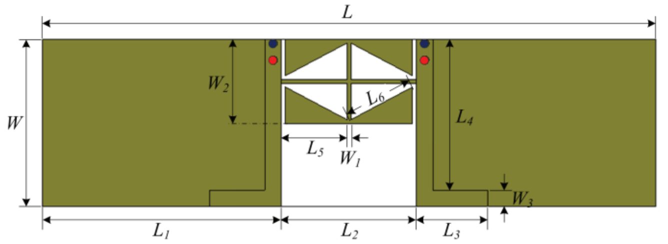
In this paper, we propose to use a CMRC to increase isolation between the two antenna elements of a MIMO antenna having a compact space. The MIMO antenna is designed for use in the WLAN band and consists of two symmetrical simple planar inverted-F antenna (PIFA) elements separated at a distance of 16.2 mm (equivalent to 0.13λ at the frequency of 2.45 GHz). The CMRC is etched on the ground plane between the two PIFA elements. The antenna is studied using the EM simulation tool CST and results show that isolation between the two PIFA elements in the MIMO can be increased from 11 to 22 dB in the 2.4-GHz WLAN band.

II. Antenna Design

The configuration of the proposed MIMO antenna used for studies is shown in Fig. 1. The MIMO antenna is designed on a single-sided PCB with an area of $L \times W$=73.76×20.13 mm^2, as shown in Fig. 1(b). The substrate has a thickness of 0.8 mm, a relative permittivity of 4.4 and a loss tangent of 0.02. The MIMO antenna consists of two simple and symmetrical L-shaped PIFA elements, denoted here as elements #1 and #2, having their own ground planes each with a size of $W \times L_1$=20.13×28.78 mm^2. A CMRC with a size of $W_2 \times L_2$=10.13×16.2 mm^2 is used to connect the two ground planes together. The L-shaped PIFA elements have a height (H) of 6 mm and strip width of W_3=2 mm. The total length (L_3+L_4) of each L-shaped PIFA element is (8.6+18.13) mm=24.73 mm, equivalent to about a $\lambda/4$ long at 2.45 GHz in the WLAN band. The separating distance L_2 between the two PIFA elements is 16.2 mm, about 0.13λ long at the frequency 2.45 GHz. Table I lists the dimensions of the design.



(a)



(b)

Fig. 1. Geometry of proposed antenna: (a) 3-D view, and (b) 2-D view.

TABLE I. DIMENSIONS OF PROPOSED ANTENNA (MM)

L	***L₁***	***L₂***	***L₃***	***L₄***	***L₅***
73.76	28.78	16.2	8.6	18.13	7.88
L₆	***W***	***W₁***	***W₂***	***W₃***	***H***
8.4	20.13	0.45	10.13	2	6

III. RESULTS AND DISCUSSIONS

Simulation has been used to study, design and optimize the proposed MIMO antenna. The simulated S-parameters of the proposed antenna with and without using the CMRC are shown in Fig. 2 for comparison. Here without using the CMRC means replacing the CMRC by a ground plane with a size of W×L$_2$ to connect the two separate ground planes together. Since the two PIFA elements are placed symmetrically, S_{11} and S_{12} are identical to S_{22} and S_{21}, respectively. Thus we only show the results for S_{11} and S_{21} in Fig. 2. It can be seen that, without the CMRC, the S_{11} of the proposed MIMO antenna is only about -6.5 dB at the center frequency 2.5 GHz, which cannot form a frequency band to support the 2.4-GHz WLAN system. Isolation between the two PIFA elements, as indicated by S_{21}, of the MIMO antenna is about 11 dB, which is lower than 20 dB required for good performance of MIMO antennas [15]. However, with the use of the CMRC on the ground plane to separate the PIFA antenna elements, Fig. 2 shows that the S_{11} of the proposed MIMO antenna is reduced to -16.5 dB at 2.45 GHz, generating a frequency band of 2.4-2.5 GHz (for S_{11} < -10 dB) for the WLAN systems. Most importantly, isolation between the two PIFA elements, as indicated by S_{21}, of the MIMO antenna is substantially increased to 22 dB at 2.45 GHz. Isolation across the entire band of 2.4-2.5 GHz is large 22 dB.

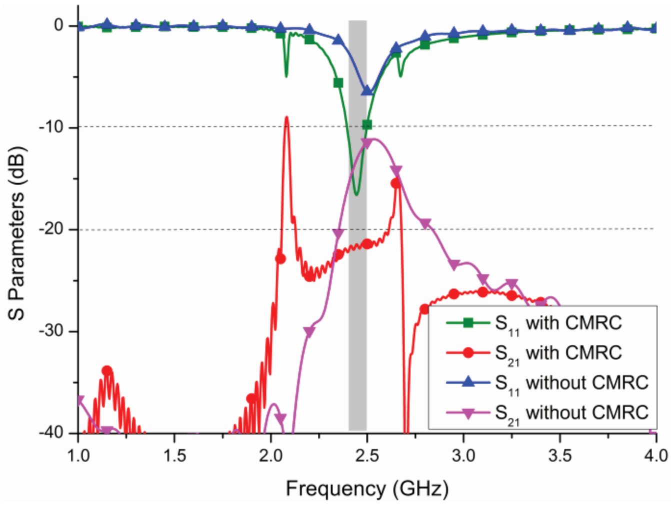
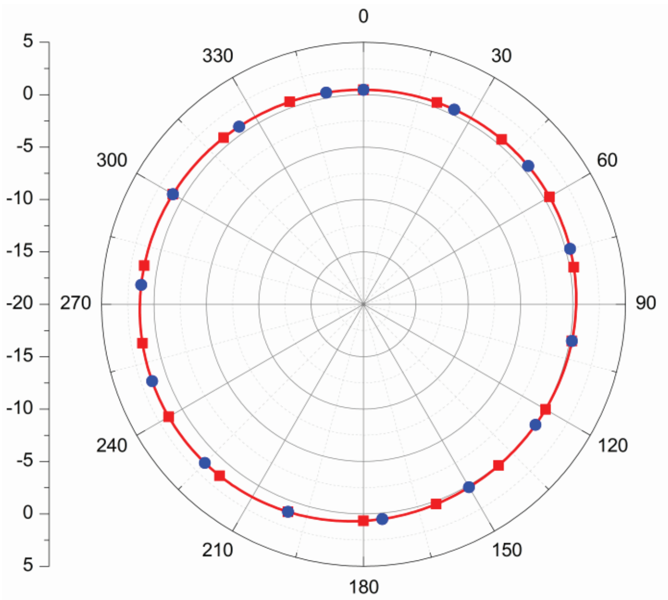
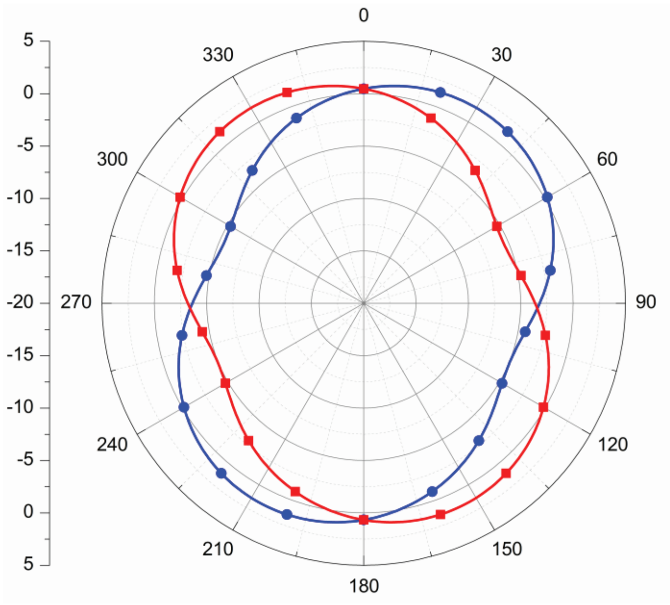


Fig. 2. Simulated S_{11} and S_{21} of proposed MIMO antenna with and without CMRC.

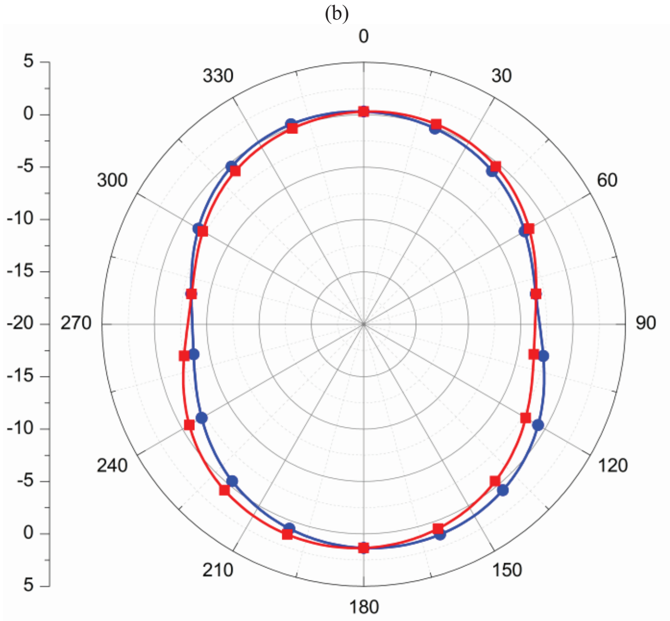
The radiation patterns of the proposed MIMO antenna at the resonant frequencies of 2.45 GHz in the *x-z*, *y-z*, and *x-y* planes are shown in Figs. 3(a), (b) and (c), respectively. In the studies, when one antenna element is excited by a 50-Ω signal source, the other antenna element is terminated with a 50-Ω load. It can be seen that the MIMO antenna with either antenna element #1 or antenna element #2 excited has an omnidirectional radiation pattern in the *x-z* plane, which is typical for PIFA. The radiation pattern of antenna #1 in the *x-z* plane is overlapped with that of antenna #2, which is due to the fact that the two antenna elements are in parallel and symmetrically placed on the PCB. It also can be seen that the radiation patterns generated by the two antenna elements in the y-z and x-y planes are complementing to each other. This is because the two antenna elements are being mirror images of each other.



(a)



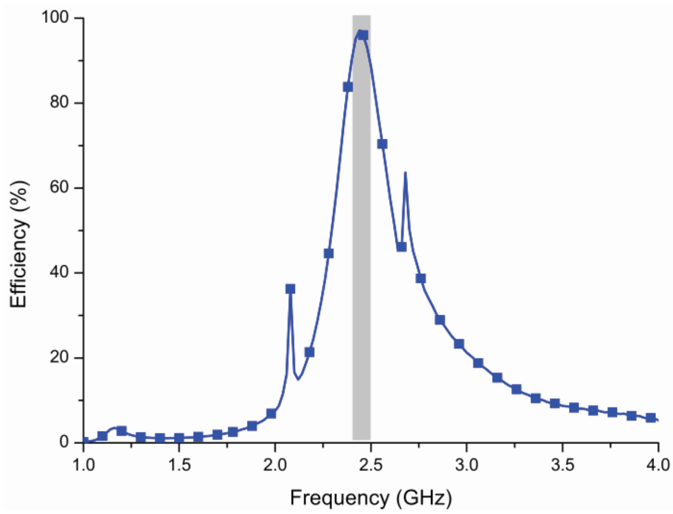
(b)



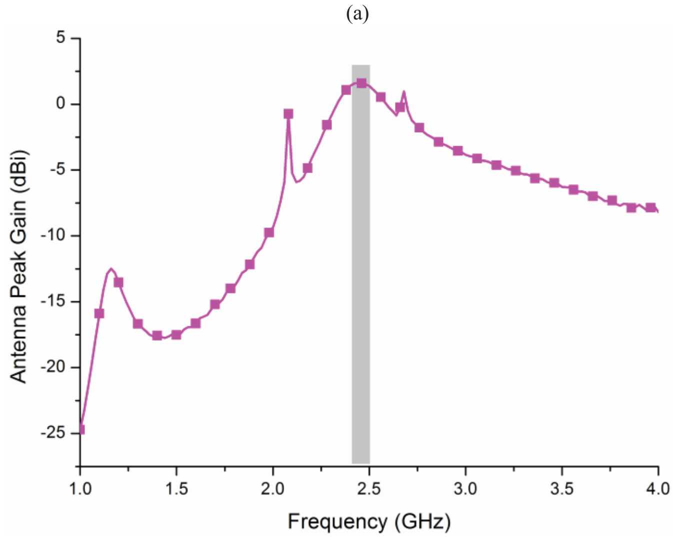
(c)

Fig. 3. Simulated radiation patterns at 2.45 GHz in (a) *x-z* plane, (b) *y-z* plane, and (c) *x-y* plane. (with antenna #1 excited; with antenna #2 excited)

The efficiency and peak gain of the MIMO antenna, with one antenna element excited with a 50-Ω signal source and the other antenna element terminated with a 50-Ω load, have also been studied. Since the MIMO antenna has a symmetric structure, the efficiency and peak gain of element #1 will be the same as those of element #2, so here we only show the efficiency and peak gain of antenna #1. The simulated total efficiency and peak gain of antenna #1 are shown in Figs. 4 (a) and (b), respectively. It can be seen that the simulated efficiency of the antenna is over 90% in the operating frequency band of 2.4-2.5 GHz and the simulated peak gain ranges from 1.38 to 1.62 dBi within the frequency band.



(a)



(b)

Fig. 4. Simlulated (a) efficiency and (b) peak gain of proposed MIMO antenna with one port excited and other port terminated with 50-Ω load..

To further evaluate the diversity performance of the proposed MIMO antenna, the envelope correlation coefficient (ECC) ρ_e is computed using the formula [15]:

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

Fig. 5 shows the computed ρ_e in the WLAN band of 2.4-2.5 GHz. It can be seen that ρ_e ranges from 0.0005 to 0.0035 over the frequency band, thus the proposed MIMO antenna has excellent envelope correlation coefficient.

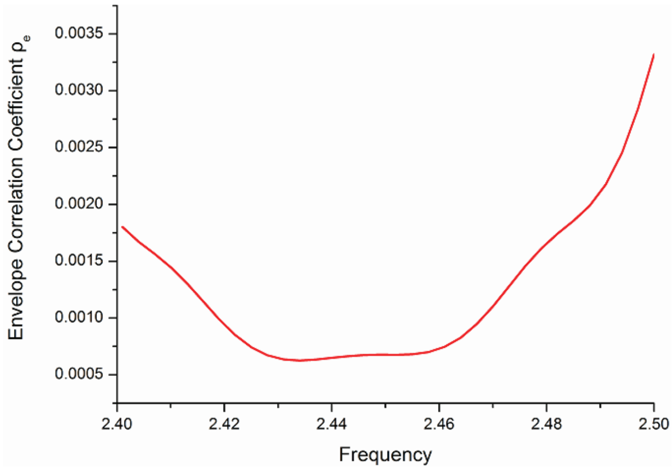


Fig. 5. Simlulated envelope correlation coefficient ρ_e calculated from S parameters.

IV. CONCLUSIONS

A CMRC has been proposed to improve isolation between antenna elements in the design of MIMO antennas. A MIMO antenna consisting of a pair of PIFA antenna elements has been used for studies. Simulated results have showed that, by using the CMRC, isolation between the two PIFA elements can be dramatically increased from 11 dB to 22 dB in the 2.4-GHz WLAN band. The envelope-correlation coefficient (ECC) is less than 0.0035. Thus CMRC can be used to improve isolation of antenna elements in the design of MIMO antennas.

REFERENCES

[1] Di Wu, S. W. Cheung, T. I. Yuk and L. Liu, “Design of a printed multiband MIMO antenna,” 2013 7th European Conference on Antennas and Propagation (EuCAP), Gothenburg, Sweden, pp. 2020-2023, 2013.

[2] K. Payandehjoo and R. Abhari, “Employing EBG structures inmultiantenna systems for improving isolation and diversity gain,” IEEE Antennas Wireless Propag. Lett., vol. 8, pp. 1162-1165, 2009.

[3] L. Liu, S. W. Cheung and T. I. Yuk, “Compact MIMO antenna for portable devicesin UWB applications,” IEEE Trans. Antennas Propag., vol. 61, no. 8, pp. 4257-4264, 2013.

[4] Y. Ding, Z. W. Du, K. Gong and Z. H. Feng, “A novel dual-band printed diversity antenna for mobile terminals,” IEEE Trans. Antennas Propag., vol. 55, no. 7, pp. 2088-2096, 2007.

[5] Z. Y. Li, Z. W. Du, M. Takahashi, K. Saito and K. Ito, “Reducing mutual coupling of MIMO antennas with parasitic elements for mobile terminals,” IEEE Trans. Antennas Propagat., vol. 60, no. 2, pp. 473-481, 2012.

[6] Di Wu, S. W. Cheung, T. I. Yuk and X. L. Sun, “A MIMO antenna for mobile applications,” 2013 International Workshop on Antenna Technology (iWAT), Karlsruhe, Germany, pp. 87-90, 2013.

[7] Di Wu, S. W. Cheung, T. I. Yuk and X. L. Sun, “A planar MIMO antenna for mobile phones,” PIERS Proceedings, Taipei, Taiwan, pp. 1150-1152, 2013.

[8] A. Chebihi, C. Luxey, A. Diallo, P. Le Thuc and R. Staraj, “A novel isolation technique for closely spaced PIFAs for UMTS mobile phones,” IEEE Antennas Wireless Propag. Lett., vol. 7, pp. 665-668, 2008.

[9] C. C. Hsu, K. H. Lin, H. L. Su, H. H. Lin and C. Y. Wu, “Design of MIMO antenna with strong isolation for portable applications, ” IEEE AP-S Int. Symp., pp. 1-4, 2009.

[10] Q. Xue, K. M. Shum and C. H. Chan, “Novel 1-D microstrip PBG cells,” IEEE Microw. Guided Wave Lett., vol. 10, no. 10, pp. 403-405, 2000.

[11] W. Qin, and Q. Xue, “Elliptic response bandpass filter based on complementary CMRC,” Electronics letters, vol. 49, no. 15, pp. 945-947, 2013.

[12] Q. Xue, K. M. Shum and C. H. Chan, “Novel oscillator incorporating a compact microstrip resonant cell,” IEEE Microw. Wireless Compon. Lett., vol. 11, no. 5, pp. 202-204, 2001.

[13] S. IS. Yang, Q. Xue, and K. M. Luk, “A wideband LNA design incorporating the CMRC circuitry,” IEEE Microwave and wireless components letters, vol. 15, no. 5, pp. 315-317, 2005.

[14] S. C. Chen and Q. Xue, “A class-F power amplifier with CMRC,” IEEE Microw. Wireless Compon. Lett., vol. 21, no. 1, pp. 31-33, 2011.

[15] R. Addaci, A. Diallo, C. Luxey, P. L. Thuc and R. Staraj, “Dual-band WLAN diversity antenna systemwith high port-to-Port isolation,” IEEE AntennasWireless Propag. Lett., vol. 11, pp. 244 -247, 2012.