Progress In Electromagnetics Research Letters, Vol. 74, 131–136, 2018

A Novel Multiband MIMO Antenna for TD-LTE and WLAN Applications

Jing Bai, Ruixing Zhi, Wenying Wu, Mengmeng Shangguan, Bingbing Wei, and Gui Liu*

Abstract—A printed multiband multiple input multiple output (MIMO) antenna system is proposed in this paper. The MIMO antenna system is composed of two identical antenna elements which are perpendicular to each other. The defected ground plane with two microstrip lines is introduced to suppress the coupling between the antenna elements. The proposed MIMO system operates at two separated impedance bandwidths of 770 MHz (2.09–2.86 GHz) and 890 MHz (5.05–5.94 GHz) with an overall size of $50 \times 50 \times 1.59\,\text{mm}^3$. The achieved isolation at the lower and higher frequency bands is higher than 20.9 dB and 17.8 dB, respectively. The proposed MIMO antenna system is feasible to be used for time-division long-term-evolution (TD-LTE, 2300–2655 MHz) and wireless local area network 802.11 a/b/g (WLAN, 2.4–2.4835 GHz, 5.15–5.875 GHz) applications.

1. INTRODUCTION

With the rapid development of the modern wireless communication technology, the demand for the quality of data transmission including channel capacity, signal transmission speed and system reliability is increasing. However, the channel capacity and spectrum resources of a wireless communication system are always limited. Multiple input multiple output (MIMO) technology can provide a valid solution for increasing the channel capacity and improving the quality of data transmission. MIMO antenna systems can be utilized at both the transmitter and receiver for data transmission.

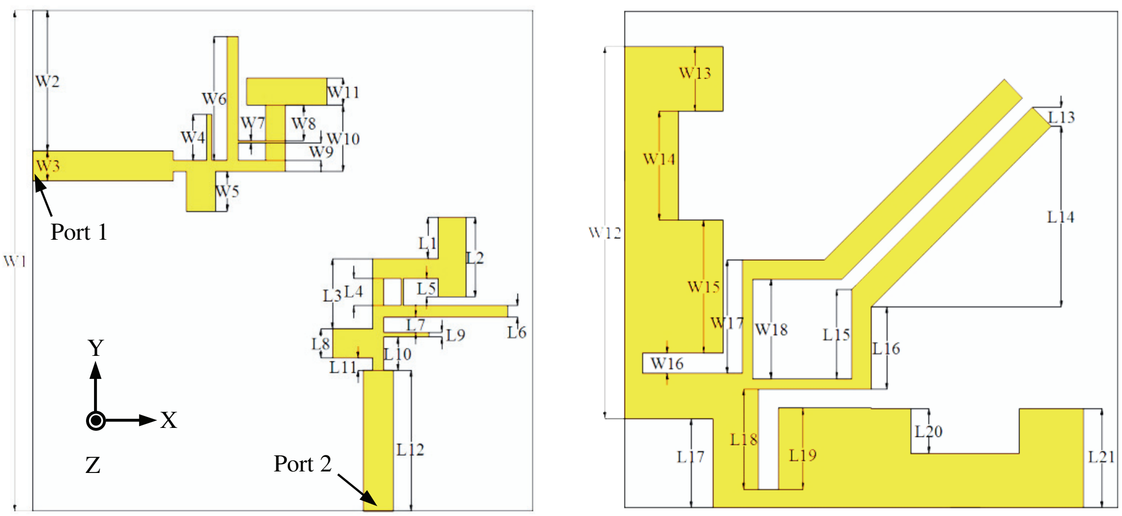
However, it is a challenging task to decrease the mutual coupling between the antenna elements in a limited space while maintaining multiband operation and high gain. In recent years, significant research efforts have been made on MIMO antenna system design [1–3]. Many decoupling techniques have been proposed such as electromagnetic band gap (EBG) [4], defected ground structure (DGS) [5–8], neutralization lines (NL) [9, 10], and parasitic elements [11]. A variety of techniques have been presented to design multiband antenna, such as split-ring resonators, slots, and artificial materials [12–14]. This paper presents a novel multiband MIMO antenna system, which can operate at two bands (2.09–2.86 GHz and 5.05–5.94 GHz) and achieve good isolation and gain in the relevant bands. It is composed of two antenna elements placed vertically to each other and a defected ground plane with microstrip lines to enhance the isolation. The measurement results of the fabricated prototype are consistent with the simulation ones. The proposed antenna is suitable for time-division long-term evolution (TD-LTE) such as TD-LTE 2300 (2300–2320, 2320–2370 and 2370–2390 MHz), TD-LTE 2500 (2555–2575 MHz), TD-LTE 2600 (2575–2635 and 2635–2655 MHz), and wireless local area network (WLAN) 802.11 a/b/g (2.4–2.4835, 5.15–5.875 GHz) applications. Section 2 describes the geometry of the MIMO antenna system in detail, and Section 3 deals with the explanation of measured results. Finally, a brief conclusion is drawn in Section 4.

Received 13 February 2018, Accepted 21 March 2018, Scheduled 5 April 2018
* Corresponding author: Gui Liu (iitgliu2@gmail.com).
The authors are with the College of Mathematics, Physics & Electronic Information Engineering, Wenzhou University, Wenzhou, Zhejiang 325035, China.

2. ANTENNA DESIGN

Figure 1 shows the geometry of the proposed MIMO antenna system. The antenna is printed on an FR4 substrate with relative permittivity 4.4 and loss tangent 0.02. The overall board dimensions are $50 \times 50 \times 1.59\,\mathrm{mm}^3$ to meet the size demand of the system miniaturization. The antenna element consists of a T-shaped strip and three short stubs. Each antenna element is fed by a $50\,\Omega$ microstrip feed line with the width of 3 mm.

In MIMO antenna system, the mutual coupling between the antenna elements results in poor isolation performance. A combination of different techniques are presented in this paper to achieve high isolation performance. Firstly, two identical antenna elements are perpendicular to each other. The size and the distance between the antenna elements have been optimized to decease the mutual coupling. Secondly, the rectangle slots etched on the defected ground plane can improve the isolation performance. Thirdly, two rectangular microstrip lines are connected to the defected ground plane by L-shaped strips which can further enhance the isolation performance.



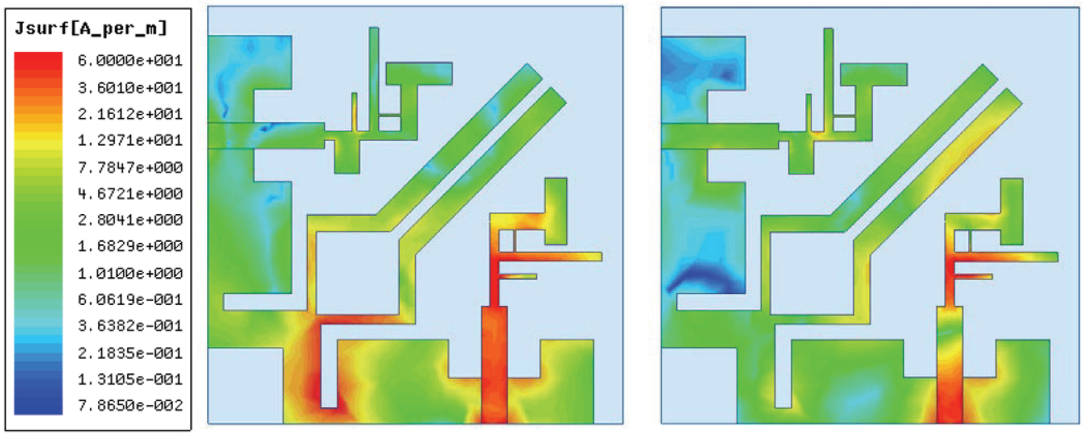
(a) (b)

Figure 1. Geometry of the proposed antenna (a) top view and (b) bottom view.

3. RESULTS AND DISCUSSION

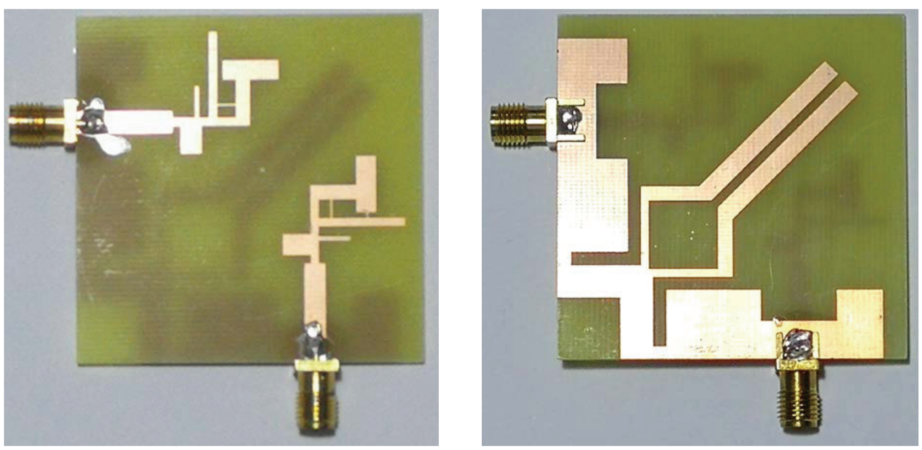
To further study the operation of the MIMO antenna system, the current density distributions are also presented in Figure 2. As shown in Figure 2(a), the currents are concentrated on the edges of two slots on the ground plane and the microstrip lines, which can prevent the current flowing from one antenna element to the other. Therefore the defected ground plane and the microstrip lines can decrease the mutual coupling at the lower frequency band. When the antenna operates at 5.5 GHz, the current distributions mainly appear on the lower branches of the radiator, the edges of the slot on the ground plane, which are just below the feed line, as shown in Figure 2(b). During the current distributions simulation, one port of the MIMO antenna is excited while the other port is terminated with a $50\,\Omega$ load.

The final dimensions (in millimeters) of the proposed antenna are $W1 = 50$, $W2 = 14$, $W3 = 3$, $W4 = 4.6$, $W5 = 4$, $W6 = 12.4$, $W7 = 0.2$, $W8 = 3.5$, $W9 = 1.8$, $W10 = 6.6$, $W11 = 2.7$, $W12 = 37.5$, $W13 = 6.5$, $W14 = 11$, $W15 = 13.4$, $W16 = 2$, $W17 = 11.4$, $W18 = 10$, $L1 = 4.1$, $L2 = 8$, $L3 = 7$, $L4 = 2.7$, $L5 = 1.9$, $L6 = 1.1$, $L7 = 1.5$, $L8 = 2.9$, $L9 = 0.5$, $L10 = 3.3$, $L11 = 1.3$, $L12 = 14.1$, $L13 = 1.9$, $L14 = 18.2$, $L15 = 9$, $L16 = 8.3$, $L17 = 9$, $L18 = 10.1$, $L19 = 8.2$, $L20 = 4.5$, and $L21 = 10$. To validate the above design strategies, the prototype of the proposed antenna is manufactured and measured. Figure 3 shows photographs of the fabricated prototype.



(a) (b)

Figure 2. Simulated surface current distributions at (a) 2.45 GHz and (b) 5.5 GHz.



(a) (b)

Figure 3. Photographs of the fabricated prototype (a) top view and (b) bottom view.

It can be found in Figure 4 that the measured −10 dB reflection coefficient bandwidths are 770 MHz (2.09–2.86 GHz) and 890 MHz (5.05–5.94 GHz). The mutual coupling (S_{21}) between two antenna elements is less than −20.9 dB at the lower frequency band (2.09–2.86 GHz) and −17.8 dB at the higher frequency band (5.05–5.94 GHz), respectively. Therefore, the proposed MIMO antenna can cover the frequency bands of TD-LTE 2300 (2300–2320, 2320–2370 and 2370–2390 MHz), TD-LTE 2500 (2555–2575 MHz), TD-LTE 2600 (2575–2635 and 2635–2655 MHz), and WLAN 802.11 a/b/g (2.4–2.4835, 5.15–5.875 GHz) applications.

Since the structures of antenna elements are identical, the radiation patterns are measured when Port 2 (as shown in Figure 1) is excited, and Port 1 is terminated with 50-Ω load. The measured normalized far-field radiation patterns of the prototype at 2.45 GHz and 5.5 GHz are given in Figure 5, respectively. The solid and dashed lines represent co-polarization and cross-polarization, respectively. It can be observed that the antenna exhibits roughly a figure "8" shape on E-plane and quasi-omnidirectional on H-plane. The deteriorated radiation patterns at the higher frequency band may be caused by the soldering effects of the SMA connector. The proposed antenna is a linearly polarized antenna according to the comparison between the co-polarization and cross-polarization patterns.

The envelope correlation coefficient (ECC) is a crucial criterion to evaluate the diversity and signal

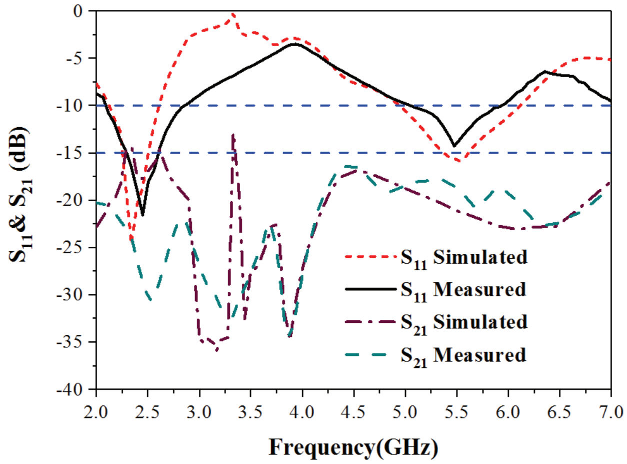


Figure 4. Measured S-parameters of the proposed MIMO antenna.

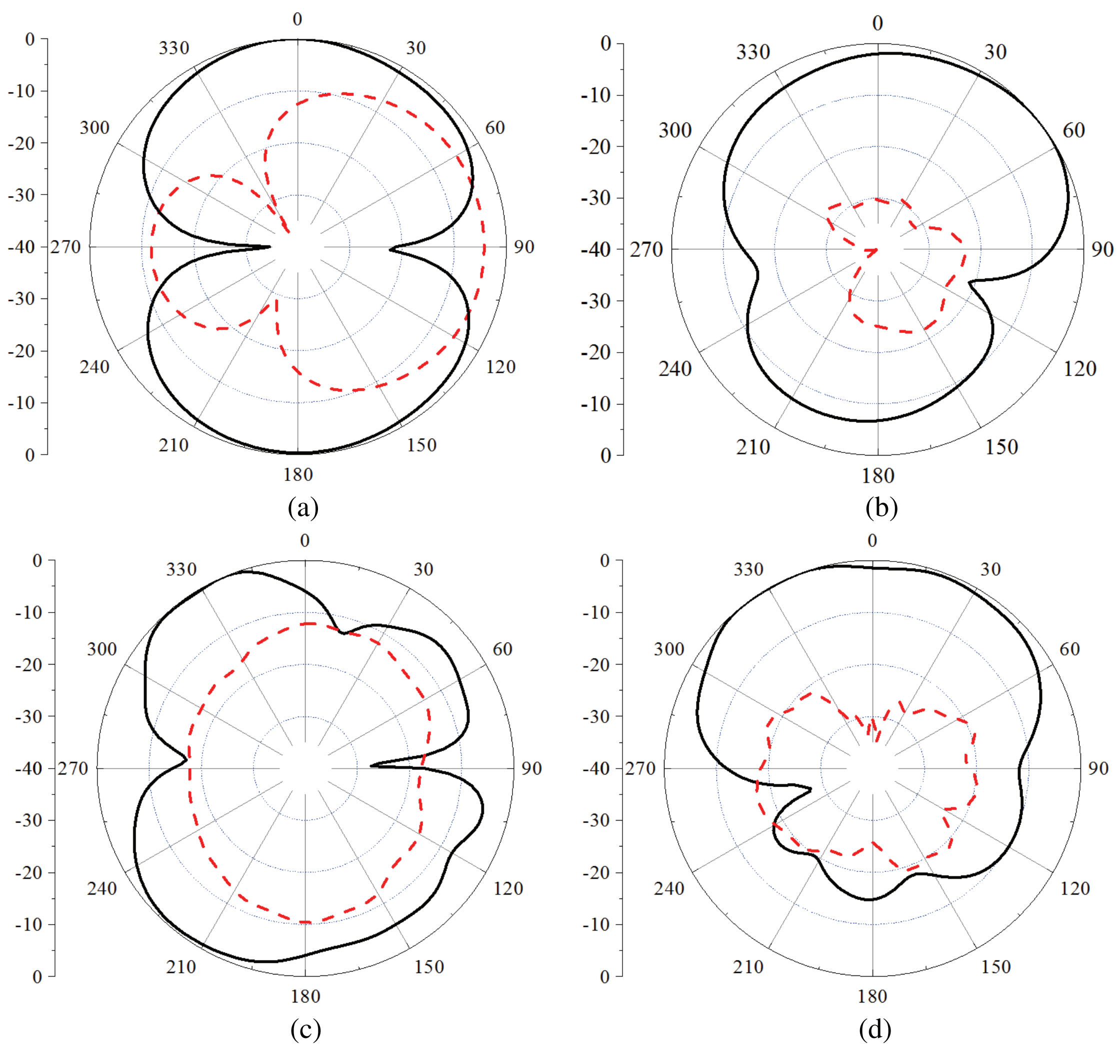


Figure 5. The measured normalized antenna radiation patterns at (a) 2.45 GHz E-plane (b) 2.45 GHz H-plane (c) 5.5 GHz E-plane and (d) 5.5 GHz H-plane.

correlations performance of MIMO antenna, which can be calculated through S-parameters by [15]

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

The measured ECC is shown in Figure 6. It can be seen that the ECC values are smaller than 0.011 over the desired operation bands (TD-LTE 2300–2655 MHz and WLAN 2.4–2.4835 GHz, 5.15–5.875 GHz), while the acceptable limit of ECC is below 0.5. Therefore, the MIMO antenna shows excellent diversity performance which improves the data rate of the MIMO system.

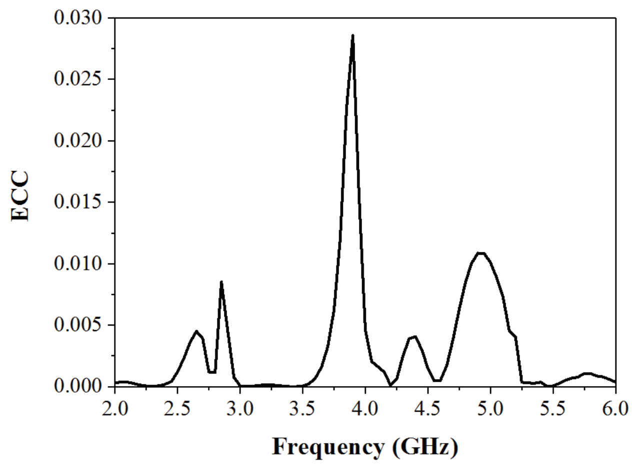


Figure 6. The measured ECC of the proposed MIMO antenna.

The peak gain and radiation efficiency are measured when Port 2 (as shown in Figure 1) is excited, and Port 1 is terminated with 50-Ω load. Figure 7 shows that the measured peak gains of the proposed MIMO antenna are greater than 1.74 dBi and 4.5 dBi at the lower (2300–2655 MHz) and higher (5.15–5.875 GHz) frequency bands, respectively. Figure 8 shows that the measured radiation efficiency of the prototype is more than 44.5% and 65.9% at the lower (2300–2655 MHz) and higher (5.15–5.875 GHz) frequency bands, respectively.

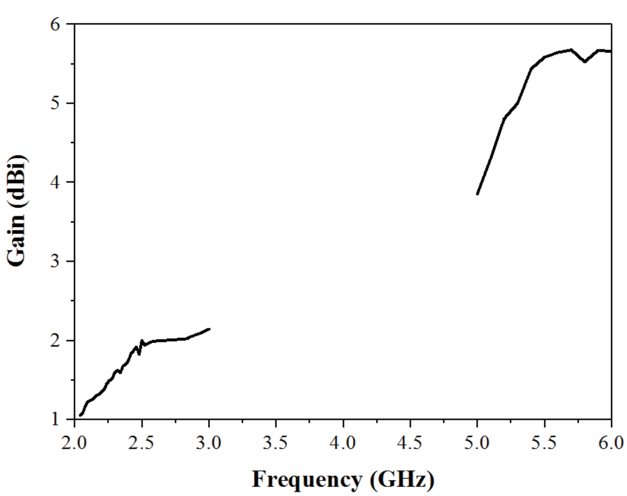


Figure 7. The measured peak gain of the proposed MIMO antenna.

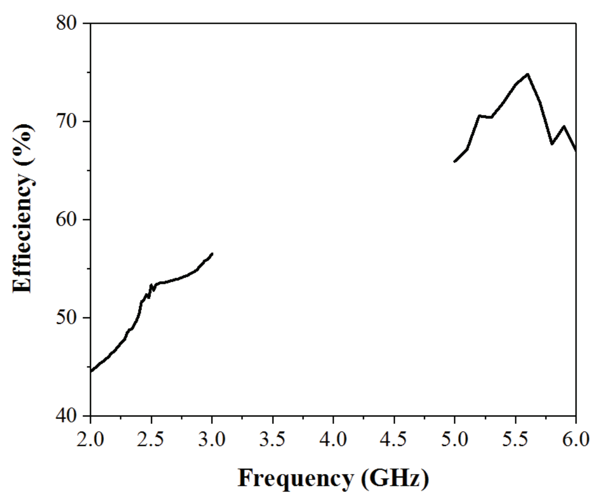


Figure 8. The measured radiation efficiency of the proposed MIMO antenna.

4. CONCLUSION

A novel multiband MIMO antenna system has been proposed in this letter. Two identical antenna elements are placed perpendicular to each other. In addition, a defected ground structure with two microstrip lines has been used to achieve high isolation. The measurement results of the fabricated prototype show that it is suitable to be used in TD-LTE (2300–2655 MHz) and WLAN 802.11 a/b/g (2.4–2.4835, 5.15–5.875 GHz) wireless communication systems.

ACKNOWLEDGMENT

This work was supported in part by Zhejiang Provincial Natural Science Foundation of China under Grant No. LY12F04002 and National Natural Science Foundation of China under Grant No. 61340049 and No. 61671330.

REFERENCES

1. Zhao, L., L. Liu, and Y.-M. Cai, "A MIMO antenna decoupling network composed of inverters and coupled split ring resonators," *Progress In Electromagnetics Research C*, Vol. 79, 175–183, 2017.
2. Luo, X., J. Yuan, and K. Chen, "Compact and low profile MIMO antenna for dual-WLAN-band access points," *Progress In Electromagnetics Research Letters*, Vol. 67, 97–102, 2017.
3. Rao, P. S., K. J. Babu, and A. M. Prasad, "Compact multi-band MIMO antenna with improved isolation," *Progress In Electromagnetics Research M*, Vol. 62, 199–210, 2017.
4. Lee, J. Y., S. H. Kim, and J. H. Jang, "Reduction of mutual coupling in planar multiple antenna by using 1-D EBG and SRR structures," *IEEE Trans. Antennas Propag.*, Vol. 63, No. 9, 4194–4198, Sept. 2015.
5. Abdalla, M. A. and A. A. Ibrahim, "Compact and closely spaced metamaterial MIMO antenna with high isolation for Wireless applications," *IEEE Antennas Wireless Propag. Lett.*, Vol. 12, 1452–1455, 2013.
6. Ghalib, A. and M. S. Sharawi, "TCM analysis of defected ground structures for MIMO antenna designs in mobile terminals," *IEEE Access*, Vol. 5, 19680–19692, 2017.
7. Chen, Y. S. and C. P. Chang, "Design of a four-element multiple-input–multiple-output antenna for compact long-term evolution small-cell base stations," *IET Microw. Antennas Propa.*, Vol. 10, No. 4, 385–392, Mar. 2016.
8. Wu, Y. t. and Q. X. Chu, "Dual-band multiple input multiple output antenna with slitted ground," *IET Microw. Antennas Propa.*, Vol. 8, No. 13, 1007–1013, Oct. 2014.
9. Yu, Y., L. Yi, X. Liu, and Z. Gu, "Compact dual-frequency microstrip antenna array with increased isolation using neutralization lines," *Progress In Electromagnetics Research Letters*, Vol. 56, 95–100, 2015.
10. Wang, Y. and Z. Du, "A wideband printed dual-antenna with three neutralization lines for mobile terminals," *IEEE Trans. Antennas Propag.*, Vol. 62, No. 3, 1495–1500, Dec. 2013.
11. Soltani, S. and R. D. Murch, "A compact planar printed MIMO antenna design," *IEEE Trans. Antennas Propag.*, Vol. 63, No. 3, 1140–1149, Mar. 2015.
12. Palandoken, M., "Dual broadband antenna with compact double ring radiators for IEEE 802.11 ac/b/g/n WLAN communication applications," *Turkish Journal of Electrical Engineering & Computer Sciences*, Vol. 25, 1326–1333, 2017.
13. Dong, X., Z. Liao, J. Xu, Q. Cai, and G. Liu, "Multiband and wideband planar antenna for WLAN and WiMAX applications," *Progress In Electromagnetics Research Letters*, Vol. 46, 101–106, 2014.
14. Palandoken, M., *Artificial Materials Based Microstrip Antenna Design*, INTECH Open Access Publisher, 2011.
15. Blanch, S., J. Romeu, and I. Corbella, "Exact representation of antenna system diversity performance from input parameter description," *Electron. Lett.*, Vol. 39, No. 9, 705–707, May 2003.