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MIMO Monopole Antenna Design with Improved Isolation for 5G WiFi Applications

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ABSTRACT

In this manuscript, a compact multiple-input-multiple output (MIMO) monopole antenna for 5G WiFi applications is proposed. The antenna is designed using a cheap FR-4 substrate with properties of ε=4.3 and δ=0.025. The proposed design has microstrip-fed circular ring radiators and a T-shaped defected ground plane (DGS). By inserting the T-shaped DGS, the mutual coupling characteristic of the antenna has been reduced and good isolation is obtained. The antenna operates in the range of 5 to 6 GHz with a reflection coefficient<-30 dB and mutual coupling<-20 dB which covers the required frequency bandwidth of 5G WiFi systems. The antenna has overall dimension of 30×20×0.8 mm^3. The simulated results in terms of different antenna specifications have been presented and discussed.

Keywords: *5G; monopole antenna, reduced mutual coupling; WiFi communications*

INTRODUCTION

5G technology can handle over thousand times more mobile traffic than previous mobile communication networks [1-3]. The evolution from 4G to 5G is mainly driven by the growing need for higher data rate communications in different applications such as high-quality video streaming [4-8]. The fifth-generation wireless fidelity (5G Wi-Fi) systems become very popular in the wireless communications. The operating frequency band of 5G WiFi is from 5.15 GHz to 5.875 GHz which provides high-speed and convenient wireless access [9-10]. In the modern wireless communications for reduced multipath fading and increased capacity, multiple-input-multiple-output (MIMO) systems is becoming a key part of wireless networks [11-12].Besides having small-size, the MIMO antenna is preferred to be low cost, easy to fabricate [13-15]. Microstrip monopole antennas have received owing their attractive features such as low-profile, low-cost, easy of fabrication, and omnidirectional radiation patterns [16-20].

Omni-directional microstrip monopole antennas are suitable for increased capacity MIMO systems [21-23]. Many antennas with different structures for MIMO applications have been reported in the last decade [24-30].This study describes the design of a small-size printed MIMO monopole antenna for 5G WiFi applications.

The antenna is working from 5 to 6 GHz covering 5.15-5.875 5G WiFi. The proposed design consists of two microstrip-fed circular-ring monopole antennas with a T-shaped slit as an isolating element in the ground plane. The inserted T-shaped DGS not only reduces the coupling characteristic of the MIMO antenna, but also improves the antenna efficiency. Simulated results of the proposed MIMO antenna including S parameters, current distribution, 3D and normalized radiation patterns are studied. The obtained results demonstrate that the proposed MIMO antenna could be used in 5G WiFi platforms.

5G ANTENNA CONFIGURATION

Figure 1 displays the configuration of the proposed MIMO antenna. As can be observed, it is composed of two microstrip-fed circular-ring monopole antennas. In addition, a T-shaped DGS has been inserted in the ground plane. Using the DGS, the antenna can provide sufficient mutual coupling characteristic. The antenna is designed on a cheap FR-4 substrate (ε=4.3 and δ=0.025) and has a compact size of $W_{sub}\times L_{sub}\times h_{sub}$=30×20×0.8 mm^3.The parameter values of the MIMO antenna are listed in Table I.

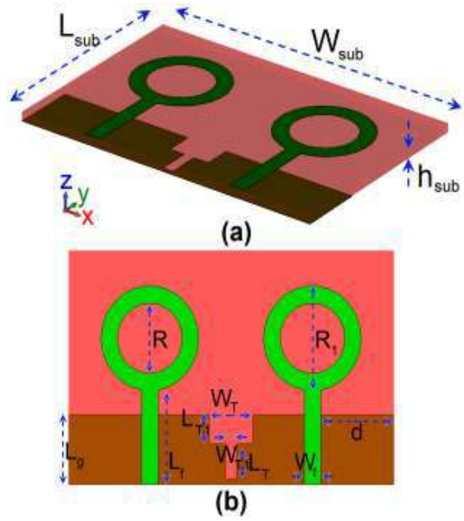

Figure1. *Configuration of the MIMO antenna, (a) side and (b) top views*

Table1. *Dimension Values of the MIMO Antenna*

Parameter	W_{sub}	L_{sub}	L_f	W_T	L_T	W_f
Value (mm)	30	20	8	4	3	1.5
Parameter	W_{T1}	L_{T1}	L_g	R	R_1	d
Value (mm)	1	2.5	6	6	9	7

SINGLE ELEMENT MONOPOLE ANTENNA

Figure 2 displays the transparent view of the monopole antenna. As shown, the antenna configuration is composed of circular-ring radiation patch with rectangular microstrip feed-line and a ground plane. The antenna size is 15×20 mm^2. It is designed on a cheap FR4 substrate to work at 5.5 GHz. The antenna frequency response (S_{11}) is illustrated in Fig. 3. It can be seen the antenna resonance is at 5.5 GHz and has more than 1 GHz bandwidth.

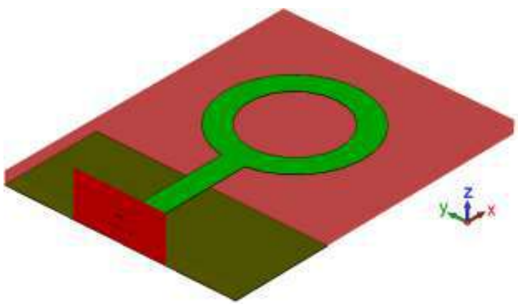

Figure2. *Single element monopole antenna*

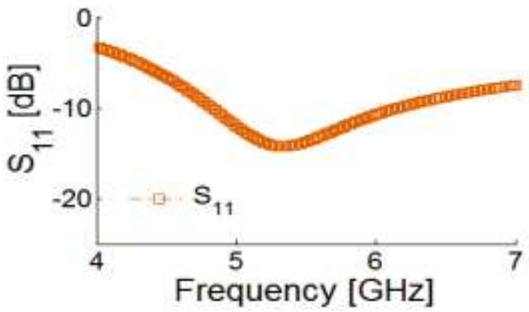

Figure3. *Frequency response of the monopole antenna.*

Figure 4 shows the 3D radiation patterns of the proposed monopole antenna at 5.2, 5.5, and 5.8 GHz, respectively. As shown, the designed monopole antenna has good radiation behavior with omnidirectional patterns. The realized gain values of the antenna varies from 1.9 to 2.1 dB in the frequency range of 5.2 to 5.8 GHz.

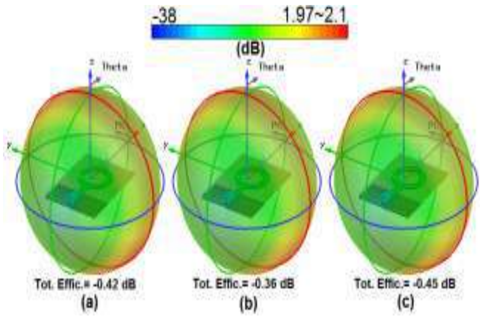

Figure4. *(a) 3D views of the antenna radiation patterns at (a) 5.2 GHz, (b) 5.5 GHz, and (c) 5.8 GHz.*

Furthermore, the proposed antenna has good radiation and total efficiency characteristics even though it is designed on a high-loss FR4 substrate. As seen, the total efficiencies of the antenna at 5.2, 5.5 and 5.8 GHz are -0.42, -0.36, and -0.45 dB, respectively. In the following, the performance of the MIMO configuration of the monopole antenna has been investigated.

THE PROPOSED MIMO ANTENNA

As illustrated in Fig. 1, a pair of monopole antenna are used to form the proposed MIMO antenna. In addition, a T-shaped DGS has been used to reduce the mutual coupling characteristics of the MIMO elements. Figure 5 depicts the simulated S_{11} and S_{21} characteristics of the final design. It can be seen that the MIMO antenna has a good frequency response in the range of 5-6 GHz. As shown, the reflection coefficient of the MIMO antenna at 5.5 GHz (resonance frequency) is less than -30 dB. In addition, the antenna has -20 dB isolation at 5.5 GHz which makes it suitable for MIMO applications.

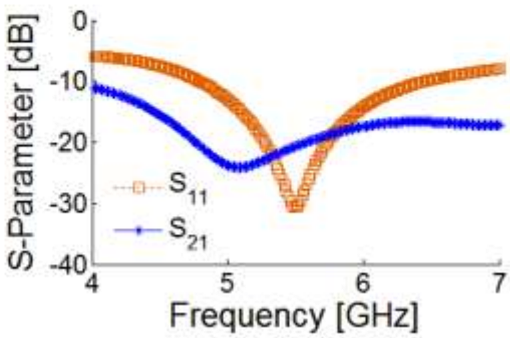

Figure5. *S_{11} and S_{21} characteristics of the MIMO antenna*

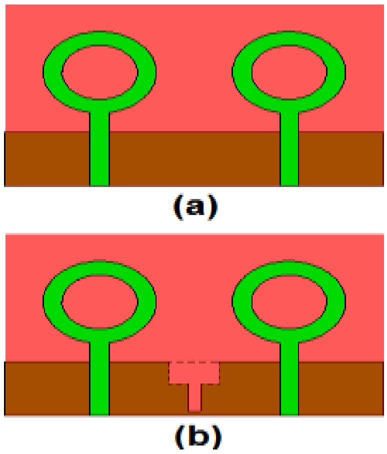

Figure6. *Configuration the proposed MIMO design, (a) with and (b) without T-shaped DGS*

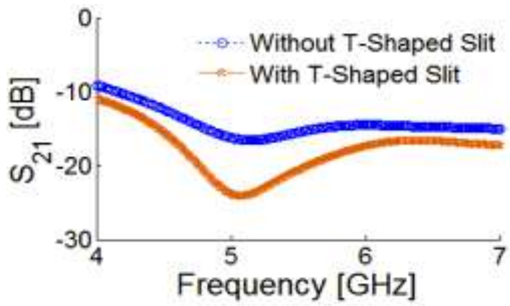

Figure7. *S_{21} characteristics of the MIMO antenna w/wo T-shaped DGS*

Figure 6 shows the configurations of the antenna w/wo the DGS.In order to known the phenomenon behind the usage of T-shaped DGS, the mutual coupling (S_{21}) characteristics of the MIMO antenna w/wo the inserted T-shaped DGS have been studied. As illustrated in Fig. 7, by using the DGS, the mutual coupling characteristic of the MIMO antenna has been decreased significantly in the operation band [31-33].

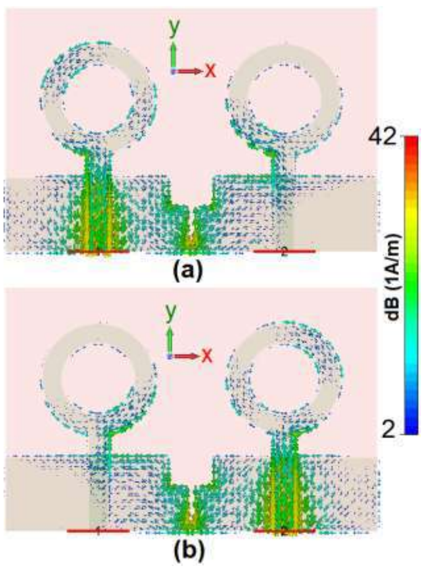

Figure8. *Current Distributions Of The Proposed MIMO Antenna When, (A) Port 1 Is Excited And (B) Port 2 Is Excited.*

The simulated Surface-current distribution for the proposed antenna at 5.5 GHz when the antenna elements are fed separately have been represented in Fig. 8. As shown, at the resonance frequency, the current flows are more dominant around of the radiation element which has been excited. In addition, the impact of T-Shaped DGS on the performance of the antenna can be observed in Figs. 8 (a) and 8 (b). From this result, we can conclude that the employed DGS has impact on the improved performance of the proposed MIMO antenna [34-36].

Figure 9illustrates the normalized radiation patterns of the proposed MIMO antenna including E-plane (phi=0) and H-plane (phi=90) at different frequencies. The illustrated results are achieved by exciting on of the elements. It can be seen that omnidirectional radiation patterns have been obtained for the proposed design [37-40]. Another monopole element has a same performance at the cited frequencies.

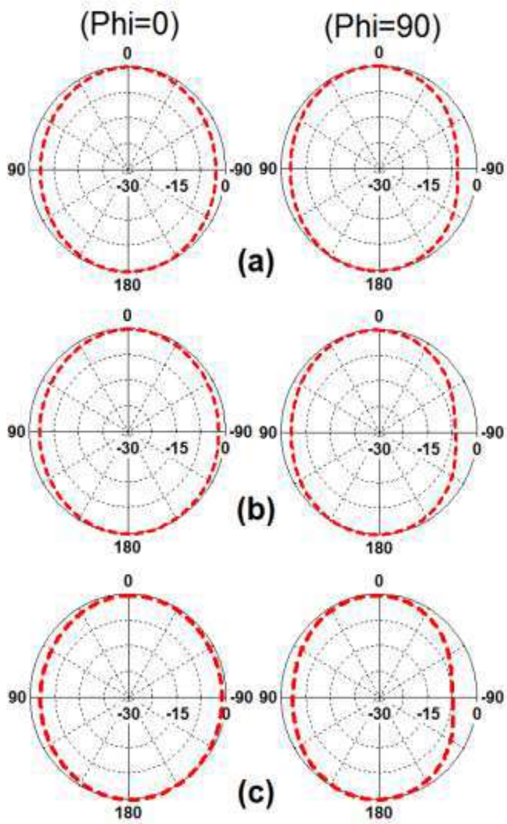

Figure9. *Normalized radiation patterns of the antenna at (a) 5.2 GHz, (b) 5.5 GHz , and (c) 5.8 GHz.*

3D radiation patterns of the proposed design with directivity values are illustrated in Fig. 10. The antenna elements are fed separately (Figs. 10 (a) and 10 (c)) and also together (Fig. 10 (b). As shown, the antenna has various polarization based on exciting the elements. In addition, good values of the directivity have been achived for the proposed design.

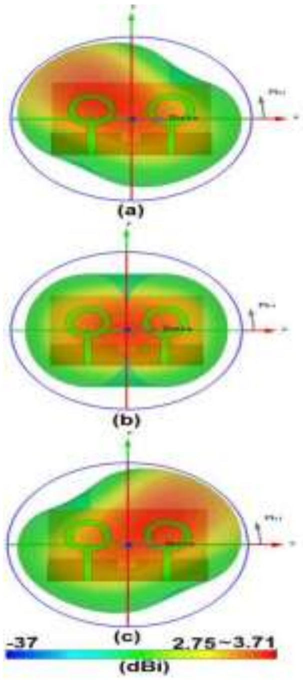

Figure10. *3D view of the antenna radiation patterns for (a) antenna 1, (b) MIMO antenna, and (b) antenna 2.*

CONCLUSION

In this paper, a compact design of MIMO antenna for 5G WiFi systems is proposed. Input impedance and fundamental radiation properties of the proposed antenna are represented. The antenna is working from 5 to 6 GHz and has some attractive features such as low-profile, good radiation behavior and high isolation.

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