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COMPACT SIZE AND DUAL BAND SEMICIRCLE SHAPED ANTENNA FOR MIMO APPLICATIONS

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Abstract—A planar dual-band semicircle shaped antenna for multi-input multi-output (MIMO) systems is introduced. The antenna was studied experimentally regarding bandwidth and radiation patterns. The measured −10 dB return loss bandwidth is from 2.27 to 2.53 GHz and 5.03 to 5.58 GHz, covering all the 2.4/5.2 GHz WLAN bands. Details of the antenna design, simulated and measured results on the return loss and the E- and H-plane radiation patterns of the proposed antenna are presented. The multi-feed 4-elements planar array is simulated using the commercially available software Ansoft HFSS and fabricated that are verified by good agreement between simulated and measured results. The enhanced performance is obtained by placing antennas uniquely to suppress mutual coupling and utilizing supplemental structure to miniaturize the size of the antennas.

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1. INTRODUCTION

The MIMO communication system has been one of the most promising technologies, well suited for high data rate communication. A MIMO system utilizing several antenna components is more advantageous than single-input single-output (SISO) in an aspect of increasing channel capacity and reducing transmitting power [1, 2]. However, multiple antennas can increase the size of the system and worsen isolation between them. Multiple antennas spaced closely in small device results in huge mutual coupling that makes distorted radiation pattern and decreases channel capacity. Several works have shown accomplishments involved in reducing the mutual coupling by using sizable features like electric wall and space between antennas [3, 4]. There is a growing interest and need for developing new antennas suitable for MMIC applications using CPW technology. CPW is an attractive feeding mechanism that is suitable for both integrations with passive and active devices.

A CPW-fed antenna not only performs better with respect to bandwidth and radiation pattern, but also is easily manufactured, which has increased its importance. Recently, there are rapid developments in wireless communications, in order to satisfy the IEEE WLAN standards in the 2.45 and 5 GHz bands [5].

The WLAN systems have been widely adopted and incorporated in commercial merchandise such as laptop computers or personal digital assistants (PDAs). Therefore, the increasing need of dual-band antennas with light weight and low profile has stimulated comprehensive researches to pursue cost-effective antenna designs. As well known, conventional microstrip antennas have these advantages at the expense of insufficient bandwidth and awkward dimensions [6, 7] while traditional slot-loaded planar inverted-F antennas (PIFAs) possess wider bandwidths at the cost of complexity in their dual mechanism [8, 9]. CPW-fed antennas have attracted more attention owing to the fact that CPW-fed antennas have the characteristics of broadband and feasibility of dual-band operations [10, 11].

A novel four E-shaped patch antennas for MIMO application is proposed in [12]. The single E-shaped patch antenna operates at 5.8 GHz and is designed using the Invasive Weed optimization algorithm. The algorithm is applied to design the selected orthogonal polarization arrangement for two and four elements MIMO antenna for coupling reduction.

Ref. [13] presents a design of wireless broadband MIMO and personal communication service (PCS) antenna for practical mobile phone. To decrease the mutual coupling of wireless broadband MIMO antennas, some slits on the ground structure can be used.

Ref. [14] presents the analysis and design of a two-probe excited circular ring antenna. The analysis is conducted by using induced EMF method and transmission line model. This antenna is suitable for MIMO system covering a long and narrow environment.

In this paper, we present a design of dual band MIMO antenna, with a compact size and low mutual coupling between antennas. Antennas operating at 2.45 and 5.2 GHz are proposed, which have −10 dB return loss bandwidths of 10.6% and 10.5%, respectively. The designed antenna has been successfully implemented, and experimental results are presented and discussed.

2. ANTENNA GEOMETRY

The geometry and parameters of the monopole antenna with semicircle shaped stub are shown in Fig. 1. The antenna is etched on Rogers RO4003 substrate with a thickness of 0.5 mm (20 mil) and dielectric constant of 3.38. The size of the antenna is $W \times L = 26\,\text{mm} \times 30\,\text{mm}$, and the dimensions of the ground plane is $W \times L_g = 26\,\text{mm} \times 5\,\text{mm}$. The antenna is excited by a 50 Ω microstrip line with semicircle shaped tuning stub. The width of the 50 Ω microstrip line is $W_f = 2\,\text{mm}$, and the gap of the CPW line is $g = 0.1\,\text{mm}$. Detailed dimensions of the proposed antenna are $L_f = 28\,\text{mm}$, $w_2 = 19\,\text{mm}$, $w_1 = 2.4\,\text{mm}$,

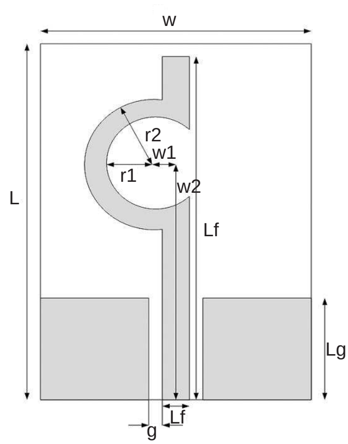

Figure 1. Geometry of the proposed antenna.

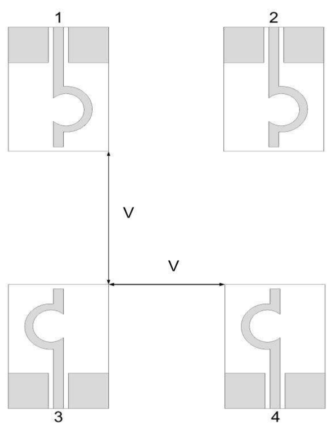

Figure 2. Geometry of the multi-feed 4-elements planar antenna array.

$r_1 = 6\,\mathrm{mm}$ and $r_2 = 8\,\mathrm{mm}$.

The configuration of the antenna that functions as MIMO system is shown in Fig. 2. Four identical antennas are printed on ROGER4003 substrate with dielectric constant of 3.38 and thickness of 0.5 mm. The size of the substrate is $90\,\mathrm{mm} \times 82\,\mathrm{mm}$, and the distance between antenna elements is $v = 30\,\mathrm{mm}$ ($\sim \lambda/4$).

The photograph of the fabricated array antenna is shown in Fig. 3.

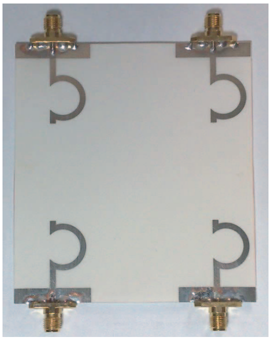

Figure 3. Photograph of multi-feed 4-elements planar antenna array.

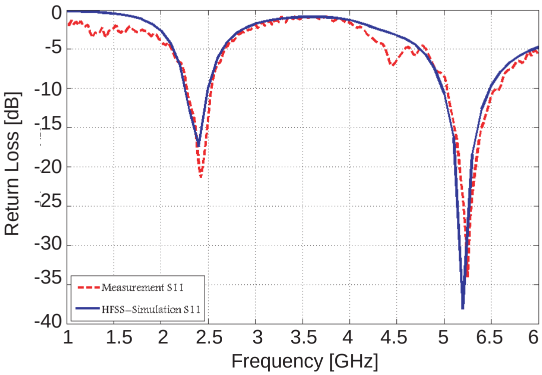

Figure 4. Measured and simulated return losses.

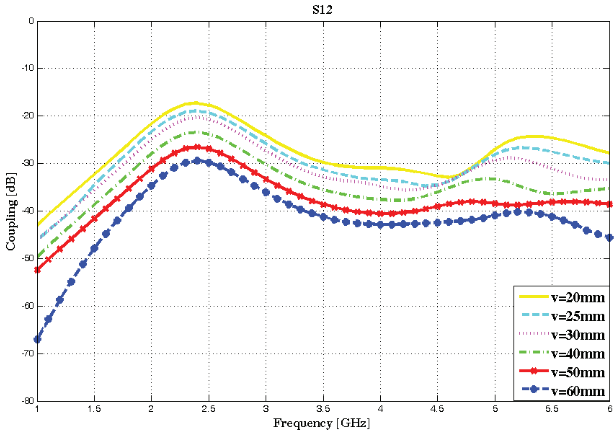

Figure 5. The effect on coupling due to the change of V (distance between antenna elements).

3. RESULTS AND DISCUSSION

The antenna performance was investigated by simulation via HFSS (High Frequency Structure Simulator) software. Fig. 4 shows the measured and simulated return losses of the proposed antenna.

The obtained −10 dB return loss bandwidths are 260 MHz (2.27–2.53 GHz) and 550 MHz (5.03–5.58 GHz), corresponding to the bandwidth of 10.6% and 10.5% with respect to the appropriate resonant frequencies. The achieved bandwidths can cover the WLAN standards in the 2.4 GHz (2.4–2.484 GHz) and 5.2 GHz (5.15–5.35 GHz) bands.

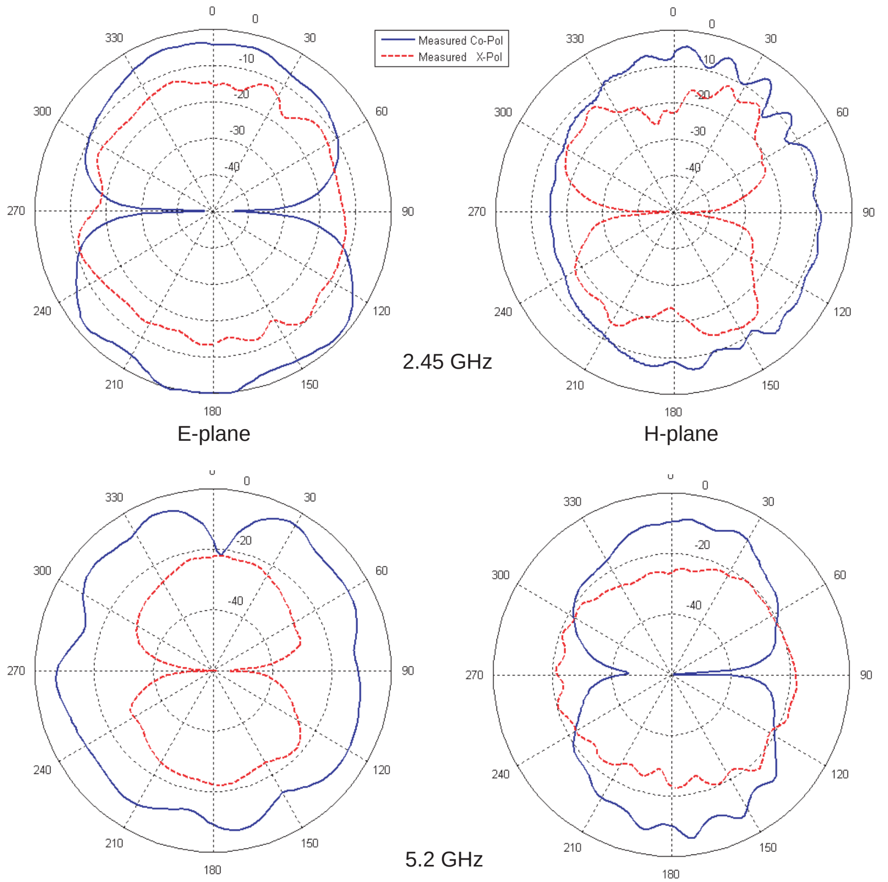

Figure 6. Measured *E*- and *H*-plane radiation pattern at 2.4 and 5.2 GHz.

Figure 5 shows the effect of changing V (distances between antenna elements) on the coupling.

Figure 6 shows the measured E- and H-plane radiation patterns at 2.45 and 5.2 GHz including both co- and cross-polarization. It can be seen that the good broadside radiation patterns are observed, and the cross polarization radiation in the H-plane is less than -12 dB; however the cross polarization in the E-plane is greater.

The measured mutual coupling results of the 4-elements planar antenna array system (2×2) are shown in Fig. 7. The mutual coupling is relatively weak. The mutual coupling is quite low ($S_{ij} < -23.25$ dB) in Fig. 7 as expected, which decreases rapidly with distance. The low coupling between the elements in the array is because of the small size of the antenna elements, which increase the distance between them. In addition, the CPW-fed antenna is inherent in low coupling between adjacent elements.

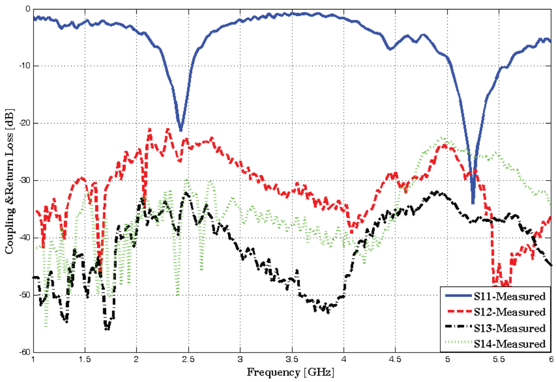

Figure 7. Measured mutual coupling results of the 4-elements planar antenna array system (2×2).

4. CONCLUSION

A CPW-fed monopole antenna with semicircle shaped stub has been proposed for the 2.4/5.2 GHz dual-band WLAN operations. The two operating frequencies of the presented antenna are of the same polarization planes and have similar radiation characteristics. The antenna has characteristics of compact size, low profile, simple structure and good omni-directionality. The antenna gains ($\varphi = 0$) are over 1.45 dB and 3.85 dB for 2.45 and 5.2 GHz bands, respectively. The multi-feed 4-elements planar antenna array formed with the compact

CPW-fed antennas also has satisfied input return loss bandwidth, and small mutual coupling are promising for MIMO applications.

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