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Research Article

Low-Profile Dual-Wideband MIMO Antenna with Low ECC for LTE and Wi-Fi Applications

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This paper presents a low-profile dual-wideband multiple input multiple output (MIMO) antenna with low envelop correlation coefficient (ECC) for long-term evolution (LTE) and wireless fidelity (Wi-Fi) applications. The antenna covers LTE band 7 and Wi-Fi as well as wireless broadband (Wibro) and Worldwide Interoperability for Microwave Access (WiMax) (except for the 3.5-GHz band). To aid with integration of a practical mobile terminal, the MIMO antenna elements are placed at appropriate locations by analyzing the surface current distribution and without using any additional isolation techniques. The measured bandwidths with reflection coefficients of < -10 dB are 36.8% in the range 2.02–2.93 GHz and 23.4% in the range 5.10–6.45 GHz. Isolation is satisfied to be >20 dB in the operating frequency ranges of both LTE band 7 and Wi-Fi. Additionally, the calculated ECC is in the range $0.005 < \rho < 0.025$, which is considerably lower than the $\rho < 0.5$ required for MIMO applications. The measured radiation patterns are appropriate for mobile terminals, and omnidirectional radiation patterns are obtained.

1. Introduction

Wireless communications systems should be of high quality and should provide services with a high data rate. Antenna diversity using MIMO is a well-known technique to improve the performance of wireless communications systems by reducing multipath-induced fading and cross-channel interference [1]. In a MIMO system, multiple antennas are used to increase channel capacity without requiring additional power sources [2]. It is relatively simple to implement a wireless communications system at a base station using antenna separation into many wavelengths; however, for high-quality wireless download signals, more than one antenna is required on the terminal side. In this type of mobile terminals, two or more antenna elements are employed, and, here, the restricted space available for the antenna is an issue of achieving channel separation [3]. Low-profile dual-band components are preferred because many communications systems operate in dual bands. However, it is difficult to closely integrate multiple antennas into a compact space while maintaining good isolation between antenna elements to achieve channel separation, particularly for dual-band antenna arrays, and the efficiency of a MIMO communications system is affected by spatial correlations due to the mutual coupling of array elements [4–6].

A MIMO antenna system requires a high level of isolation between antenna elements; however, in a typical MIMO system, the space limitations mean that antennas must be placed close to each other. Therefore, we should investigate optimal locations for closely spaced antenna elements to achieve channel separation [7]. Some attempts have been made to design arrays with little interference using mushroom-like electromagnetic band-gap structures, ground structures containing defects, and parasitic elements [8–10]. However, these techniques cannot be employed in a practical mobile terminal with a printed circuit board (PCB) along with other

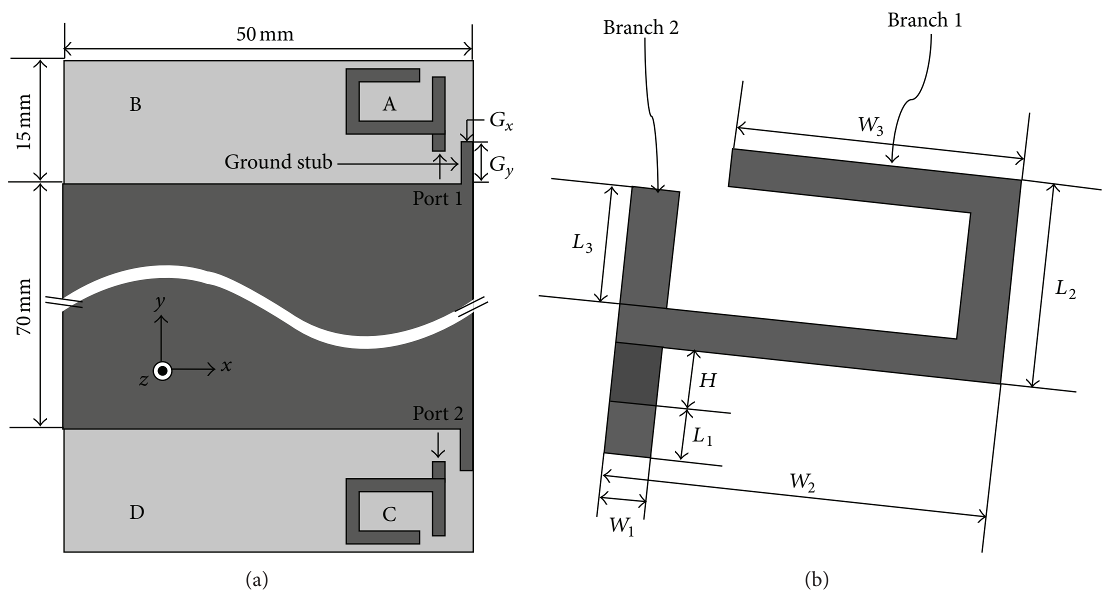


Figure 1: Proposed WLAN antenna: (a) geometry and (b) radiator.

electronic components because these techniques require additional areas where the solid ground plane is modified or removed. Recently, the MIMO antennas yielding good isolation performances without the use of extra isolation enhancement element have been studied [11, 12]. However, they have a high profile, 6 dB return loss bandwidth, and high ECC.

In this paper, we propose a low-profile dual-wideband MIMO antenna for long-term evolution (LTE) band 7 and Wi-Fi applications. A single antenna with a wide bandwidth that exhibited a reflection coefficient of $S_{11} < -10$ dB using a ground stub is designed; the locations of the antenna elements were adjusted to achieve minimal interference through the current distribution analysis without employing additional isolation techniques, which may not be practicable. CST Microwave Studio was used for the design and analysis of the structure, which was subsequently fabricated and characterized.

2. Antenna Design

The MIMO antenna should cover all frequency bands required for LTE band 7 and Wi-Fi applications. Figure 1 presents the geometry of the proposed MIMO antenna. The prototype of the antenna is the two-strip monopole antenna. After satisfying the S_{11} characteristic of the antenna element, the optimal position of the MIMO antenna is identified.

The current path length of branch 1 is set at approximately 30 mm, which corresponds to a quarter-wavelength of 2.5 GHz. Thereafter, the length of branch 2 is set not only to ensure the resonance is 5.2 GHz as in branch 1 but also to ensure narrow impedance bandwidths. To improve the bandwidth, a ground stub ($G_x = 1.5$ mm × $G_y = 5.0$ mm) is inserted. This ground stub increased the lower bandwidth from 21.6% (2.06~2.56 GHz) to 28.3% (2.09~2.78 GHz), and increased the higher bandwidth from 4.1% (4.72~4.92 GHz) to 24.1% (4.75~6.05 GHz).

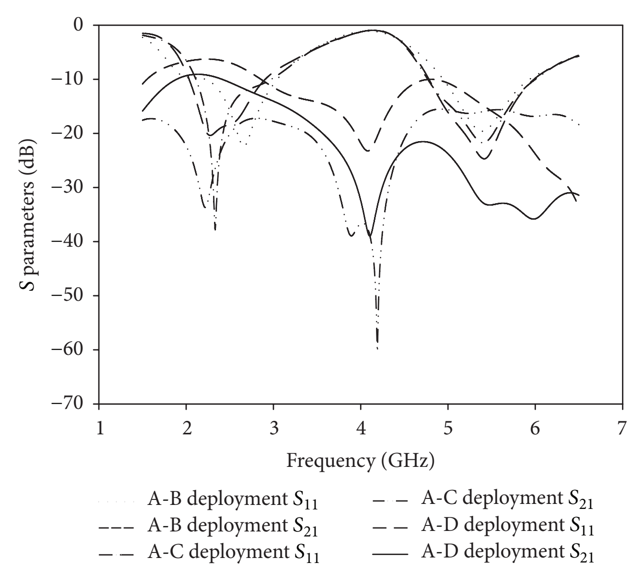
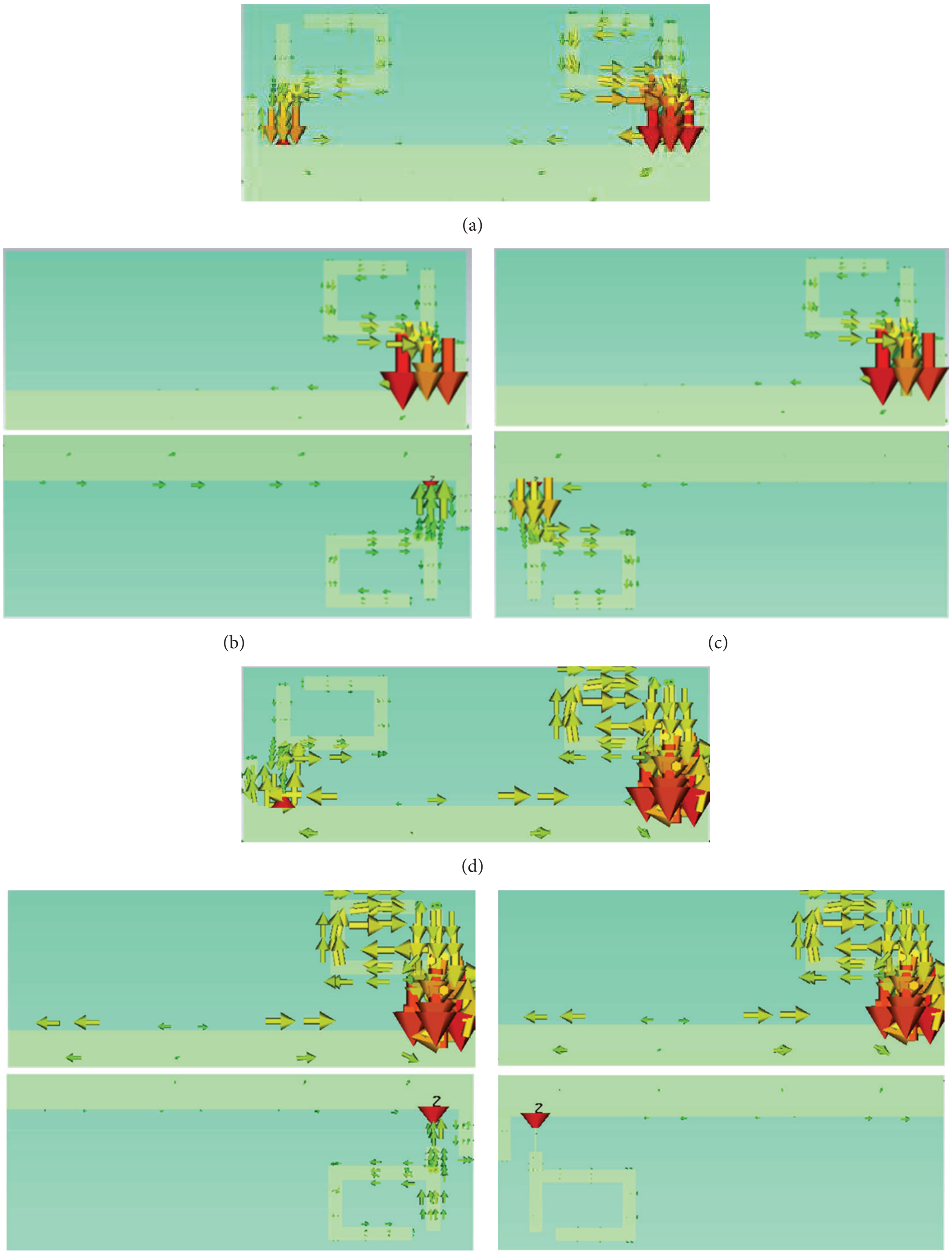


Figure 2: The S-parameters of the MIMO antennas separated along the lines A-B, A-C, and A-D.

Figure 2 presents the S_{11} and S_{21} characteristics of the proposed MIMO antenna elements A-B, A-C, and A-D. S_{22} and S_{12} do not appear because the proposed MIMO antenna elements are deployed symmetrically. One might expect that S_{21} would perform best when the MIMO antenna elements are deployed in an A-D configuration, because the distance between the antenna elements is the greatest among these configurations. However, results reveal that S_{21} performs best in the A-C configuration at the low operating frequency bands. S_{21} performs satisfactorily above 7 dB, 17 dB, and



(a) (b) (c) (d) (e) (f)

Figure 3: The current distribution at 2.5 GHz and 5.5 GHz in the MIMO antennas separated along (a) the width (A-B), (b) the length (A-C), and (c) the diagonal (A-D) at 2.5 GHz, (d) the width (A-B), (e) the length (A-C), and (f) the diagonal (A-D) at 5.5 GHz.

10 dB, respectively, for the A-B, A-C, and A-D configurations. Both the distance between the antenna elements and the current distribution are important characteristics of S_{21}. The amount of coupling between the two adjacent antennae depends on both the direction of the current flow on the surface and the distance between the two antennae. If the current direction is the same on the adjacent sides of both antennae, the mutual coupling increases; if the current flow is opposite, then induced mutual coupling is cancelled. As shown in Figure 3, in the A-B and A-D configurations, the current direction is the same. In contrast, in an A-C configuration, it is the opposite.

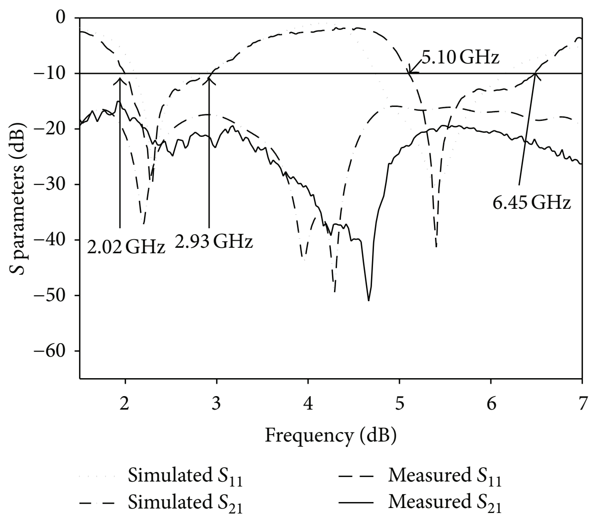


Figure 4: Simulated and measured reflection and transmission coefficients of the MIMO antennas.

3. Measurement Results

The MIMO antennas were fabricated using the optimized parameters from the simulation analysis described above, which are listed in Table 1. A 0.8mm thick FR4 substrate with dimensions of 50 × 100 mm and relative permittivity of $\varepsilon_r = 4.4$ was used. The overall volume of the antenna array was less than $12 \times 8 \times 1\,\text{mm}^3$. Identical antennas were deployed symmetrically along the diagonal A-C. The MIMO antennas were characterized using an HP 8719ES network analyzer.

Figure 4 shows the simulated and measured reflection coefficients, as well as the transmission coefficients S_{21}, which show the isolation of the antennas. The measurement results are in good agreement with the simulation analysis, albeit with a small shift in the resonance frequency, which is attributed to the fabrication tolerances at the feed points. The fractional bandwidth of the fabricated antenna, where the reflection coefficient was $S_{11} < -10$ dB, was 36.8% in the range of 2.02–2.93 GHz and 23.4% in the range of 5.10–6.45 GHz. The measured isolation was favorable, and no additional area or removal of the solid ground plane of the PCB was required. The isolation was less than −20 dB across the operating frequencies of LTE band 7 and Wi-Fi applications, and, therefore, these results are of practical utility.

Another important parameter of MIMO antennas is the envelope correlation coefficient (ECC). The diversity of a MIMO system can be evaluated using ECC. For a two-element MIMO system, ECC can be calculated as follows [13]:

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

The ECC values at various frequencies are listed in Table 2. For a MIMO system, we require $\rho < 0.5$ [14]. The data listed in Table 2 reveal that our fabricated MIMO antennas easily satisfy this criterion.

Table 1: Optimized parameters of the MIMO antenna.

Parameter	Value (mm)
W_1	1.5
W_2	12.0
W_3	9.0
G_x	1.5
H	1.0
L_1	2.0
L_2	8.0
L_3	5.5
G_y	5.0
Ground	50 × 70

Table 2: ECC for our fabricated MIMO antennas at various frequencies.

Freq. (GHz)	ECC
2.4	0.00834
2.5	0.01674
2.6	0.01447
2.7	0.00522
5.2	0.01241
5.4	0.02419
5.6	0.00968
5.8	0.02151

Figure 5 shows the measured radiation patterns at 2.5 GHz and 5.5 GHz. The data shown are for the antenna in position A, which is identical to the other antennae because of the symmetry of the system. The measured radiation patterns were nearly omnidirectional. The small degree of directivity results from the yz-plane at high frequencies and is attributed to the large ground plane. The measured gain of the antenna was 4.09 dBi at 2.5 GHz and 4.32 dBi at 5.5 GHz.

4. Conclusion

We have described a compact multiband MIMO antenna with low ECC for LTE band 7 and Wi-Fi applications. The measured reflection coefficients of a single antenna were 36.8% in the range of 2.02 to 2.93 GHz and 23.4% in the range of 5.10 to 6.45 GHz. Isolation was satisfied to be above 20 dB across the operating frequency ranges for LTE band 7 and Wi-Fi applications. This was achieved without requiring an additional area or the removal of any of the solid ground planes of the PCB based on an analysis of the distribution of the surface currents. The calculated ECC was in the range $0.005 < \rho < 0.025$, which is considerably lower than the $\rho < 0.5$ required for MIMO applications. The measured radiation patterns were appropriate for mobile terminals, and omnidirectional radiation patterns were obtained. The measured gain was 4.09 dBi at 2.5 GHz and 4.32 dBi at 5.5 GHz. Based on these metrics, the MIMO antennas reported here are suitable for practical mobile terminals for both LTE band 7 and Wi-Fi applications.

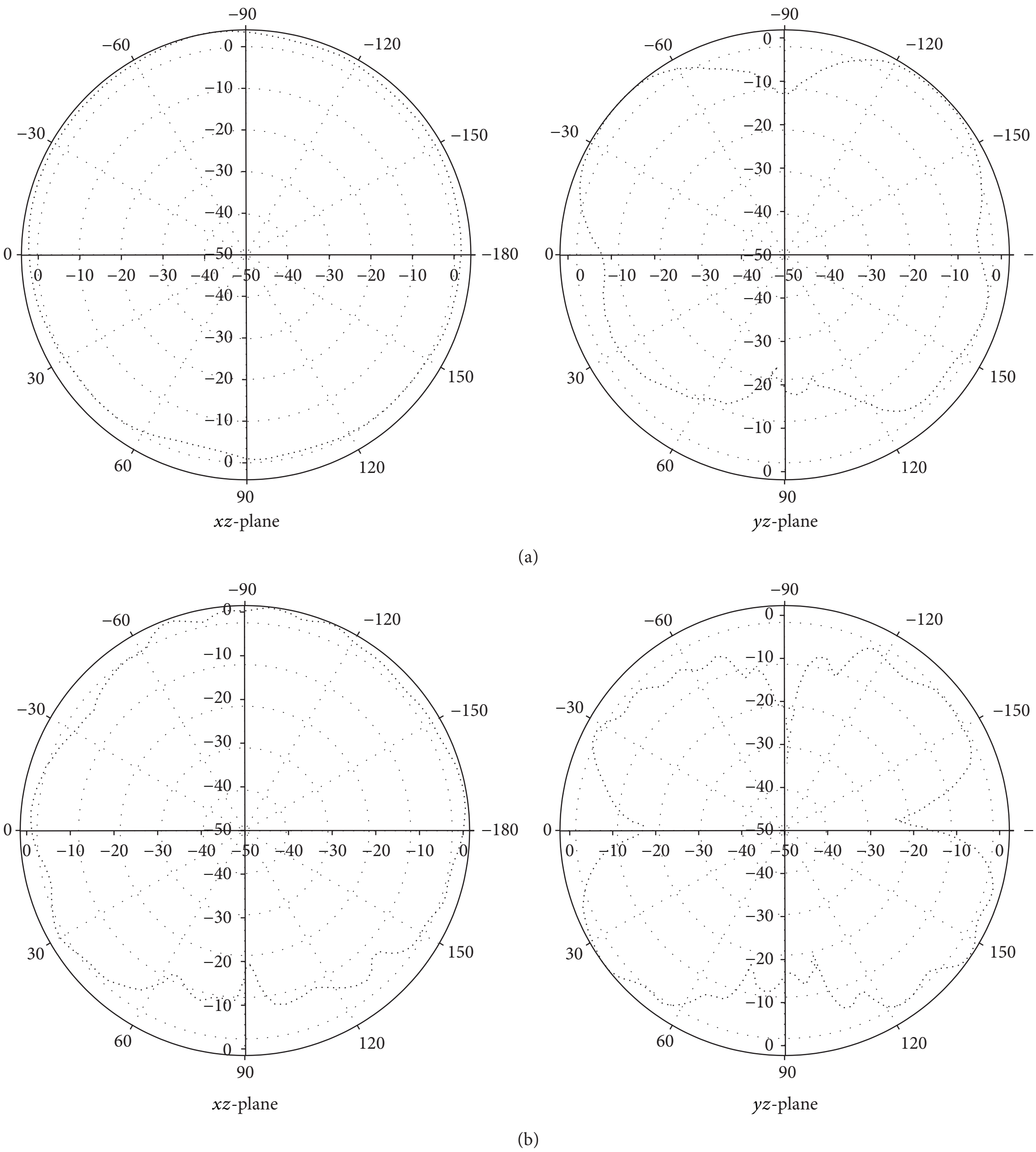


Figure 5: Measured radiation patterns of the antenna at (a) 2.5 GHz and (b) 5.5 GHz.

Conflict of Interests

The authors declare that there is no conflict of interests regarding the publication of this paper.

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