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# A Single-Layer Planar Monopole Dual-Band Coupled Line Antenna with Low Cross-Polarization for LTE Applications

**Wanyi Li, Weimin Wang*, Yongle Wu, and Yuanan Liu**

**Abstract**—In this paper, a novel dual-band antenna with coupled line and different impedance extension lines is presented and analyzed. This simple antenna is composed of three antenna radiations with symmetric coupled lines, and it occupies a compact space of $80 \times 30 \times 1\,\mathrm{mm}^3$. The achieved 10-dB bandwidths of the dual-band operation in free-space condition are 200 MHz and 100 MHz, respectively, which support the 1.8/2.6 GHz Long Term Evolution (LTE) operating bands. Furthermore, various parameters are investigated to examine the effects of the antenna parameters on return loss as well as the gain of the proposed antenna.

## 1. INTRODUCTION

Nowadays, the LTE system with two operating bands, for example, band #3 (1710∼1880 MHz) and band #38 (2570∼2620 MHz), has played an important role in 4G Wireless Wide Area Network (WWAN). To effectively promote the portability of modern personal communication terminals, antennas of low cost, dual-band operation and miniaturized size are in increasing demand. Therefore, some compact and multi-band antennas of low profile and high gain for LTE applications have been proposed recently [1–3], with pony size but unnecessarily complicated structure [4, 5]. The rapid development of wireless local area network (WLAN) applications and wearable communication devices sector promotes the inventions and innovations of relevant antennas [6–10]. Conventional antenna design for WLAN applications usually requires folded or bent metal strips to reduce the overall size, as well as to achieve multi-band operation [11–13]. However, these inventions also inevitably increase the difficulty of antenna manufacturing, leaving insufficient space for further improvement.

Thus, in this letter, a single-layer planar monopole antenna of dual-band operation is introduced. One of its significant improvements is a change in the structure of conventional folded antennas, by designing the symmetrical coupled line. It results in not only dual-band characteristics, but also minimizing the size well. Instead of a direct connection between antenna branches, the coupled line can commendably help reduce the unexpected cross-polarization. In addition, this antenna has no influence on the intact ground structure, greatly guaranteeing the wholeness of the mobile device's original template, in comparison to "DGS" (Defected Ground Structure) antenna designs [3, 6, 8, 14, 15]. Furthermore, it is because of the completely symmetrical structure that this antenna can get the good characteristic of almost omnidirectional radiation in these two resonance frequencies. Low cost, simple process and compact structure create unlimited possibilities for mass production and strong practicability.

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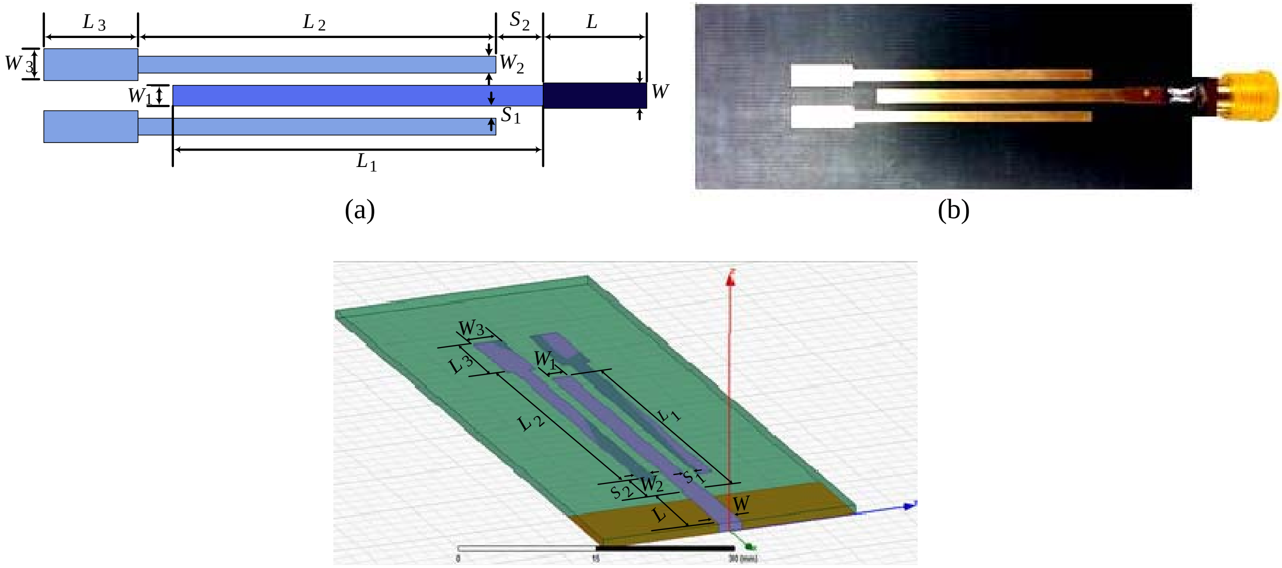


(c)

**Figure 1.** (a) The microstrip layout, (b) a photograph, and (c) a three-dimensional view of the dual-band antenna.

**Table 1.** Optimized dimensions of the proposed antenna.

| **Parameter** | $L$ | $L_1$ | $L_2$ | $L_3$ | $W$ | $W_1$ | $W_2$ | $W_3$ | $S_1$ | $S_2$ |
|---|---|---|---|---|---|---|---|---|---|---|
| **Length (mm)** | 11 | 39.3 | 38 | 10 | 2.7 | 2.2 | 1.8 | 3.4 | 1.3 | 5 |

## 2. ANTENNA DESIGN

The geometrical configuration of the presented dual-band monopole antenna for LTE operations is illustrated in Figures 1(a)–(c), and all the parameters are shown in Table 1. The proposed monopole antenna is a planar structure fed by microstrip line. The radiators include a central stem and a pair of completely symmetric coupled stems, which achieve both of a compact size and two operating bands without folded branches, proposed in Figure 1(a). It is printed on a $80 \times 30 \times 1\text{-mm}^3$ F4B substrate with a relative permittivity of 2.65 and dielectric loss tangent of 0.001, and designed to resonate at around 1.8 and 2.6 GHz. Meanwhile, a photograph is presented in Figure 1(b), and for more intuitive, Figure 1(c) shows a three-dimensional view of the antenna. Above all, the achievement of a complete parametric analysis of each element targeting for specific antennas operation would make it possible to adjust operations of other frequency bands by using the resulting design.

## 3. PARAMETER ANALYSIS

To optimize the antenna for the best effect, it is essential to study how the parameters of the antenna affect $S_{11}$, which is proposed in Figures 2(a)–(e). The tunability of the operation bands is studied under several variable branches of this antenna. In simulation, these elements are represented by the corresponding tabs of $L_1$, $L_2$, $W_3$, $S_1$ and $S_2$ in the geometry model of Figure 1(a). A great amount of information is generated from the results, some of which is further explained in the following parts.

First, with $L_1$ changing from 35.3 mm to 43.3 mm, Figure 2(a) indicates that $L_1$ mainly influences the higher band but has a little effect on the lower one; nevertheless, both bands will be lower as $L_1$ or $L_2$ gets longer. However, the $S_{11}$ of the lower band decreases when $L_1$ grows, which is in contrast to the higher band. Such a result diametrically opposes to the impact of different lengths of $L_2$ on two operation bands presented in Figure 2(b). Apropos of $W_3$ in Figure 2(c), it has little effect on neither

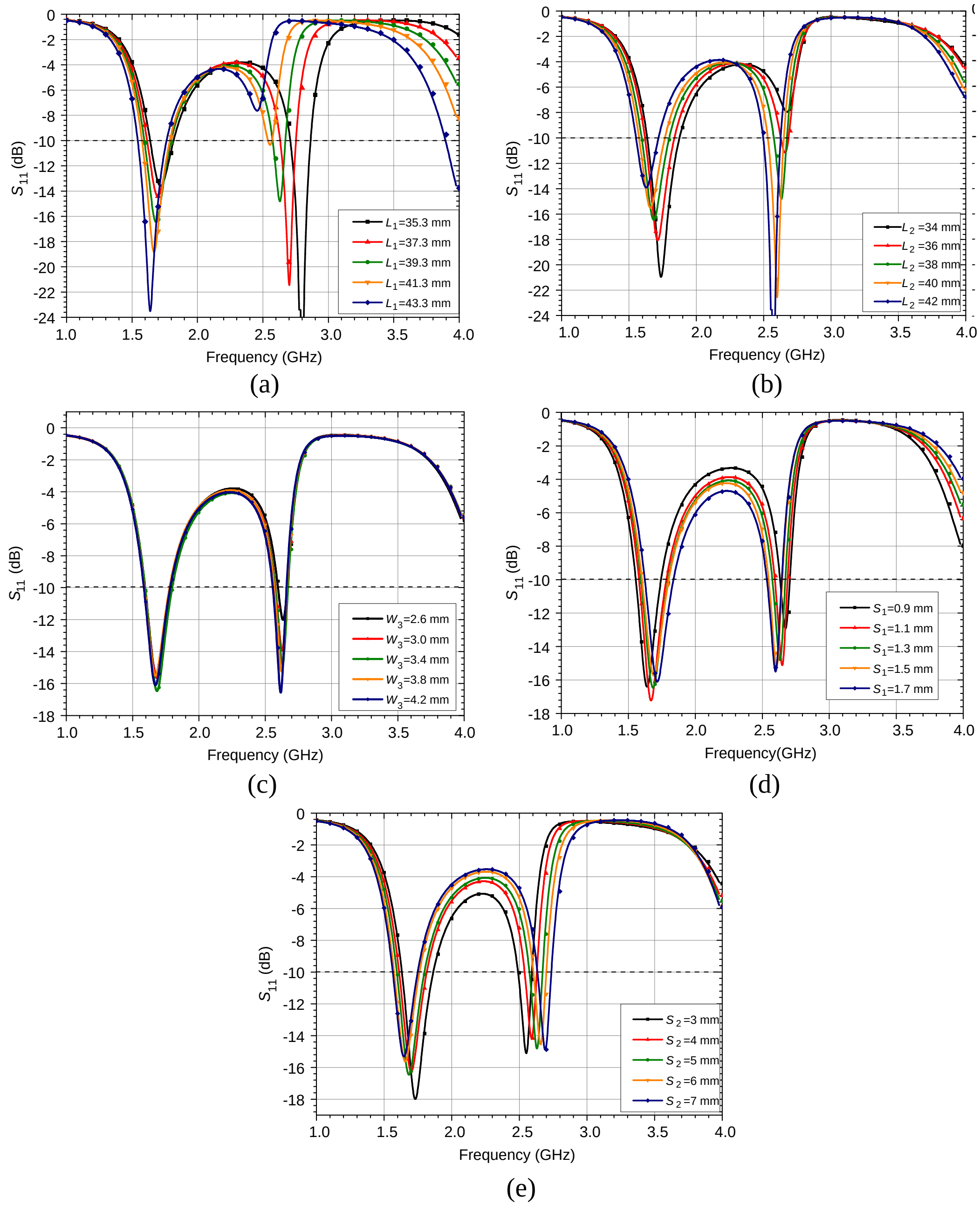


**Figure 2.** Simulated scattering parameters $S_{11}$ for various (a) $L_1$, (b) $L_2$, (c) $W_3$, (d) $S_1$, and (e) $S_2$ values.

the frequency deviation nor the $S_{11}$ of the lower band. As for the coupled line, the gap between two radiators would be in lager part of an impact factor on two frequency bands shown in Figures 2(d)–(e). With $S_1$ decreasing from 1.7 mm to 0.9 mm, the measured resonant frequency in the higher band shifts from 2.6 GHz to 2.7 GHz, while the lower one changes from 1.73 GHz to 1.65 GHz, respectively. Besides, it is noticeable that the resonant frequencies of the two bands get closer as tuning the length of $S_2$ from 7 mm to 3 mm. Thus, the frequency ratios from those simulated data can be studied in Table 2. It is universally acknowledged that the operation bands would obviously change with branches transforming of the antenna. Considering the possibility of independently controlling the upper resonance frequency from the lower one and in view of the obtained results for the parametric analysis, the proposed antenna design can be easily tuned to operate in other frequency bands for other intended dual-band applications.

**Table 2.** Frequency ratios analysis with different parameters.

| $L_1$ (mm) | *35.3* | *37.3* | *39.3* | *41.3* | **43.3** |
|---|---|---|---|---|---|
| low band (GHz) | 1.723 | 1.702 | 1.688 | 1.673 | 1.643 |
| High band (GHz) | 2.801 | 2.711 | 2.64 | 2.564 | 2.465 |
| **Frequency ratios** | 1.626 | 1.593 | 1.564 | 1.533 | 1.500 |
| $L_2$ (mm) | *34* | *36* | *38* | *40* | **42** |
| low band (GHz) | 1.743 | 1.718 | 1.688 | 1.663 | 1.631 |
| High band (GHz) | 2.683 | 2.668 | 2.64 | 2.608 | 2.574 |
| **Frequency ratios** | 1.539 | 1.553 | 1.564 | 1.568 | 1.578 |
| $W_3$ (mm) | *2.6* | *3.0* | *3.4* | *3.8* | **4.2** |
| low band (GHz) | 1.683 | 1.684 | 1.688 | 1.676 | 1.677 |
| High band (GHz) | 2.644 | 2.637 | 2.64 | 2.633 | 2.627 |
| **Frequency ratios** | 1.571 | 1.566 | 1.564 | 1.571 | 1.566 |
| $S_1$ (mm) | *0.9* | *1.1* | *1.3* | *1.5* | **1.7** |
| low band (GHz) | 1.643 | 1.673 | 1.688 | 1.694 | 1.72 |
| High band (GHz) | 2.682 | 2.658 | 2.64 | 2.615 | 2.608 |
| **Frequency ratios** | 1.632 | 1.589 | 1.564 | 1.544 | 1.516 |
| $S_2$ (mm) | *3* | *4* | *5* | *6* | **7** |
| low band (GHz) | 1.735 | 1.702 | 1.688 | 1.661 | 1.65 |
| High band (GHz) | 2.561 | 2.601 | 2.64 | 2.668 | 2.701 |
| **Frequency ratios** | 1.476 | 1.526 | 1.564 | 1.606 | 1.637 |

## 4. SIMULATION AND MEASUREMENT RESULTS

To investigate the gain of the optimized antenna, a full-wave analysis of the antenna using Ansoft's HFSS is performed in Figure 3, showing that this antenna achieves 2.3 dBi in 1.8 GHz and 1.5 dBi in 2.6 GHz, respectively. As mentioned before, the coupled line structure prefers to greatly reduce as much unwanted cross-polarization as possible rather than directly connect with antenna branches, proved in Figures 4(a)–(b).

For the analysis on the gain of the antenna in each plane, the measured and simulated radiation patterns in the $E$- and $H$-planes for 1.7, 1.8, 2.6 and 2.65 GHz are normalized and plotted in

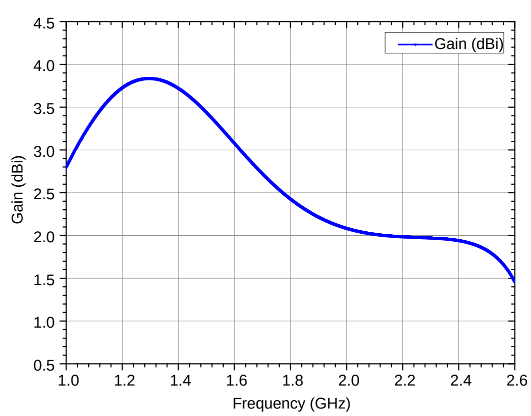


**Figure 3.** Gain of the dual-band antenna in simulation.

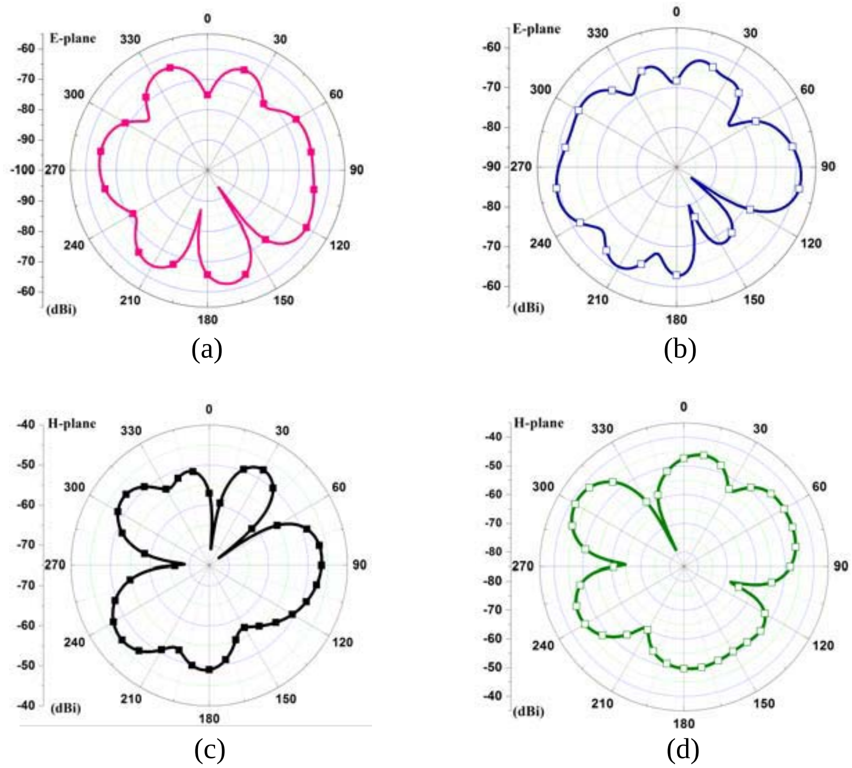


**Figure 4.** (a) Cross-polarization in $E$-plane, (a) at 1.8 GHz and (b) at 2.6 GHz; in $H$-plane (c) at 1.8 GHz and (d) at 2.6 GHz.

**Table 3.** Performance comparison of this proposed antenna with the previous ones.

| Types | Coupled line | Design method | "DGS" structure | cross-polarization reducing |
|---|---|---|---|---|
| [1] | No | Simple | No | No |
| [3] | No | Complicated | Yes | No |
| [7] | No | Simple | No | Yes |
| [9] | No | Complicated | No | No |
| **This antenna** | **Yes** | **Simple and symmetric** | **No** | **Yes** |

Figures 5(a)–(d), respectively. Typical monopole patterns are observed in satisfactory results. Nonetheless, the measured patterns are validated with the simulated ones to a certain extent. Moreover, such a proposed antenna has similar radiation patterns at different planes in two LTE frequencies, achieving omnidirectional radiation in free-space condition.

Computer simulation is used to study the frequency bands of the antenna, which is affected by some variable parameters. The simulated $S_{11}$ of the optimized antenna and the measured results are presented and compared in Figure 6. The simulation results in Figure 6 show that the designed antenna covers from 1.60 to 1.80 GHz resonating at 1.7 GHz in the lower frequency band and covers from 2.58 to 2.68 GHz resonating at 2.64 GHz in the upper band. Thus, according to the obtained simulation results, the presented monopole antenna clearly supports the targeted LTE frequency bands. As for the measurement using an Agilent N5230C vector network analyzer, the simulated and measured resonant frequencies obviously agree with each other very well.

Finally, to compare with previous published dual-band antennas clearly, a simple performance comparison is given in Table 3.

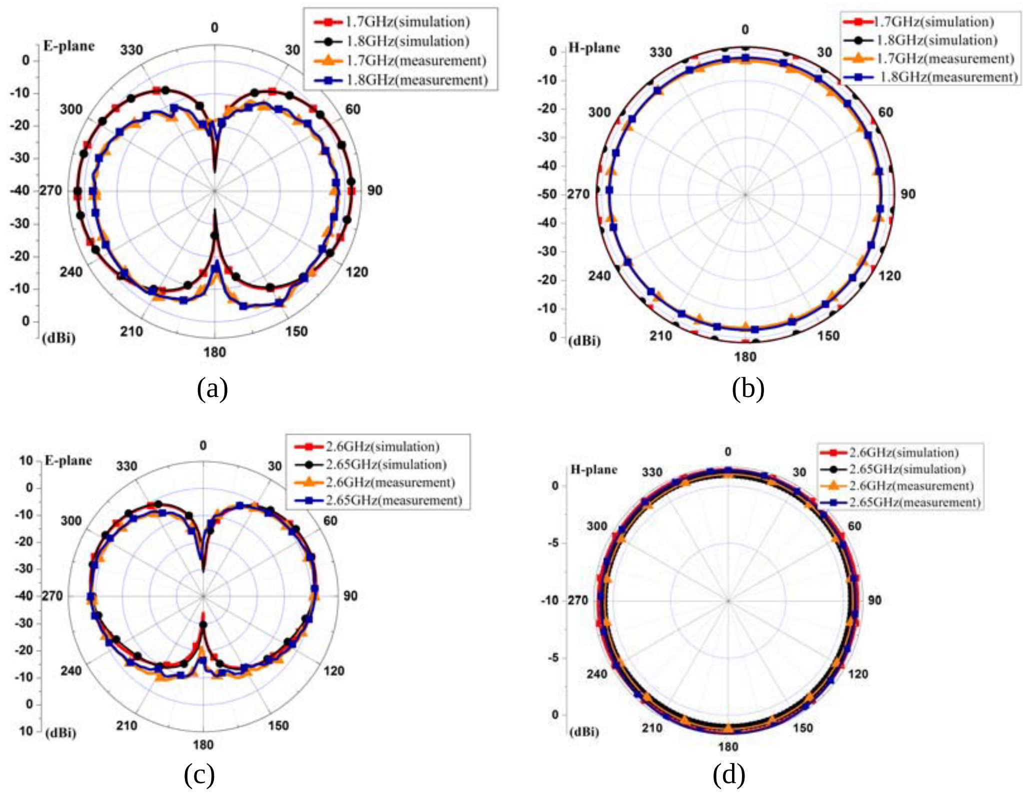


**Figure 5.** Simulated and measured radiation patterns: (a) in $E$-plane and (b) $H$-plane at 1.7 GHz and 1.8 GHz; (c) in $E$-plane and (d) $H$-plane at 2.6 GHz and 2.65 GHz.

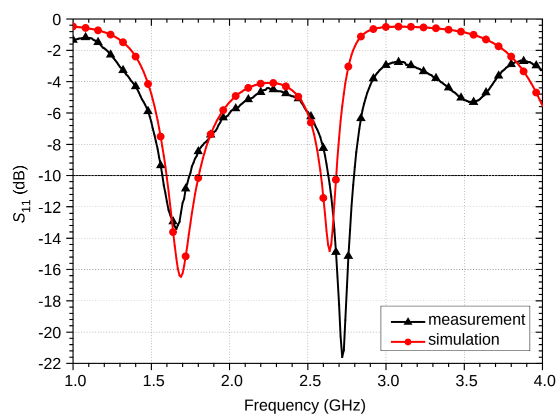


**Figure 6.** The scattering parameters $S_{11}$ in measurement and simulation.

## 5. CONCLUSION

In this paper, a dual-band monopole antenna with a complete symmetrical structure has been proposed to meet the two operating bands of band #3 (1710∼1880 MHz) and band #38 (2570∼2620 MHz). The presented antenna has several advantages, such as miniaturized size, low cost, simple design without a defected ground structure, low cross-polarization, high practicability and great radiation patterns with typical monopole response even at a higher frequency. Moreover, the resonant frequency can be varied by tuning all parameters of the antenna basically. Measurement results show that good radiation patterns are achieved in the working bands.

## ACKNOWLEDGMENT

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