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A printed dual-wideband magneto-electric dipole antenna for WWAN/LTE applications

Botao Feng[a,*], Shufang Li[a], Wenxing An[b], Weijun Hong[a], Shuai Wang[a], Sixing Yin[a]

[a] *Wireless Communication and Electromagnetic Compatibility Key Laboratory, School of Information and Communication Engineering, Beijing University of Posts and Telecommunications, Beijing 100876, China*

[b] *Department of Electronic Engineering, School of Information Science and Technology, Tsinghua University, Beijing 100084, China*

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ABSTRACT

A planar-printed dual-wideband U-shaped magneto-electric dipole omnidirectional antenna with a composite feeding structure for WWAN/LTE applications is proposed. Firstly, a U-shaped electric dipole structure is presented to provide a dual-wideband by changing the surface-current distributions. In addition, in order to reduce antenna size and improve impedance matching, a new feeding structure designed with inverted U-shaped tapered line and meandering T-shaped line is introduced. Finally, instead of a conventional vertical ground plane, a small-size one is printed on the reverse side of the substrate to achieve stable gains and omnidirectional radiation patterns. The antenna prototype can attain a bandwidth of 35.8% (0.78–1.12 GHz) with a stable gain of 3 ± 0.5 dBi for the lower band, and a bandwidth of 50.5% (1.66–2.78 GHz) with a gain of 3.8 ± 0.6 dBi for the upper band, covering the frequency bands granted for WWAN/LTE systems. To the best of our knowledge, it is the first real-sense planar magneto-electric dipole antenna proposed. In comparison with the existing ME dipole antennas, the proposed antenna, which is planar-printed on a small-size FR4 substrate with a simple structure, can be easily fabricated at low cost and thus is promising for WWAN/LTE communication.

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1. Introduction

With the rapid advancement in modern wireless communications, various radio frequency technologies have been applied in WWAN/LTE communication systems. Two separated frequency bands ranging from 824 MHz to 960 MHz and from 1.71 GHz to 2.69 GHz have been allocated [1,2] to these systems, respectively. In these communication systems, antennas that satisfy the high demand in terms of wide impedance bandwidth, stable gain, stable radiation pattern and omnidirectional radiation are increasingly desirable. Due to their advantages including antennas number reduction and installation area minimization, dual-band antennas have attracted tremendous attention [2–5]. On the other hand, over the past decades, related research has been extensively carried out on magneto-electric (ME) dipole antennas, which can meet the high requirement of wideband mobile communications, due to their excellent electrical characteristics such as low cross-polarization, stable gain as well as nearly identical E- and H-plane patterns across the operating band. With staircase-shaped feeding strip [6,7,3,8,9], differential feeding structure [10,11], as well as special dielectric material [11–13], such antennas have attained excellent performance as stated above.

However, there are still unacceptable drawbacks in most of the existing ME dipole and dual-band antennas. The conventional ME antennas with complex and bulky structures [8,9] are incompatible with most of the portable wireless devices. Moreover, the ME antennas which are made of special dielectric material [11,14] or with differential feeding structure [11] are at high cost. And the conventional dual-band antennas are usually arrayed for improved gains [2]. Otherwise, bandwidths and gains have to be compromised [15,1,16,5]. Hence, it is challenging and desirable to propose a novel design of dual-band magneto-electric dipole antenna for WWAN/LTE application with low-profile structure, stable gains, ease and low cost to fabricate. Recently, a dual-broadband ME dipole antenna has been presented for base stations [3]. However, it still cannot cover the whole frequency band in LTE networks. Moreover, the gain becomes unstable since the radiation main beam is split to two beams at high frequencies. Other designs such as the low-profile wideband antenna [14] and the vertical planar-printed unidirectional antenna [12] cannot cover the whole WWAN/LTE frequency band either and are incompatible with most mobile devices due to their large three-dimensional volumes.

* Corresponding author. Tel.: +86 18811597132.
E-mail addresses: fengbotao@bupt.edu.cn, 1979588@qq.com (B. Feng).

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In this paper, to further reduce the size and increase the impedance bandwidth for practical WWAN/LTE applications, a printed dual-wideband U-shaped magneto-electric dipole omnidirectional antenna with a composite feeding structure is proposed. To the best of our knowledge, it is the first genuine planar-printed ME dipole antenna ever proposed, which is entirely printed on both sides of a FR4 substrate. In comparison with existing techniques for ME dipole antenna miniaturization, size reduction is more effective. In addition, the double U-shaped electric dipoles can provide a wideband property through changing the current distribution. Meanwhile, a composite feeding structure, which consists of an inverted U-shaped tapered line and a meandering T-shaped line, is employed to improve the impedance matching. The new feeding structure contributes to gain stabilization and bandwidth expansion by increasing the effective length of the coupling strip in an infinite space. Last but not least, omni-directionality resulted from the small size of back ground satisfies the ever-increasing demand for portability in today's mobile communication systems.

2. Antenna description and design geometry

In respect of the versatility and cost, the proposed antenna has a size of 176 × 122 mm^2 printed on a FR4 substrate, which has permittivity of 4.4 and thickness of 0.8 mm. Basically, the proposed antenna comprises a double U-shaped electric dipole, a composite feeding structure, a pair of shorted stubs and a small size of rectangular ground. The electric dipole, feeding structure and shorted stubs are printed on the front side of the substrate while the ground is printed on the back side of the substrate. The shorted stubs are connected to ground through shorted vias. One end of transmission line of the feeding structure is connected to the SMA connector under the ground plane.

2.1. Operation principle of complementary antenna

On the basis of Huygen's source theory [17,18], crossed or separated electric and magnetic dipoles can be applied to complementary antenna. And according to [14], the far-field electric fields in the E- and H-planes of a ME dipole antenna can be identically expressed as

$$\vec{E} = j\frac{E_y d_x d_y}{2\lambda r}\left[e_\theta \sin\varphi\left(1+\cos\theta\right) + e_\varphi \cos\varphi\left(1+\cos\theta\right)\right] e^{-jkr} \quad (1)$$

and the radiation pattern can be expressed as

$$F\left(\theta\right) = \frac{\left(1+\cos\theta\right)}{2} \quad (2)$$

The back radiation can be cancelled by having θ = 180° and F(θ) = 0, while the front radiation can be enhanced by having θ = 0° and $F(\theta)$ = 1. According to the complementary characteristics [19], the relationship between electromagnetic and magnetic fields can be described as

$$\vec{E} = -j\vec{H} \quad (3)$$

That is to say, electric dipoles and magnetic dipole alternate with equivalent function over time, and thus work well in complementary radiation effect. In our design, the double U-shaped electric dipoles and portion of the magnetic dipole are orthogonal. They collaborate with each other to provide complementary radiation patterns. In other words, electric dipoles and magnetic dipole alternately produce nearly equivalent radiation patterns over a period of time. In particular, the ground on the backside, which is a part of magnetic dipole, is key for the directivity of radiation patterns. When the ground on the backside is large enough, the radiation patterns mainly present unidirectional. On the contrary, the radiation patterns chiefly appear omnidirectional while the ground on the backside is properly small.

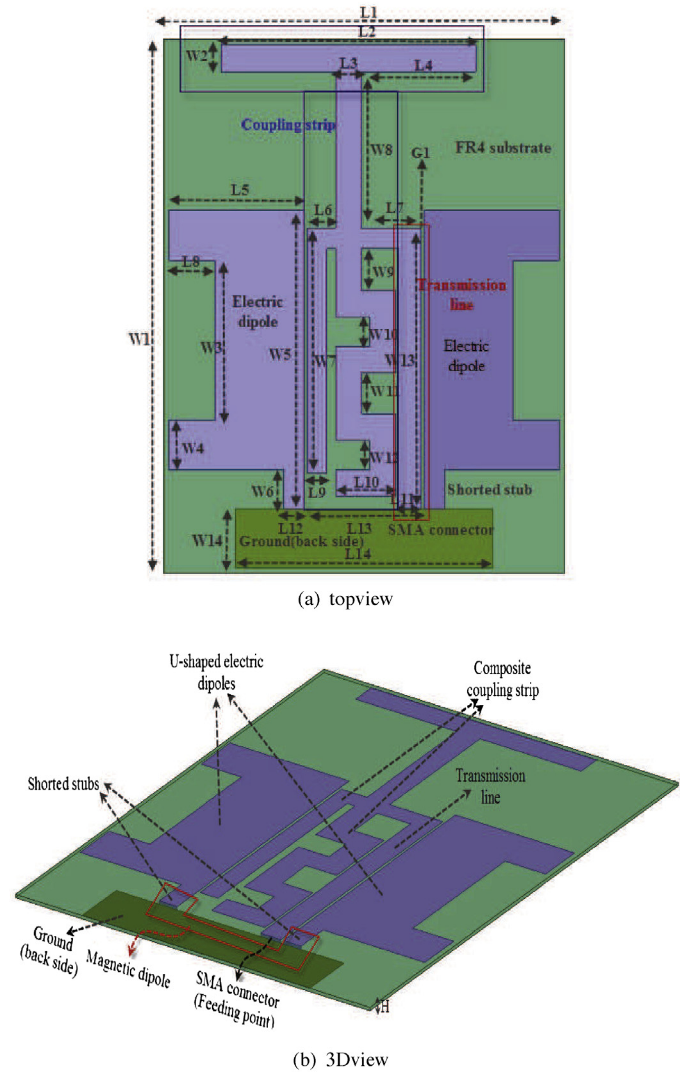

Fig. 1. Geometry of the proposed antenna.

2.2. Double U-shaped magneto-electric dipole geometry

Fig. 1 shows the geometry of the presented antenna. The electric dipoles are constituted by a pair of U-shaped patches, which have two rectangular grooves with a size of 54 × 16 mm^2. The U-shaped patches with the rectangular grooves can broaden the bandwidth due to changes in the current distribution, which can produce a new resonance point. Therefore, the U-shaped electric dipoles can control the SWR and enhance broadside gain. The two U-shaped patches are jointed by a pair of parallel rectangular shorted stubs, which are connected to a small size of rectangular ground on the back side. The pair of stubs are separated by a distance of L_{13} = 33 mm. The parallel rectangular shorted stubs and the portion of the ground plane between them form a magneto dipole. The electric dipoles and the magneto dipole jointly form a planar ME dipole. Excellent complementary electrical characteristics are resulted from mutual coordination between them.

2.3. Composite feeding structure

In order to excite the antenna, reduce the size of the antenna and achieve good impedance matching, a new feeding structure

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