A Compact Dual-band Balanced Slot Antenna for LTE Applications

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Abstract— A low profile dual-band balanced slot antenna is presented and developed, exhibiting a dual-band operation at 700 MHz and 2600 MHz bands with a good impedance matching ($S_{11} \leq -10$ dB) for use in Long Term Evolution (LTE) applications. The proposed antenna was implemented based on built-in planar dipoles with a folded arm structure. The antenna occupies a volume of $50 \times 12 \times 4\,\mathrm{mm}^3$ in which mounted on top of a finite ground plane with dimensions of $100 \times 50\,\mathrm{mm}^2$. The performance of the proposed antenna has been analysed and optimised for the two targeted frequency bands. The antenna performance is characterised in terms of the reflection coefficient, radiation pattern and surface current distribution. Owing to the compact size and simple structure, the proposed antenna can be a promising candidate for mobile handset and wireless communication applications.

1. INTRODUCTION

In recent years, the current needed on mobile phone have increased greatly in term of its shape, performances, qualities and its technology. The new technology in wireless communication has brought a lot of portable devices in the future, such as a mobile phone that will possess Long Term Evolution (LTE) function for the voices and data transmissions [1]. Conventionally, the unbalanced planar inverted F antenna (PIFA) is one of the most popular candidates for compact internalized antennas for mobile handsets due to its unique characteristic that makes it suitable for use in portable wireless device especially on mobile handsets.

However, PIFAs use the ground plane as a part of the radiator, enabling very small antennas to achieve adequate gain and bandwidth [2–4]. Therefore, radiating currents are induced on both the ground plane and the antenna element, resulting in currents flowing on the human body, which degrade the performance of the antenna's radiation characteristics and introduce losses and uncertainty in its matching [5].

To solve these problems, a balanced structure is introduced to not only to eliminate such constraints but also to avoid the degradation of antenna performance in aforementioned unbalanced antennas. In this kind of antennas, currents cancel the effect of each other, the current flows only on the antenna element and not on the ground plane. Therefore, the coupling between the antenna and the user's body will be neglected when the mobile is held by its user which leads in no effect on the performance of the antenna. In other word, the currents are mostly confined to the radiating elements, thus reducing the current flow to the ground plane [6]. It follows that a well-designed balanced antenna will reduce the specific absorption rate (SAR) to the user's body [5]. Lately, several mobile antennas with the balanced technique have proved the enhanced stability of antenna performance, compared to the unbalanced type especially when the handset is positioned in a close vicinity to the human head and/or hand [7–10]. However, all these balanced antennas in [7–10] are not capable to meet the present work target, namely 700/2600 MHz frequency bands of LTE. Thus, this work has been investigated to offer a low profile antenna for Long Term Evolution (LTE) applications at 700 MHz and 2600 MHz bands using the balanced antenna concept. The proposed antenna will be implemented based on built-in planar dipoles with two folded slot arms structure.

The layout of the paper is as follow. Section 2 presents the antenna design and concept, the results and discussions were shown and demonstrated in Section 3 and Section 4 is summarized the final conclusions of this study.

2. ANTENNA DESIGN CONCEPT

The proposed balanced antenna was achieved to generate the dual band operation of 700 and 2600 MHz LTE bands. Figure 1 shows the geometry of the balanced antenna for a mobile phone.

The antenna was designed first and then was mounted 4 mm on top of a finite ground plane with dimension of $100 \times 50\,\mathrm{mm}^2$ which acts as the mobile handset chassis or what today we would identify as the ground plane of a practical mobile phone handset, as seen in Figure 1. The dimensions of the proposed antenna geometry were found to be comparable to the practical handset size as illustrated in Table 1. The slot has a uniform width of 2 mm. The antenna was constructed from a copper sheet with thickness of 0.15 mm. One side of the folded dipole antenna, in which the cooper plate was folded up to become a folded dipole antenna as depicted in Figure 1.

Table 1: Detailed dimensions of folded arms radiators.

Parameter	Value (mm)	Parameter	Value (mm)
L_1	16	L_7	12
L_2	3.2	S_1	19
L_3	5	S_2	8
L_4	23	S_3	14
L_5	23	S_4	9
L_6	2	h	4

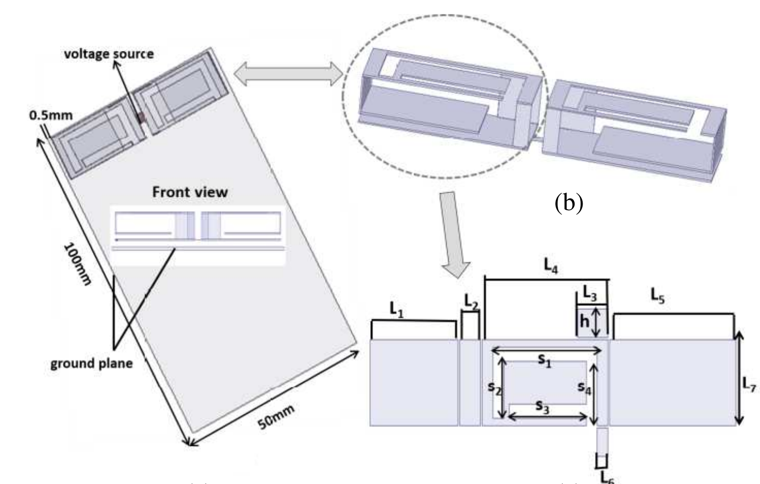

Figure 1: Basic antenna structure; (a) 3D, (b) folded slotted arms, (c) unfolded slotted arm.

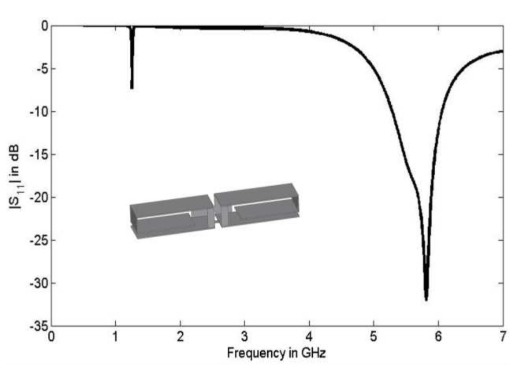

Figure 2: Reflection coffeicent of folded arms unslotted proposed antenna.

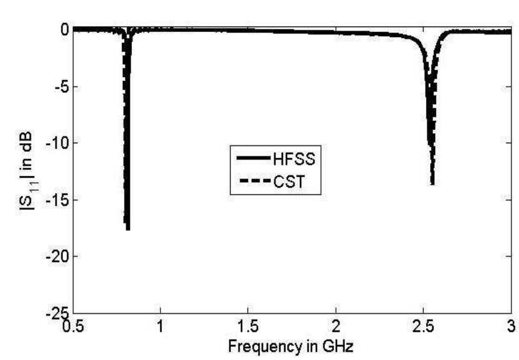

Figure 3: Reflection coffeicent of folded arms slotted proposed antenna.

3. RESULTS AND DISCUSSIONS

In order to accomplish the targeted frequency bands, two procedures were carried out. Firstly, it was started by folding the monopole arm and without slot patterned in both folded arms surface.

The proposed antenna without the inclusion of slot operates at dual band of 1200/5800 MHz as depicted in Figure 2.

However, this was not the desired goal within the proposed work. Therefore, the second step was to create/introduce slots over the surface of both folded arms as shown in Figure 1. The effectiveness of the embedded slot was seen through the simulated S_{11} in two different softwares. I.e., HFSS and CST [11, 12] for comparison and validation purposes. The slot forces the antenna to downshift both aforementioned frequencies obtained from the unslotted antenna. The loaded slot reduces the resonance frequency and thus the electrical antenna dimensions drastically. So, fundamentally, the objective of the slot was to tune the radiator structure to resonate at our targeted bands of LTE 700/2600 MHz. This was achieved through multiple simulated attempts, by conducting several modifications of the antennas in [9, 10] to move toward the desired outcome of developing highly compact and dual-band antenna for use in LTE applications. It is obvious that the S_{11} of proposed antenna generated by HFSS agrees well with the one obtained from the CST as shown in Figure 3.

The analysis of the current surface on the ground plane of the proposed antenna was studied using the EM simulator at the 700 MHz and 2600 MHz. I.e., the targeted frequencies within this work as shown in Figure 4. One can clearly note that, most of the current is induced exactly underneath the two folded slotted arms at both resonant frequencies while it is more or less vanished on the rest of the ground plane in which proves the concept of balanced antenna whereby it reduces the coupling between the handset and the user's hand.

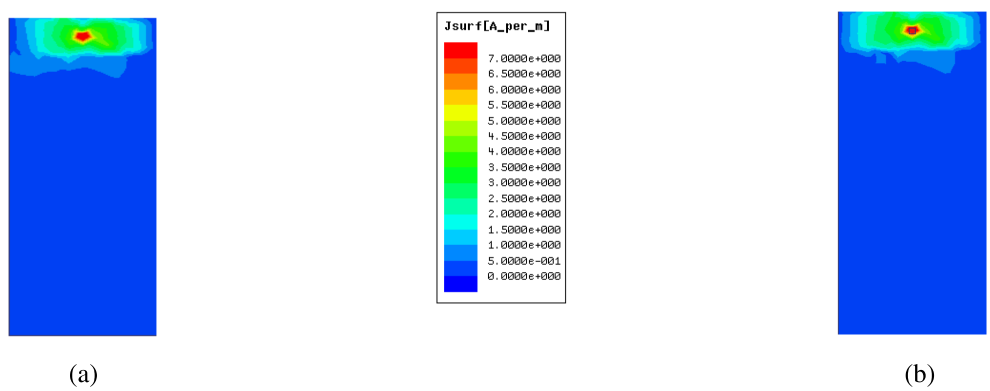

Figure 4: Surface current distributions for the proposed balanced antenna at (a) 700 MHz, (b) 2600 MHz.

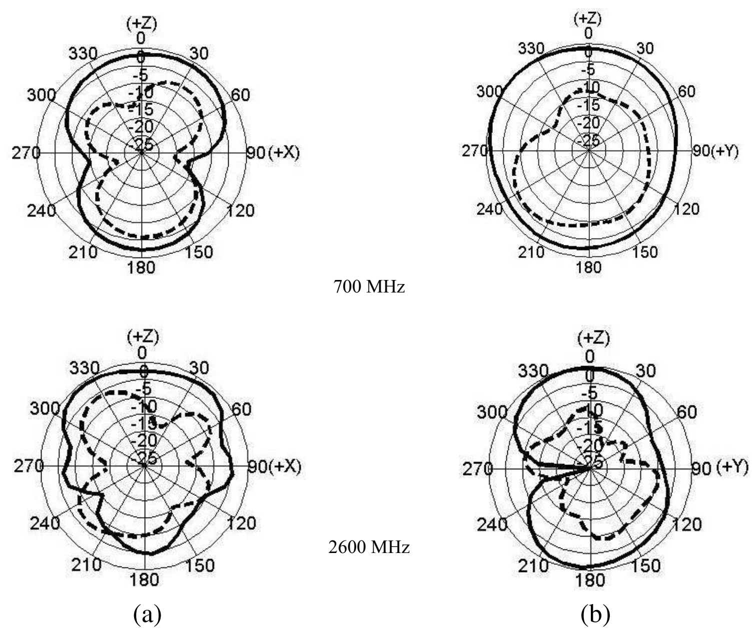

Figure 5: Normalized antenna radiation patterns for two planes ((a) xz, (b) yz) at 700 MHz, 2600 MHz, "—" co-polarization, "- - -" cross-polarization.

The radiation patterns of the proposed antenna was shown in Figure 5. Two pattern cuts were taken for both targeted operating frequencies within this study. The radiation patterns in the *zx* plane and *zy* plane for the antenna were tested at 700 and 2600 MHz as indicated in Figure 5. The patterns of the proposed antenna are seen to be quite similar to each other for both cases. Moreover, as expected the figures presented a nearly omni-directional radiation pattern in both intended two frequency components.

4. CONCLUSIONS

In this paper, a design methodology for producing miniaturized and compact dual-band balanced folded arm slot antenna suitable for LTE applications has been demonstrated. By embedding a slot over the surface of folded arms of the antenna, it has been shown that a high level of miniaturization can be achieved while covering the 700 and 2600 MHz LTE frequency bands. The results over the two frequency bands and the compact volume are important factors, which leads that the proposed design can be recommended as a promising candidate mobile-antenna solution for LTE applications.

ACKNOWLEDGMENT

This work is carried out under the grant of the Fundacão para a Ciência e a Tecnologia (FCT-Portugal), with the reference number: SFRH/BPD/95110/2013.

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