Metal-Frame Inverted-F Antenna for the LTE Metal-Casing Smartphone

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***Abstract* - A metal-frame inverted-F antenna for the metal-casing smartphone is presented. The antenna is formed by two inverted-F Antenna (IFA) structures to cover 824-960 MHz (low band), 1710-2690 MHz (middle band), and 3400-3600 MHz (high band). The antenna for the metal-casing smartphone has a narrow metal clearance of 2 mm. The feeding and shorting strips with matching networks for the two IFAs are disposed on a small dielectric substrate as the feed circuit board. Results of the fabricated antenna are presented to verify the simulation results.**

***Index Terms* — Metal-frame antennas, LTE antennas, inverted-F antennas (IFAs).**

1. Introduction

The antenna with a narrow ground or metal clearance has been very attractive for the modern metal-casing smartphone application. Such narrow-clearance antennas can allow a large display panel to be disposed in the smartphone. The smartphone with a metal casing [1] not only provides esthetic appearance but also increases the robustness of the device. The metal casing includes the metal back cover and the metal frame around the edges thereof. Recently, some antennas use the metal frame as the antenna's radiator [2]-[4]. In order to achieve LTE operation, it is noted that the antenna structure in [3] and [4] requires a wide clearance of width 10 mm or 5 mm.

In this article, we present a metal-frame inverted-F antenna (IFA) capable of providing an LTE operation in the 824-960, 1710-2690, and 3400-3600 MHz bands for the metal-casing smartphone. The antenna requires a narrow metal clearance of 2 mm only. There are two IFAs used to provide a low band, a middle band, and a high band. The IFA's radiating metal strips are configured as a portion of the metal frame disposed on the top edge of the metal-casing smartphone. The antenna uses a small-size dielectric substrate to be a feed circuit board, which is separated from the metal back cover. Details of the proposed antenna are presented.

2. Proposed Antenna

Fig.1 shows the geometry of the proposed antenna. The metal casing comprises a metal back cover with a notch of small depth 2 mm as metal clearance for the antenna and a metal frame disposed around the edges thereof. There are two openings on the IFA's radiating metal strips which are disposed at the top edge of the metal-casing smartphone. The metal back cover is a planar metal plate having dimensions of 78 × 150 mm^2. All of the feeding and shorting strips with matching networks are disposed on the feed circuit board.

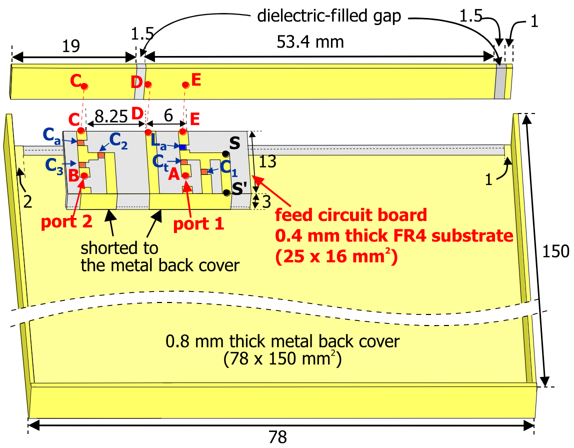

Fig. 1. Geometry of the metal-frame inverted-F antenna.

The corresponding equivalent circuit model of the antenna can be seen clearly in Fig. 3. The antenna is obtained by combining two IFAs of Ant1 and Ant2. Ant1 has a longer strip and is an inductively coupled-fed IFA. The feed network of Ant1 consists of a series chip inductor L_a embedded in the feeding strip, a band-pass matching circuit [5] with L_{eq} and C_1, and a fine-tuning capacitor C_f. Ant1 can cover the low band of 824-960 MHz with the aid of the feed networks. On the other hand, Ant2 is a capacitively coupled-fed IFA with a series chip capacitor C_a embedded in its feeding strip. The matching circuit also includes a shunt chip capacitor C_2 and a series chip capacitor C_3. Ant2 provides a widened bandwidth for the antenna's middle and high bands to cover 1710-2690 MHz and 3400-3600 MHz.

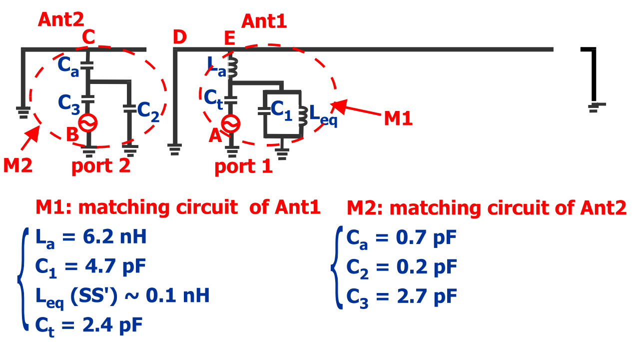

Fig. 2. Equivalent circuit model.

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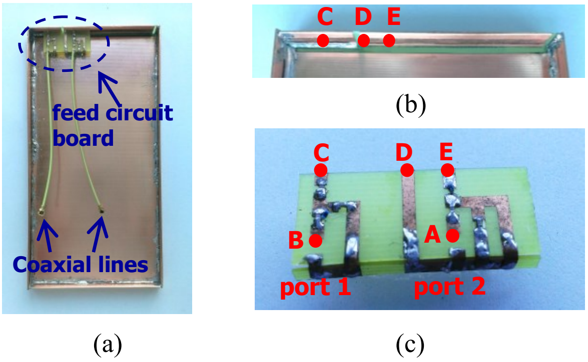

Fig. 3. (a) Front view. (b) Radiating metal frame. (c) Feed circuit board.

The proposed antenna can be decomposed into two IFAs. Fig. 4 shows the structure of the two IFAs and the simulated *S* parameters for the case with the inductively coupled-fed IFA only (Ant1, excited by port 1), and the case with the capacitively coupled-fed IFA only (Ant2, excited by port 2). It is seen that the S_{11} in the low band and the S_{22} in the high band for the proposed antenna are similar to the corresponding results for Ant1 and Ant2. It can cover the low band and high band with Ant1 and Ant2, respectively. However, the bandwidth of Ant2 alone is hard to cover the middle band. On the other hand, the *S* parameters of the proposed antenna can cover the middle band in addition to low band and high band. This is owing to the effect of combining Ant1 and Ant2 into the proposed antenna.

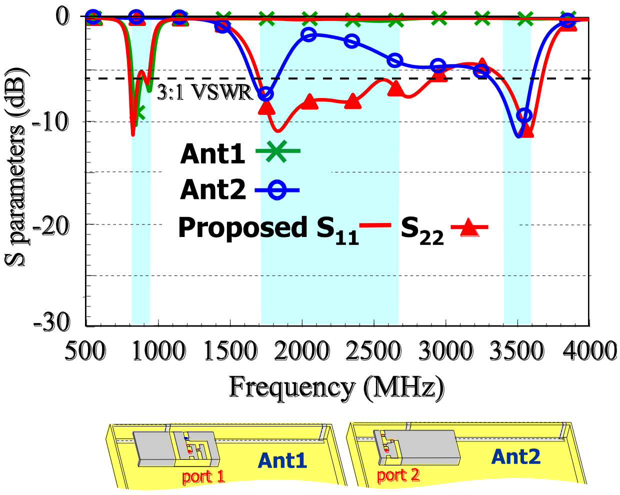

Fig. 4. Simulated *S* parameters for the proposed antenna, Ant1, and Ant2.

3. Experimental Result And Discussion

Photos of the fabricated antenna are shown in Fig. 3. The measured and simulated *S* parameters of the fabricated antenna are shown in Fig. 5. Agreement between the measured data and simulated results is seen. The measured and simulated antenna efficiencies of the fabricated antenna are shown in Fig. 6. The measured antenna efficiency varies in the range of about 46-63% in the low band, 55-87% in the middle band, and 76-88% in the high band. The antenna efficiencies are acceptable for practical mobile communication.

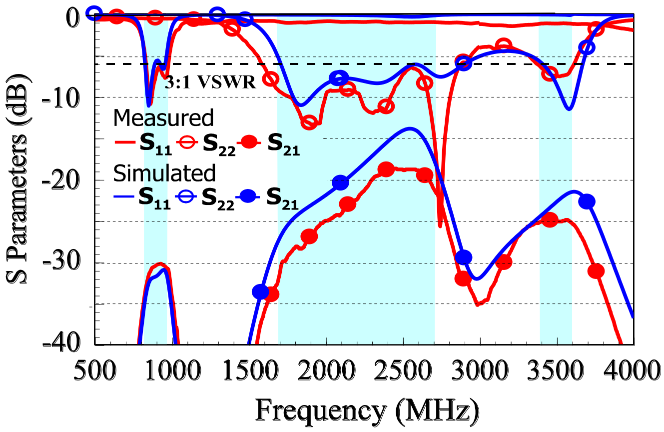

Fig. 5. Measured and simulated *S* parameters.

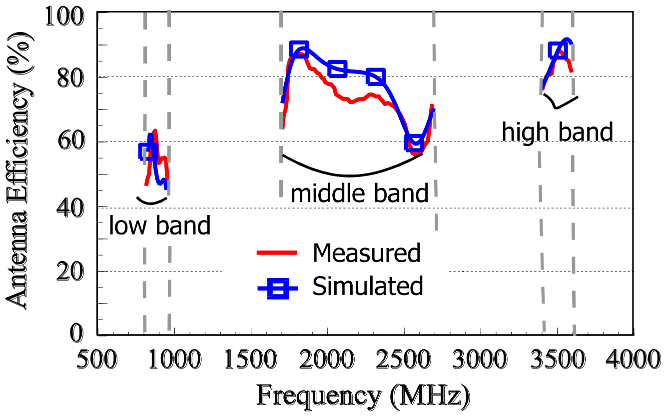

Fig. 6. Measured and simulated antenna efficiencies.

4. Conclusion

A metal-frame inverted-F antenna for the LTE metal-casing smartphone has been proposed and experimentally studied. With a narrow metal clearance of 2 mm, the metal-casing smartphone antenna can provide three wide bands of 824~960, 1710~2690, and 3400~3600 MHz for LTE operation.

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