# Small-Size Printed Antenna with Shaped Circuit Board for Slim LTE/WWAN Smartphone Application


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***Abstract*—An on-board printed WWAN/LTE antenna of simple structure disposed in a small clearance of 8 × 36 mm$^2$ in the ground plane of shaped circuit board in a slim handset is presented. The shaped circuit board has a large rectangular notch such that the battery of the handset can be embedded therein to decrease the thickness of the handset, and lead to much enhanced bandwidth of the antenna disposed thereon. This is mainly because stronger surface currents on the ground plane of the shaped circuit board can be excited, which greatly helps improve the operating bandwidth of the antenna disposed thereon. The proposed design makes a simple, small-size printed PIFA capable of providing two wide operating bands to cover the GSM850/900 and GSM1800/1900/UMTS/ LTE2300/2500 bands.**


## I. INTRODUCTION

For the slim handset, the system circuit board therein may have a large rectangular notch or slot to accommodate the battery to decrease the total required thickness of the handset. In the proposed design, a battery generally having a metal enclosing is disposed in the large notch of the shaped circuit board. A metal midplate, which is used to provide the handset with structural support, is also included in the proposed design. By connecting both the battery and metal midplate at proper locations to the ground plane of the shaped circuit board, large bandwidth enhancement for a small-size antenna can still be obtained.

The antenna used in this study is a printed inverted-F antenna, which can be disposed in a small clearance of 8 × 36 mm$^2$ in the ground plane of the shaped circuit board. In the proposed design, stronger surface currents excited on the ground plane of the shaped circuit board, compared to those on the ground plane of a corresponding simple circuit board, are observed. This behavior leads to enhanced bandwidth of the small-size antenna. Two wide operating bands are generated to cover the GSM850/900 and GSM1800/1900/ UMTS/LTE2300/2500 bands.

## II. PROPOSED DESIGN

As shown in Figure 1(a), there are three parts in the proposed design, which include a shaped circuit board with an on-board printed inverted-F antenna thereon, a battery, and a metal midplate. The shaped circuit board is modeled using a 0.8-mm thick FR4 substrate of relative permittivity 4.4 and loss tangent 0.024. The width and length of the circuit board are respectively 60 and 115 mm, which are reasonable dimensions of practical smartphones. A ground plane is printed on the back side of the shaped circuit board. A large notch of size 45 × 50 mm$^2$ is cut in the circuit board to accommodate the battery of the handset. In this study, the shaped circuit board with a notch size which is reasonable for some practical handset batteries can have stronger surface currents excited on the ground plane thereof, compared to those on the ground plane of a corresponding simple circuit board.

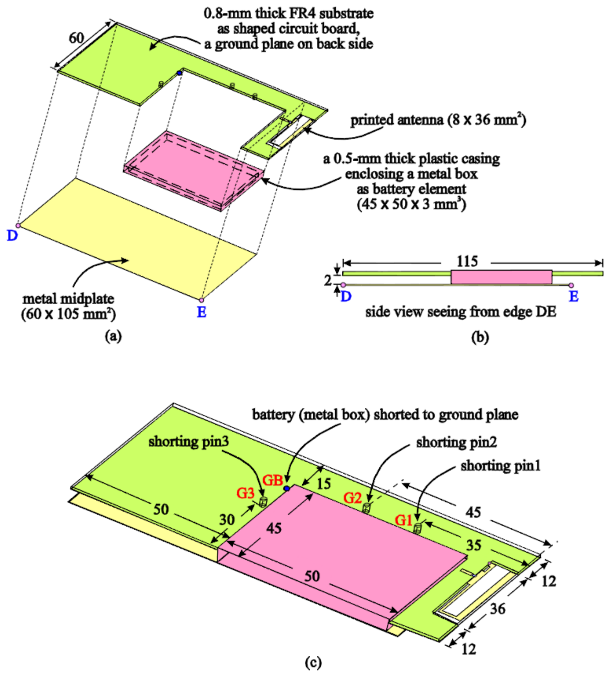


Figure 1. Proposed WWAN/LTE handset antenna with shaped circuit board, battery and metal midplate. (a) Exploded view. (b) Side view. (c) Front view.

As shown in Figure 2, the inverted-F antenna has a folded radiating arm of length 66 mm (section AB) and a shorting strip of length 10 mm (section AS). A chip capacitor of 3.3 pF is added at feeding point A, which mainly compensates for large inductance for frequencies at about 900 MHz to achieve improved impedance matching for the proposed antenna. In this study, two wide operating bands can be provided to cover the WWAN/LTE operation bands, although the antenna has a small size of $8 \times 36$ mm$^2$ only.

The battery is modeled as a metal box enclosed by a 0.5-mm thick plastic casing. The metal box is also short-circuited at the location GB to the ground plane of shaped circuit board. The selected location GB can make the excited surface currents on the ground plane of shaped circuit board slightly affected such that enhanced bandwidth of the antenna can still be obtained, when the battery is embedded in the notch of shaped circuit board. The midplate is usually added to provide the handset with structural support and can be used to support the display of the handset. In this study, the midplate is considered to be a metal plate and has a size of $60 \times 105$ mm$^2$.

The configuration of the proposed design can be seen more clearly in Figure 1(b) and (c). By properly selecting the shorting positions (G1, G2, and G3 in this study) to connect the midplate to the ground plane, the excited surface currents on the region of the midplate facing the battery (that is, facing the notch of shaped circuit board) can be suppressed. Hence, enhanced bandwidth can still be obtained for the small-size antenna in this study.

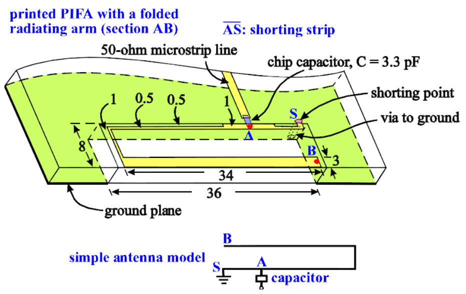


Figure 2. Dimensions of the metal pattern of the antenna (printed PIFA with a folded radiating arm).

## III. RESULTS AND DISCUSSION

The proposed design was implemented and shown in Figure 3. Figure 4 shows the measured and simulated return losses of the antenna. The simulated results are obtained using simulator HFSS version 14, and agreement between the simulation and measurement is seen. The obtained lower and upper bands of the antenna cover the WWAN bands and the LTE2300/2500 bands, the impedance matching is better than 3:1 VSWR or 6-dB return loss, which is the design specification widely used for the internal WWAN/LTE handset antennas [1]-[3].

The measured antenna efficiency is shown in Fig. 5. The antenna efficiency includes the mismatching loss. Over the lower band (824~960 MHz), the antenna efficiency is better than about 60%, while that over the upper band (1710~2690 MHz) is better than about 65%. The measured antenna efficiencies are good for practical handset applications. More results on parametric analysis, measured three-dimensional total-power radiation patterns, surface current distributions, and SAR results will be discussed in the presentation.

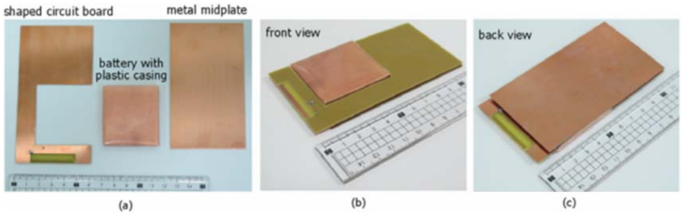


Figure 3. Photos of the fabricated prototype. (a) Shaped circuit board, battery element and metal midplate. (b) Front view seeing from the battery side. (c) Back view seeing from the midplate side.

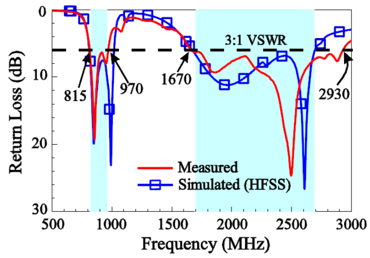


Figure 4. Measured and simulated return losses of the antenna.

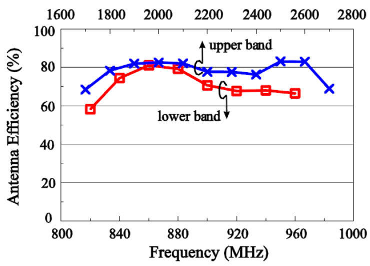


Figure 5. Measured antenna efficiency with mismatching loss.

## IV. CONCLUSION

A simple, small-size printed inverted-F antenna has been shown to provide wide operating bands to cover the WWAN and LTE2300/2500 operation bands for the slim handset application. The proposed design can still have the ground plane of shaped circuit board excited as an efficient radiator to greatly enhance the operating bandwidth of the antenna. Good far-field radiation characteristics for frequencies in the operating bands have also been obtained. The proposed design is especially suitable for the slim handset application.

## REFERENCES

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