Frequency Reconfigurable Narrow-frame Antenna for WWAN/LTE Smartphone Applications

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Abstract— A compact narrow-frame antenna loaded a PIN diode for hepta-band smartphone applications is presented. The greatest highlight is that the edge of the no-ground planet is quite narrow of only 5 mm, which meets the requirements of the popular narrow-frame smartphone designs with larger touch-screens. Furthermore, the reconfigurable technology is applied to realize a wide coverage with a small volume and a compact structure. The hepta-band operation is successfully achieved by combining the two working states. Detailed considerations of the design are studied in this paper and the proposed antenna is successfully simulated, fabricated, and measured.

1. INTRODUCTION

For smartphone applications, larger touch-screens with narrow-frames have been widely pursued for not only the appearance design but also the user experience. Therefore, besides the fundamental demands of multi-band operation, the antenna should also be miniaturized, compact and narrow-frame for smartphone applications. However, when applied to the antennas with a narrow frame of 5 mm for multi-band smartphone applications, most of these antenna patterns have poor coverage due to the close space between the antenna and the system planet which leads to the high value of Q. Moreover, the troubles in multi-band narrow-frame antenna design for smartphone applications in a limited area occur not only for the lower-band but also for the upper-band.

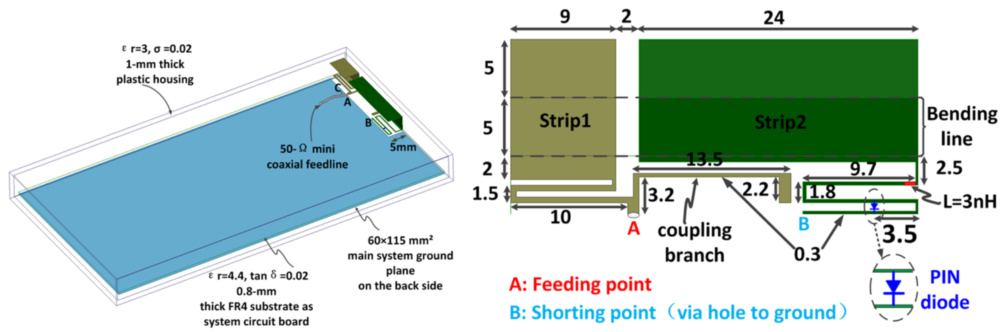
Recently, antennas with narrow-frames for hepta-band smartphone applications have been presented and studied in [1, 2]. The narrow-frame antenna proposed in [1] employes a band-stop matching circuit structure to obtain wideband operation with a small size of $5 \times 40 \times 3\,\mathrm{mm}^3$, while the other narrow-frame antenna presented in [2] applies a loaded chip capacitor to realize the hepta-band operation with a size of $5 \times 60 \times 5\,\mathrm{mm}^3$.

To further reduce the sizes of the antennas, the reconfigurable antennas [4–10] which have been proposed and widely studied are considered to be an efficient solution. In this paper, a folded coupled-fed narrow-frame antenna for hepta-band WWAN/LTE smartphone applications is proposed and studied. The proposed antenna can be reconfigured by employing a PIN diode, which changes its resonant modes by modifying the electrical length for the lower-band in two working states, and exerts little effect on the upper-band. With outstanding merits of a narrow frame of only 5 mm and a compact structure of $5 \times 5 \times 35\,\mathrm{mm}^3$, the proposed antenna is quite practical for smartphone applications with larger touch-screens. The proposed PIN diode loaded antenna has also been proved applicable with simple structures, acceptable insertion loss and low cost. The prototype with the PIN diode and the bias circuit was built, while the measured results including radiation efficiencies and gains are acceptable.

2. PROPOSED ANTENNA CONFIGURATION

Figure 1 shows the geometry of the proposed compact frequency-reconfigurable narrow-frame antenna, which is mounted on the bottom edge of the FR4 ($\varepsilon_r = 4.4$, $\tan\delta = 0.02$) printed circuit board and has a whole volume of $35 \times 5 \times 5\,\mathrm{mm}^3$ of no-ground area. On the back side of the FR4 printed circuit board, a ground plane of $110 \times 60\,\mathrm{mm}^2$ is printed to serve as the system ground of the mobile phone with the protruded ground of $25 \times 5\,\mathrm{mm}^2$ connected to the system ground. A 50-Ω mini coaxial feed line is employed to excite the antenna and it is connected to the feeding point (point A) and the PCB shorting point (point C). In the study, a 1-mm thick plastic slab ($\varepsilon_r = 3$, $\sigma = 0.02\,\mathrm{S/m}$) is also employed to build a plastic case to simulate the handset housing in practical applications. In addition, detailed dimensions of the proposed antenna are shown in Fig. 1(b).

The proposed compact antenna mainly comprises two folded strips (strip1 and strip2 with a lumped inductor of 3 nH), which are designed to generate upper-frequency resonant mode at about



(a) (b)

Figure 1: Proposed antenna array configuration. (a) Geometry of proposed narrow-frame antenna. (b) Detailed dimensions of the proposed antenna. (Unit: mm).

2000 MHz and lower-frequency resonant mode at about 910 MHz, respectively. However, higher-order mode generated by strip2 leads to failure in widening the bandwidth for the upper-band, which is mostly in coincidence with the resonant mode generated by strip1 at about 2000 MHz. To solve this trouble, a coupling branch is employed to generate the other upper-frequency resonant mode at about 2400 MHz, and reduce the capacitance of strip1 to generate a lower-frequency resonant mode at about 850 MHz. In addition, the introduction of the coupling branch also forms a coupled loop together with the system ground and part of the strip2, which contributes a half-wavelength upper-frequency resonant mode at about 2900 MHz, covering the GSM850/1800/1900/UMTS/LTE 2300/2500 operation. To further meet the multi-band requirements, the reconfigurable technology is employed to cover the GSM900 band by modifying the electrical length for the lower-band, which is realized by a PIN diode and has little effect on the upper-band.

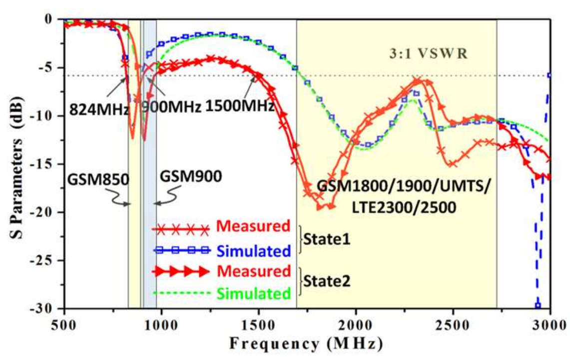


Figure 2: Measured and simulated S parameters.

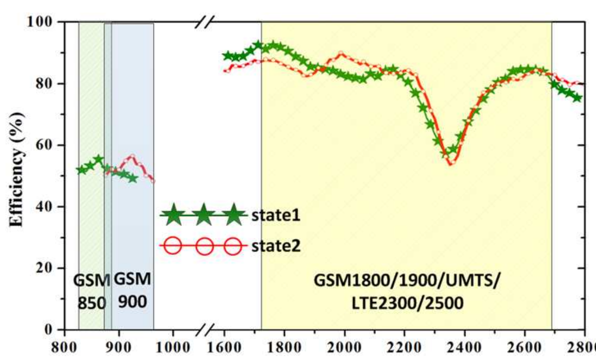


Figure 3: Measured radiation efficiency.

The PIN diode loaded reconfigurable antenna works in two different states, namely state1 (the PIN diode is OFF) and state2 (the PIN diode is ON). When the antenna works in state1, the operating bands of GSM850/1800/1900/UMTS/LTE2300/2500 are covered. The specified position of the PIN diode is optimized to meet the requirements of covering the operating band of GSM900. When the antenna works in state2, the electrical length is reduced by about 7 mm, which shifts the lower-frequency resonant mode from about 870 MHz to about 910 MHz, covering the GSM900/1800/1900/UMTS/LTE2300/2500 operation. In addition, the insertion of the PIN diode brings little influence on the upper-band. Consequently, the proposed narrow-frame antenna has finally covered the GSM850/900/1800/1900/UMTS/LTE2300/2500 operation by combining the two working states.

3. RESULTS AND DISCUSSION

The proposed narrow-frame antenna with the PIN diode was successfully fabricated and tested. The type of the PIN diode is selected as Siemens BAR65-02W with low capacitance and loss. The simulated results of both working states are obtained by Ansoft HFSS version 13, while the measured results are tested by using an Agilent N5247A vector network analyzer. Measured and simulated reflection coefficients presented in Fig. 2 with good agreement between them for the lower-band. The measured impedance matching bandwidth is based on 3 : 1 VSWR. For state1, the obtained bands are 824–900 and 1500–2690 MHz. For state2, the achieved bands are 880–960 and 1520–2690 MHz. Therefore, by combining two working states, the hepta-band WWAN/LTE operation is successfully covered. The measured radiation efficiency is depicted in Fig. 3.

4. CONCLUSION

A compact frequency-reconfigurable narrow-frame antenna for hepta-band WWAN/LTE smartphone applications is proposed and studied. The edge of the no-ground planet to support the antenna is only 5 mm, which is quite promising for narrow-frame smartphone applications. By combining two working states of the PIN diode, hepta-band including GSM/850/900/1800/1900/UMTS-/LTE2300/2500 can be successfully covered with a compact volume of $35 \times 5 \times 5\,\text{mm}^3$, which is much smaller than the previous designs. In addition, the measured results including reflection coefficients, antenna efficiencies and gains are presented and can meet the requirements of smartphone systems.

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