A Loop Antenna with Coupling Strip and Tuner for All-Metal-Shell Handset Application

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***Abstract*—A dual-band frame antenna with coupling strip and tuner is proposed in this work for all-metal-shell mobile telephone application with all the metal devices being considered The metal-shell handsets are getting more and more popular nowadays due to the robustness and its fascinating appearance. The metal-shell associated with surrounding electronic components would occupy the metal clearance, which will absorb the energy radiated by the antenna. This work provides an optional solution to design the antenna with all the metal components like front-and-back facing cameras, telephone receiver and steel sheet taken into consideration, where the metal shell of the handset and a coupling strip are utilized as part of the antenna. The metal shell of the handset has a symmetric C-shaped gap with a width of 2mm and no other breakpoints to decrease the robustness of the structure. The proposed antenna is able to generate radiation covering the bandwidth of 824-960 MHz (GSM) and 1710-2690 MHz (DCS/PCS/UMTS/LTE) for mobile communication. With the application of the tuner, the antenna can get a broadband characteristic and the coupling strip may add the capacitance of the structure, making the antenna resonate at the lower band as 0.25λ resonant mode and as 0.5λ resonant mode at the higher band. The principle of the tuner has also been discussed in the paper, helping locate the proper situation to induce the switchable inductor. A prototype has been fabricated to verify the radiation performance in a practical handset test environment.**

Keywords—dual-band; coupling strip; all-metal-shell; mobile communication

I. Introduction

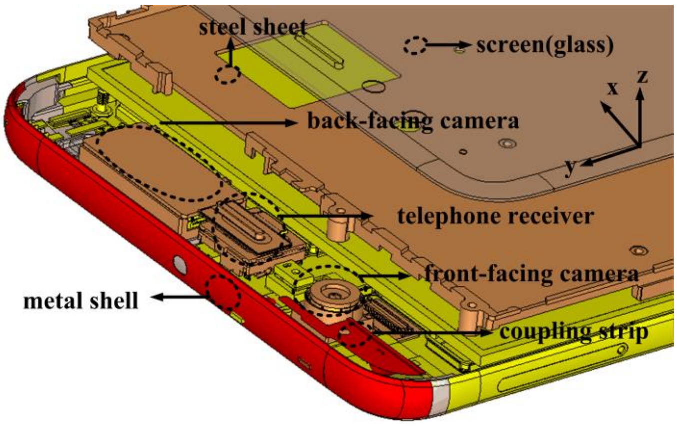
Antenna designed for all-metal shell has aroused significant attentions and made remarkable progress recently. The mobile handset, known as smart phone is one of the embodiments. More radio-frequency (RF) components and devices like front-and-back-facing cameras, all-scale screen and telephone receivers are required to realize more functionalities, occupying the metal clearance of the antenna. Therefore, the space available for antenna always limits its design freedom and more problems are raised currently in advanced cell phone development.

Several handset antennas have been proposed in [1-4] for metal-shell devices. The dual-loop antenna proposed in [5-6] is capable of covering GSM850 /900 /DCS /PCS /UMTS2100 /LTE 2300 /2500 operating bands by using the metal-rimmed the part of the antenna. The metal-rimmed antenna makes a better appearance and robustness of the smart phone, whereas an all-metal shell handset has an advantage over it. Some other antenna designs for smart phone have been discussed in [9-12], even including the 5G smart phone antenna design. Reconfigurable loop antenna using RF switch is designed in [9], which can cover a wider band while switching the four working states of the RF switch.

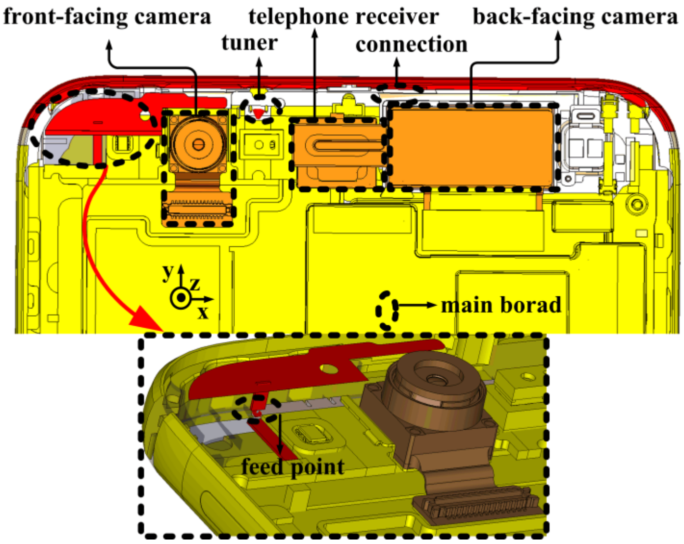
In this paper, a reconfigurable frame loop antenna with a tuner for all-metal shell handset applications is proposed, covering the bandwidth of 824-960 MHz (GSM) and 1710-2690 MHz (DCS/ PCS/ UMTS/ LTE) for mobile communication. The RF tuner has been introduced to switch more working states compared with RF switch mentioned in [9], for a tuner is continuously adjustable. The antenna has been designed using the metal shell as the main radiator of the antenna. The all-metal shell has a merely 2 mm symmetric gap to act as the metal clearance for the proposed antenna. Two cameras, a telephone receiver and other metal components which occupy the finite space for antenna are all taken into consideration while the antenna design process. In this paper, the main objective is to propose an optional approach to develop a reconfigurable frame antenna in a full-metal-shell handset environment.

II. Design in Handset Environment

Fig. 1 shows the antenna design environment in a full-metal-shell handset model with an explosive view of different layers and an enlarged view of the coupling strip and the feeding point. To demonstrate the main structure more clearly, other dielectric material has been hidden to make the metal structure more conspicuous. The whole model of the handset shown in Fig. 1 (a) is mainly composed of four colors: the part marked in gray color is glass, representing the screen of the handset; the other three colors are all metal materials, the yellow one is copper, including the metal shell of the handset and some other metal components; the material highlighted in brown color is PEC acting as the components which has a close relationship with the antenna performance, including the



(a) explosive-view of the handset

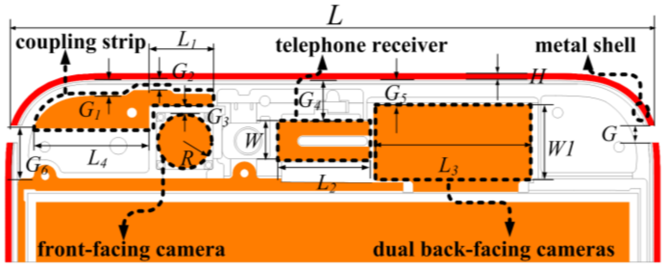


(b) enlarged view of the proposed antenna in the handset environment

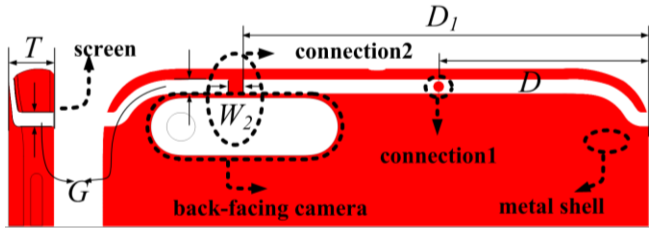
Fig. 1. Configuration of the antenna in the handset environment with other dielectric material hidden to make the metal structure conspicuous.

steel sheet, the dual-back-facing cameras, the front-facing camera and the telephone receiver. The coupling strip is laser-engraved on the ABS substrate via the Laser Direct Structuring (LDS) technology, which is shown in red color. What need to be mentioned is that the coupling strip is also copper and changing it to red color makes it more recognizable. Fig. 1(b) shows enlarged view of the main antenna structure. In order to achieve a better identification of the coupling strip, it has also been changed to red color. The antenna can be considered as a loop antenna using the metal frame as the main radiator, with a tuner at roughly the middle of the antenna (connection 1) shown in Fig. 2(b) to adjust the center frequency of the radiation.

Also, the antenna has been fed by the coupling strip instead of feeding directly, which can effectively compensate for the large inductive resistance of the antenna at 0.25λ resonant mode for lower band. A connection has been used to connect the metal frame and the metal shell together shown in Fig.



(a) top-view



(b) bottom-view

Fig. 2. Geometry of the proposed antenna in the handset environment with all the metal components loading surrounding.

1(b), making the antenna act as a loop and resonate at 0.5λ resonant mode for higher band. Two desired resonant modes can hence be excited by the proposed antenna to cover the GSM (824-960 MHz), DCS (1710-1880 MHz), PCS (1850-1990 MHz), UMTS (1920-2170 MHz) and LTE (2170-2690 MHz) band for multiband operation with the help of the tuner widening the bandwidth.

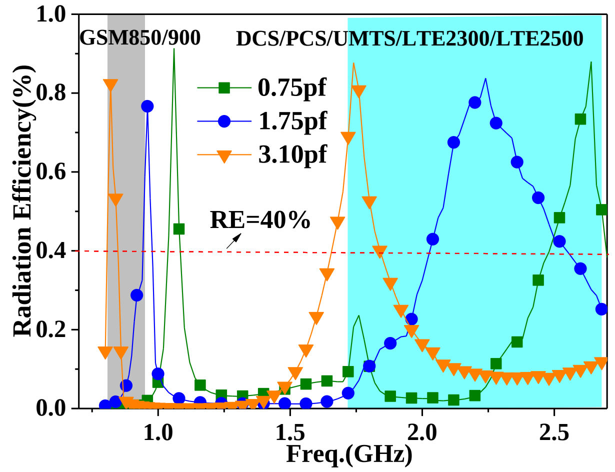
Fig. 2 presents the detailed configuration of the proposed antenna alone, where all the dielectric materials have been hidden. As is known to us all, the handset environment contains metal devices including dual-back-facing and front-facing cameras, telephone receiver and steel sheet. All the devices and the metal shell will occupy the clearance space for the antenna radiation and worsen the performance of the antenna inevitably. All the parameters mentioned in the Fig. 2 are demonstrated in Table I

TABLE I
OPTIMIZED GEOMETRIC PARAMETERS FOR THE PIFA WITH U-SHAPE STRIP

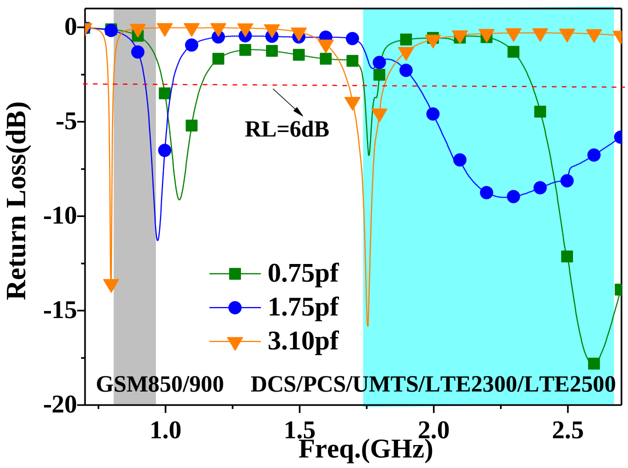
Parameter	Value(mm)	Parameter	Value (mm)
G	2.0	L	74.2
G_1	1.5	L_1	7.3
G_2	0.9	L_2	10.6
G_3	0.8	L_3	18.3
G_4	4.5	L_4	13.2
G_5	2.6	W	4.2
G_6	4.0	W_1	8.5
H	0.8	W_2	2
D	30.8	D_1	41.8
T	5		

III. Simulated Results of The Proposed Antenna

To better understand the principle of the proposed antenna, the simulated results of the proposed antenna are listed in Fig. 4 and Fig. 5. The Fig. 4 shows the simulated S-parameter of



(a) simulated efficiency



(b) simulated return loss

Fig. 4 Simulated return loss and the efficiency of the proposed with different capacitor-loading.

the antenna, what can be seen is that the resonances of both the upper and the lower band will tune as the different values of the capacitor-loading. The same will happen to the efficiency of the proposed antenna. Through the simulation, the bandwidth of the antenna will cover 824-960 MHz and 1710-2690 MHz with the efficiency up to 80% at both lower and upper frequency, shown in Fig. 4 (a) and (b). Also, the radiation patterns of the proposed antenna at three representative bands are illustrated in Fig. 5, verifying the design feasibility of the proposed antenna for all-metal-shell handset application.

IV. Conclusion

A novel dual-band frame antenna with coupling strip has been developed in an all-metal-shell handset. Good bandwidth performance and stabilized radiation patterns can be achieved with high efficiency (up to 80%) at the frequency of 824-960 MHz and 1710-2690 MHz. The practical environment in a handset with surrounding metallic electronic components has been taken into account during the design process. The work shows the proposed antenna is a good candidate for full-metal-shell handset application.

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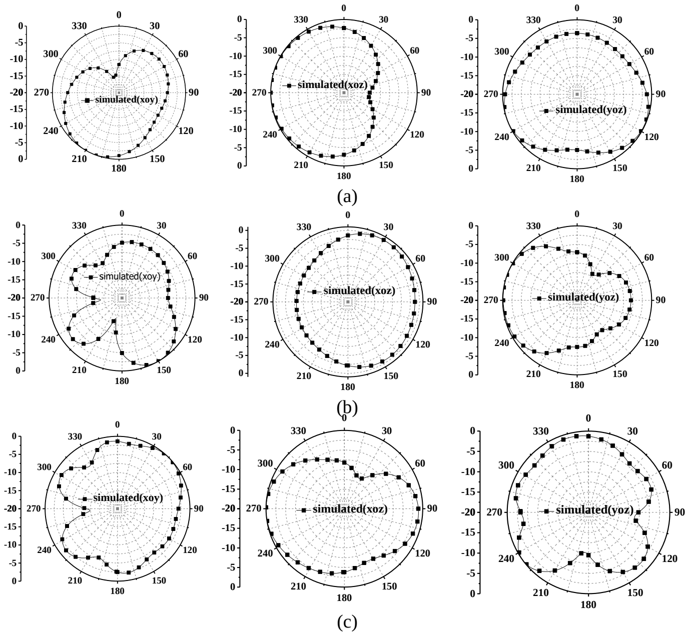

Fig. 5. Radiation patterns of the proposed antenna at three representative bands: (a) at 900 MHz; (b) at 1900 MHz; (c) at 2400 MHz

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