# Novel Hepta-band Coupled-fed Antenna for WWAN/LTE Metal-ring-frame Smartphone Applications

**Li-Wan Zhang and Yong-Ling Ban**
Institute of Electromagnetics, University of Electronic Science and Technology of China
2006 Xi-Yuan Avenue, Western High-Tech District, Chengdu, Sichuan 611731, China

**Abstract**— A novel hepta-band coupled-fed antenna is presented for WWAN/LTE metal-ring-frame (MRF) smartphone applications in this paper. Unlike the conventional solutions simply removing the redundant resonances generated by the metal ring, A creative couple-fed scheme is utilized in this proposed antenna to take full advantage of the metal ring resonances. With compact size occupation and wide band coverage, the proposed antenna for smartphones enhances the bandwidth coverage, as well as user experience of cosmetic appearance and mechanical strength.

## 1. INTRODUCTION

The metal-ring frame embracing the samrtphone can enhance the user experience of cosmetic appearance and mechanical strength, but also impede the effective radiation of the internal mobile phone antennas. When the mobile antenna is embraced by a full metal frame in the vicinity of antenna, the coupling between the antenna and the adjacent metal ring would be very intensive to excite multiple additional resonances and set up a negative feedback to the antenna's original radiation.

Concerning the antenna design problem for MRF smartphones, a effective option [1] is to push the multiple metal-ring resonances out of the working band so as to eliminate the adverse effects on the performance of the original antenna. To make better use of radiation generated by the metal ring, a $15 \times 56.5\,\mathrm{mm}^2$ planar slot antenna operated under surroundings of an unbroken metal ring is introduced in [2].

While the problem of the designed antennas for the mental-ring-frame smartphones should be addressed on their large size and failure to cover the LTE2300/2500 operation.

In this paper, an innovative hepta-band couple-fed antenna for WWAN/LTE MRF smartphone applications is presented, which has a compact layout of a printed monopole and the metal-ring frame. By applying the coupled-fed technique [3–8] in a creative way, the sections of the disjointed metal-ring frame are capacitively fed by the printed monopole to generate a dual-resonance mode at the GSM850/900 operation and a higher-order resonant mode at LTE2300/2500 operation. With multiband operation, metal-ring frame, and small size occupation, the proposed scheme might initiate a new antenna design for MRF smartphone applications coving GSM/1800/1900/UMTS2100/LTE2300/2500 (1710–2690 MHz) banding operation.

## 2. PROPOSED ANTENNA

The geometry of the proposed antenna integrated with a notched system ground plane for WWAN/LTE operation in the MRF smartphone is shown in Fig. 1. Embraced by a metal ring frame with close proximity, the system circuit board is a 0.8-mm thick FR4 substrate of relative permittivity 4.4, loss tangent 0.0245, and size of $120 \times 60\,\mathrm{mm}^2$. The directly feeding monopole is deposed at the bottom corner of the system circuit board with no-ground portion of $10 \times 40\,\mathrm{mm}^2$. At the bottom side of the system circuit board, there is a protruded ground of size $20 \times 10\,\mathrm{mm}^2$ extending from the main ground plane, which can be used to accommodate associated electronic elements in the smartphones.

As shown in Fig. 1, a 0.3-mm-thick brass sheet with two cuts encloses the main circuit board as the metal ring frame, which has a distance of 2 mm to the substrate. Two slits and two grounding patches divide the metal ring into four sections, which are Section 1, Section 2, Section 3 and Section 4 respectively. The length of each section is well tuned for good impedance matching. Unlike the design in iphone4 which cuts slits on the length side of mobile phone, the two slits filled with engineering plastic of Polyoxymethylene (POM) are etched on bottom of the metal ring in our proposed scheme, which can reduce the possibility to be covered by hand at the talk mode. To realize slim smartphone design, the height of the metal ring is only 5 mm. To achieve good artistic appearance of the metal ring, $S_2$ (inserted slit 2) is etched on the bottom edge with the same distance of $S_1$ (inserted slit 1) to its nearby bending corner which creates a symmetrical image for the users. Besides the ornamental function, the metal ring also play an important role to enhance the antenna radiation.

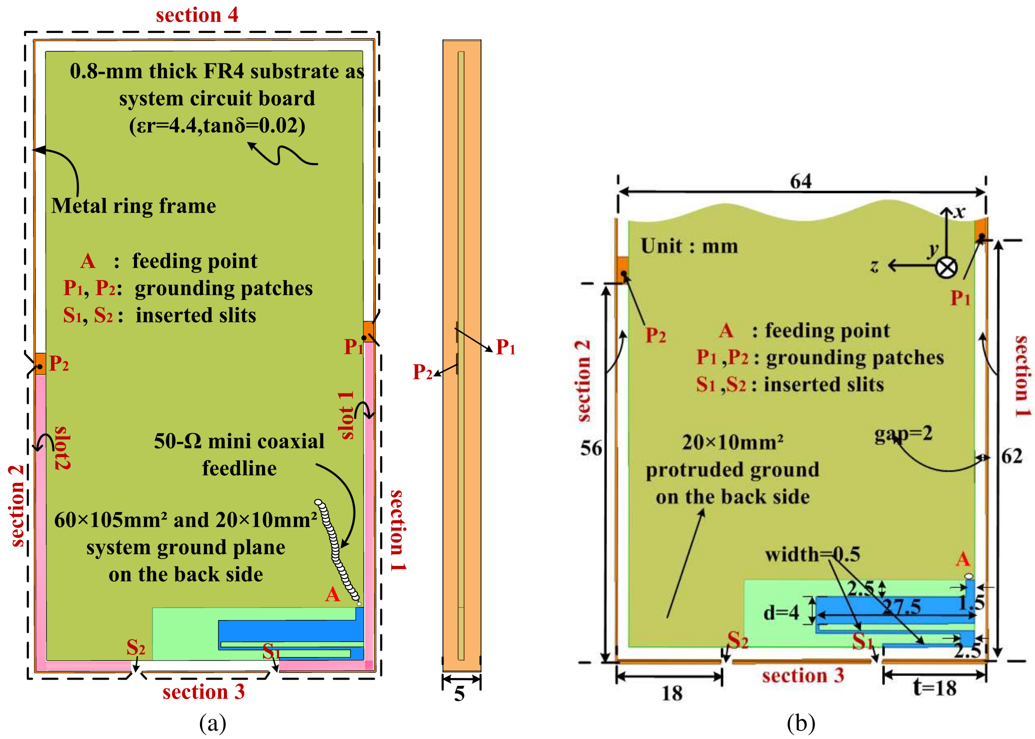


Figure 1: Configuration of the proposed antenna. (a) Geometry of the small size hepta-band antenna with a metal ring frame. (b) Detailed dimensions of the proposed antenna (Unit: mm).

The detailed dimensions of the proposed antenna has be given clearly in Fig. 1(b). The printed part of antenna is composed of a driven meandering monopole, with length of 76 mm, and occupies a small area of $10 \times 27.5\,\text{mm}^2$. The meandering monopole is directly fed by a $50\,\Omega$ mini coaxial feeding line and acts as the primary radiator for the upper band while the metal ring is couple-fed by the monopole and works as a parasitic radiator. Shorted by grounding patch $P_1$, Section 1 and the ground plane forms an open Slot 1 with length of 78 mm, which excites its fundament resonant mode as $\lambda/4$ monopole slot at 850 MHz and its third-order at 2450 MHz. While Section 2 and the ground plane shorted by patch $P_2$ forms the other open Slot 2 with length of 74 mm, about 0.237 wavelength at 950 MHz, which also generates a $\lambda/4$ monopole slot at 950 MHz. The lower band operation(GSM850/950) could be successfully covered by these two $\lambda/4$ resonant modes. And the impedance matching of the upper band (1710–2690 MHz) is also enhanced by the fundament resonant mode of driven monopole and the higher-order resonant mode of monopole slot 1.

Compared with the traditional couple-fed antennas [6–10] that have a compact structure of the primary radiator and the parasitic radiator, our design has presented a distributed couple-fed layout achieving wide band coverage and miniaturization.

## 3. RESULTS

The proposed coupled-fed antenna for hepta-band MRF smartphone applications is fabricated to measure. Results of the measured and simulated return loss are presented in Fig. 2. The simulated result is obtained by Ansoft HFSS version 12, while the measured result is tested by using an Agilent N5247A vector network analyzer. The impedance matching for frequencies more over the desired lower band of 824–960 MHz and upper band of 1710–2690 MHz are better than 3 : 1 VSWR or 6 dB return loss, which is widely accepted as the design specification for the WWAN/LTE mobile phone antennas.

The antenna peak gain and radiation efficiency of the proposed mobile phone antenna is also measured in Satimo chamber as seen in Fig. 3. Over the lower band of GSM850/900 (824–960 MHz), the antenna gain varies from about −1.7 to 0.9 dBi. For the upper band operation which includes DCS1800/PCS1900/UMTS 2100/LTE2300/2500, the antenna gain ranges from about 0.2 to 5 dBi.

Measured radiation efficiency is about 47%–82% in the lower band and 65%–91% in the upper band. The result demonstrates an high total radiation efficiency of the proposed antenna, which is suitable for the practical WWAN/LTE MRF smartphone antenna applications.

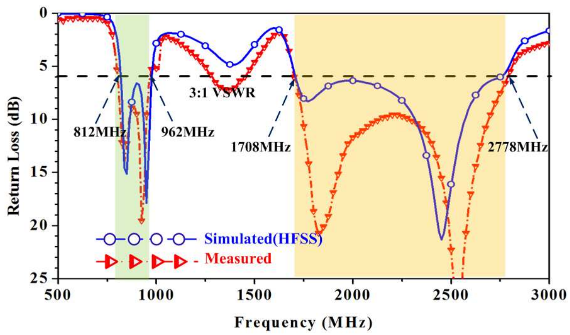


Figure 2: Measured and simulated return loss.

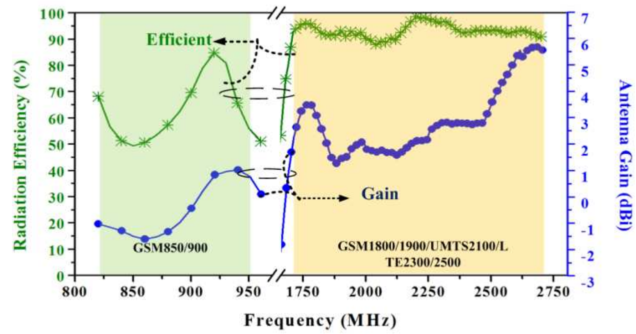


Figure 3: Measured gain and radiation efficiency.

## 4. CONCLUSION

A novel hepta-band antenna for WWAN/LTE MRF smartphone applications is proposed, which presents a distributed couple-fed layout achieving wide operating bands of 824–960 and 1710–2690 MHz. The disjointed metal-ring frame is capacitively fed by a printed meandering monopole according to the couple-fed mechanism, and generates a dual-resonance mode of GSM850/900 operation and a higher-resonance mode of LTE 2300/2500 operation. By effectively applying the metal-ring resonances, the proposed antenna achieves size reduction and wider bandwidth for MRF smartphone applications. The obtained measured results including return loss, antenna peak gain, and radiation efficiency indicate that the proposed antenna is promising for practical wide band MRF smartphone applications with excellent aesthetic consideration and enhanced mechanic sturdiness.

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