Printed Multi-band Slot Antenna Surrounded by a Metal Ring for WWAN Smartphone Applications

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Abstract— A printed monopole slot antenna for WWAN metal-ring frame (MRF) smartphone applications is presented and studied in this paper. The greatest highlight of the proposed antenna is that the band of 824–960 MHz scarcely affected by the modified MRF and achieves great stability. The MRF resonance is also utilized to enhance the bandwidth of the upper band of 1710–2170 MHz. With small size of $8 \times 40\,\mathrm{mm}^2$ occupation and wide band coverage, the proposed antenna is a promising candidate for the MRF smartphone applications.

1. INTRODUCTION

Recently, more and more phone manufactures incline to use a metal ring frame embracing the smartphone for mechanical strength or aesthetic feelings. Inevitably, The coupling between the antenna and the adjacent MRF is very intensive which excites multiple additional resonances and sets up a negative feedback to the antenna's original radiation. So, The MRF usually deteriorate the performance of the antenna. For this reason, it becomes a tremendous challenge to modify the MRF to achieve the desired performance of the antenna.

The study of the antenna design surrounded by metal ring have been reported [1]. A $15 \times 56.5\,\mathrm{mm}^2$ planar slot antenna operated under surroundings of an unbroken metal ring is also introduced in [2]. By applying the coupled-fed technique, slot and band-stop matching circuit were also adopted to design the antenna embraced by the MRF [3–8].

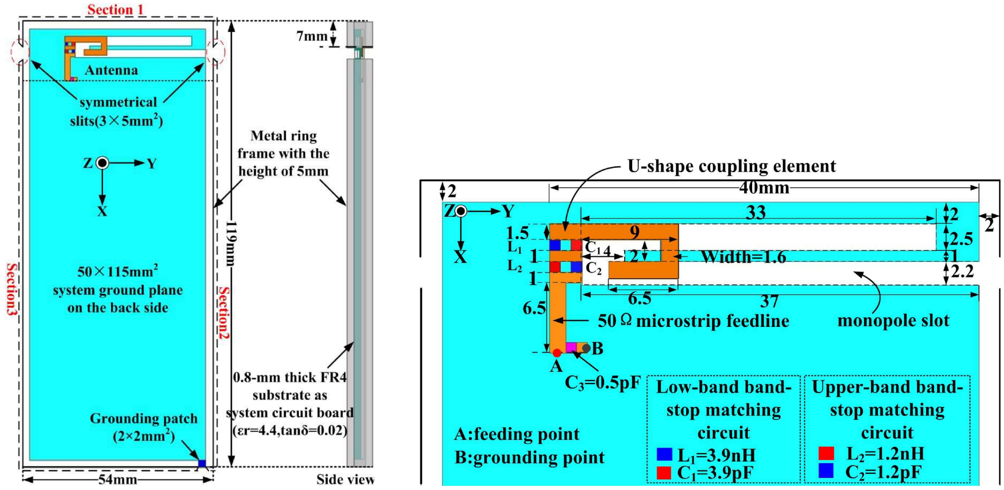
In this study, The advantage of this proposed antenna is that the band of 824–960 MHz scarcely affected by the modified MRF and achieves great stability. The MRF resonance is also utilized to enhance the bandwidth of the upper band of 1710–2170 MHz. Moreover, the antennas are planar, printed, small size according to the requirement of the modern smartphone.

In this paper, a novel compact monopole slot is utilized for metal-ring frame smartphone applications. As the main radiator, the slot occupy a small size nearly $8 \times 40\,\mathrm{mm}^2$ on the system circuit board corner. The dual-band band-stop matching circuit in this article can generate two separate parallel resonances and lead to two dual-resonance excitations of the quarter-wavelength and higher-order resonant modes of the monopole slot antenna to apparently enhance the bandwidths of both the antenna lower and upper bands. This proposed antenna can cover the WWAN operation in the 824–960 and 1710–2170 MHz bands.

2. PROPOSED ANTENNA CONFIGURATION

Figure 1(a) shows the geometry of the proposed monopole slot antenna with dual-band band-stop matching circuit at the bottom corner of the system circuit board, and the dimensions of the antenna metal pattern are given in Fig. 1(b). In this study, a 0.8-mm thick FR4 substrate of relative permittivity 4.4, loss tangent 0.02, and size $50 \times 115\,\mathrm{mm}^2$ is used as the system circuit board of the practical smartphone applications. The system circuit board is embraced by an almost negligible thickness metal ring, which has a height of 5 mm in the design and the distance between the circuit board and the metal ring is 2 mm. By means of splitting two symmetrical slits whose length is 3 mm and height is 5 mm near the bottom of the rectangle metal ring, connecting the ground of circuit board to the rectangle metal ring through metallic patch whose size is $2 \times 2\,\mathrm{mm}^2$ in the top right of the circuit board, the metal-ring frame is divided into three sections, which are Section 1, Section 2 and Section 3 as depicted in Fig. 1(a). The distance of the slit to the top of the metal ring is 7 mm.

Detailed dimensions of the proposed antenna are shown in Fig. 1(b). The proposed antenna consists of a shorter feeding strip and a longer coupling monopole slot seen from its functions. The monopole slot is folded to achieve a compact antenna configuration and consisted of two parallel slot sections in the upper and down location respectively. The upper slot section have a length of 33 mm and a width of 2.5 mm and the down slot section have a length of 37 mm and a width of



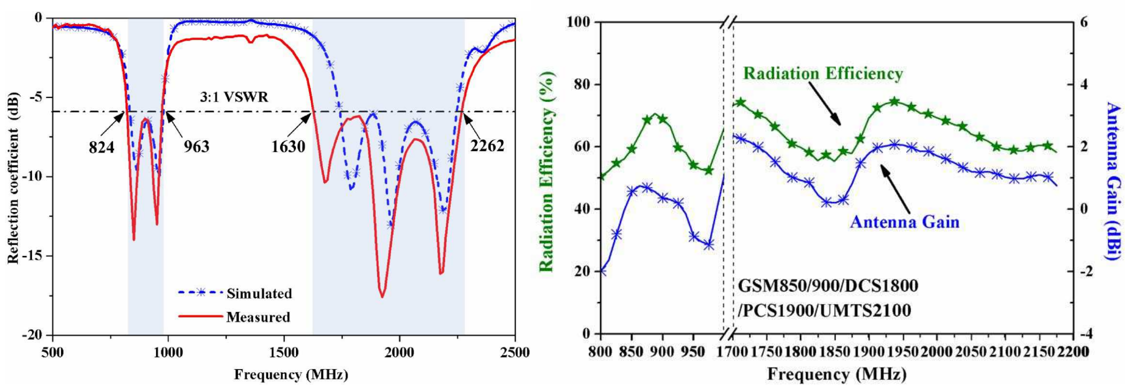
(a) (b)

Figure 1: (a) Geometry of the proposed WWAN monopole slot antenna disposed at the system ground plane. (b) Dimensions of the antenna's metal pattern (Unit: mm).

2.2 mm in the ground plane. So, the monopole slot have a length of about 72 mm in total. The feeding strip consisted of the U-shape coupling element, the dual-band band-stop matching circuit and the 50-Ω microstrip feedline. The U-shape coupling element has an overall length of 20.5 mm and is adjusted to extend from the upper slot section to the down slot section. the 50-Ω microstrip feedline has a length of 6.5 mm. To achieve good impedance matching of the antenna, a 0.5-pF chip capacitor is displaced parallel to the microstrip feedline at the feeding point.

3. RESULTS AND DISCUSSION

The simulated results are gained by Ansoft HFSS version 13, while the measured results are tested by using an Agilent N5247A vector network analyzer. The results of the measured and simulated reflection coefficient are shown in Fig. 2. The desired operating bands (824–960 and 1710–2170 MHz) are shown in the shaded regions in the figure. Based on 3 : 1 VSWR definition, the obtained bandwidths cover the desired operating bands. Good agreement between the measurement and the simulation obtained is also seen. the measured antenna peak gain and radiation efficiency for the proposed smart-phone antenna. Over the desired lower band of GSM850/900 (824–960 MHz), the antenna gain is varied from about −1.9 to 0.7 dBi, and the radiation efficiency is generally larger than 50%. For the desired upper band of DCS1800/PCS1900/UMTS2100 (1710–2170 MHz), the antenna gain is varied from about 0.2 to 2.4 dBi, and the radiation efficiency is larger than about 55%.



(a) (b)

Figure 2: (a) Measured and simulated S parameters. (b) Measured antenna gain and radiation efficiency.

4. CONCLUSION

A monopole slot antenna printed on a FR4 substrate of $50 \times 115\,\mathrm{mm}^2$ surrounded by a rectangle MRF is presented. In this paper, by means of splitting two symmetrical slits near the bottom of the rectangle metal ring ,connecting the ground of circuit board to the metal ring through metallic patch in the top right corner of the circuit board and a dual band band-stop matching circuit in the 50-Ω micro-strip line which feeds the monopole slot, both the bandwidths of the antenna's lower and upper bands can be covered. The obtained measured results including reflection coefficient, antenna peak gain, and radiation efficiency are presented, which indicate that the proposed antenna is promising for the smartphone applications.

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