Enhanced Internal Loop Antenna for Triple Band Mobile Terminals

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1. Introduction

Internal antennas for mobile communications are increasingly demanded to be more compact and to be capable of multiband operation. Therefore, it is desirable for a single internal antenna to have wider bandwidth and omni-directional radiation pattern in all bands. Particularly multiband antenna based on the planar inverted-F antenna (FIPA) structure is difficult to obtain omni-directional pattern in higher band due to variation of current distributions on the ground plate. Conventionally quarter-wavelength resonance antennas such as the PIFA and the monopole have been utilized for general mobile terminals. For these antennas, generally there are two methods to obtained dual band or multi-band operations. The first method is that the dual or multi-band is generally obtained by inserting slits, slots, or additional radiating elements of different dimensions. For this design method, a single resonance is usually generated for each one of the lower and upper bands. The second method is that the dual or multi-band is generated by using higher resonant modes without any additional radiating elements. However, these methods usually make the antenna with insufficient impedance bandwidths. To improve the impedance bandwidth, several approaches in conjunction with parasitic element, capacitive feed have also been demonstrated, which results in construction complexity, difficulty in separate impedance matching for each frequency bands, and poor radiation pattern in higher band [1]-[4]. In this paper, we proposed a novel triple-band antenna with sufficient impedance bandwidths and new concept of impedance matching method.

2. Antenna Design and Discussion

Fig. 1(a) shows the structure of the proposed antenna. The antenna consists of a radiator with a folded loop structure, a FR4 layer, an air layer, and a finite ground plane. The radiator is constructed on both top and bottom of a common FR4 layer to extend the resonant length in a limited space. Dimensions of antenna element and ground plane are 36mm × 15mm and 36mm × 80mm, respectively. The total height of the antenna is 6mm including an air layer (3.6mm) and a FR4 ($\varepsilon_r = 4.7$) layer (2.4mm). The feeding and shorting posts are located at the center area of the radiator. The antenna is designed to resonate as half-wavelength at lower band and as one-wavelength at higher band, respectively. Fig. 2 shows return loss of the proposed antenna. Fig. 2(a) shows the simulated result for dual resonances come from a single radiator without an additional radiating element. The dual resonances are obtained due to half-wavelength at lower band and one-wavelength at higher band. However, it indicates that the bandwidth is narrow at higher band. To enhance the impedance bandwidth, the additional radiating element is added for the upper band. Fig. 2(b) and (c) show the simulated and measured results with additional radiating element. One can see that the bandwidth at high band is considerably increased, and the lower frequency is barely shifted. In general, the resonant frequency of an antenna is adjusted by the electrical length, and the impedance of PIFA is matched by adjusting the distance between short and feed point. Therefore, it is difficult for multiband antenna based on PIFA to match for dual band or multi-band because the characteristics of the impedance is simultaneously and considerably affected each other for both at lower and higher frequencies. The feed structure has a single short point and a single feed point as shown in Fig. 1. This feed structure is generally applied to a loop antenna, or a half-wavelength or one-wavelength antenna, however it is difficult to match the impedance at resonant

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frequency [3]. In this paper, placing the feed port and inserting additional element around the position where the E-field maximum occurs for the lower band (the E-filed minimum occurs for the upper band), the bandwidth of the upper band is considerably increased with barely changing of antenna characteristics at the lower band. From Fig. 3 shown the current distributions (using IE3D simulator) for lower and upper patch, it is noticed that the E-field maximum for the lower band (the E-filed minimum for the upper band) occurs right above the feed position. Compared with the conventional PIFAs, the impedance of the proposed antenna could be effectively and easily matched for both lower and higher band. The proposed antenna resonates as one-wavelength at higher band. The directions of current at open ends are opposite each other at higher band (see Fig. 3(b)). Controlling the gap distance between open ends, amount of induced current on the ground plate, which contributes the radiation pattern, can be reduced. As the gap distance increases, the positive and negative charges at open ends increases the induced current on the ground plate. As the gap distance becomes smaller than distance between the open end and the ground plate, amount of the positive and negative charges to induce the current on the ground may be reduced. It should be mentioned that the effect of a human contact can be decreased, and the radiation pattern is also less affected by the ground current with the proposed antenna.

3. Measured Results

Fig. 2(c) shows the measured return loss. The measured impedance bandwidths (VSWR<3) are 6.5% in GSM band, 17.3% in the DCS/US-PCS band, respectively. The measured radiation patterns are shown in Fig. 4. The measured peak gains are -1.06dBi, 1.05dBi and -2.05dBi in GSM, DCS and US-PCS band, respectively. The average gains are -2.5dBi, -1.3dBi and -3.2dBi in each band. The radiation pattern of the proposed antenna is omni-directional in H-plane.

4. Conclusion

The multiband internal antenna for mobile handset applications is proposed. The bandwidth for the upper band is considerably increased without disturbing the antenna characteristics for other band. The omni-directional radiation pattern in the upper band is achieved by reducing the effect of the ground current, which can not obtain from the PIFA. The proposed antenna may reduce the effect of human contact.

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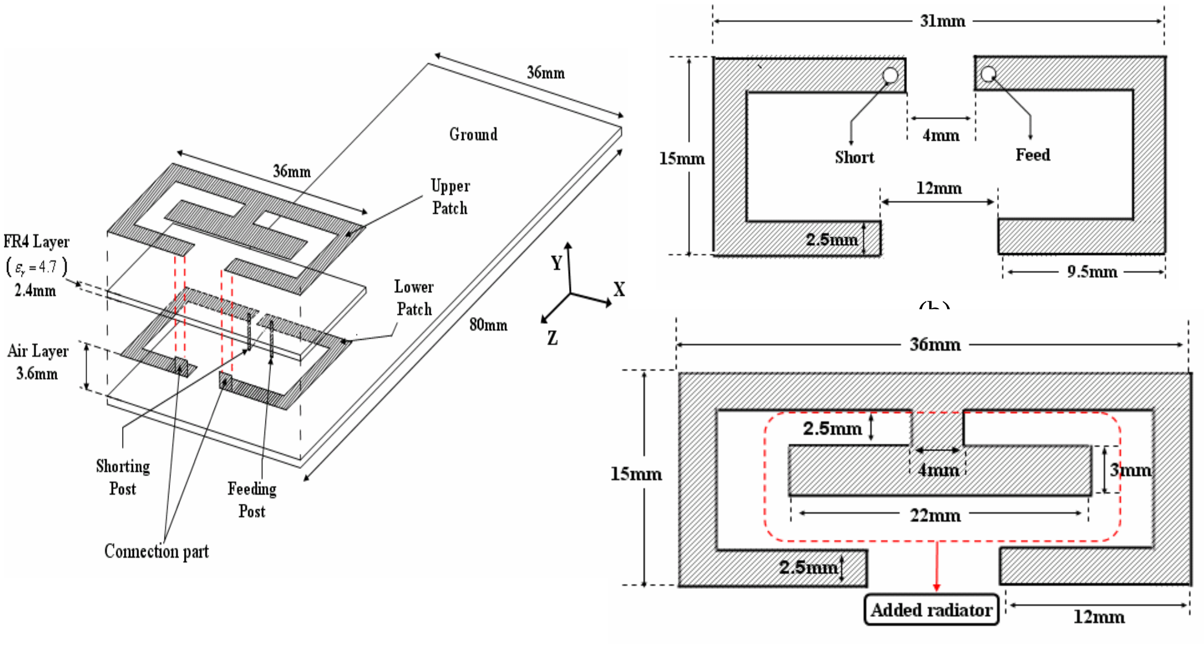


(a) (c)

Fig. 1 Geometry of the proposed antenna: (a) Overall view, (b) Upper patch, (c) Lower patch

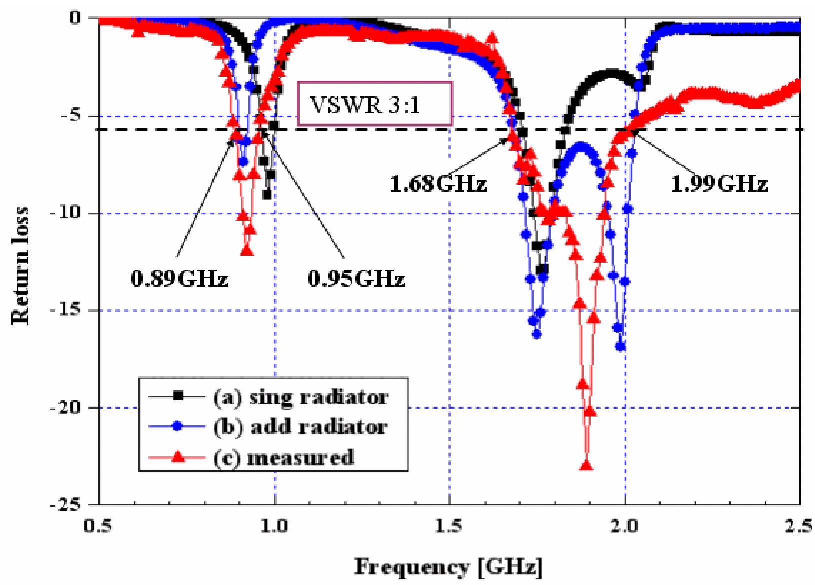
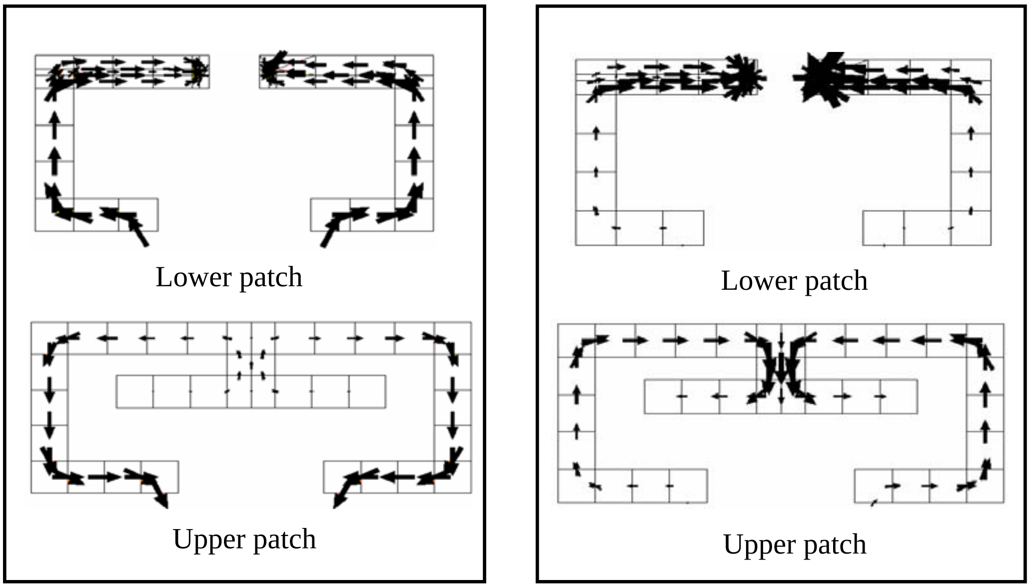


Fig. 2 Return losses



(a) (b)

Fig. 3 Current distribution by using IE3D

(a) 0.92 [GHz] (b) 1.92 [GHz]

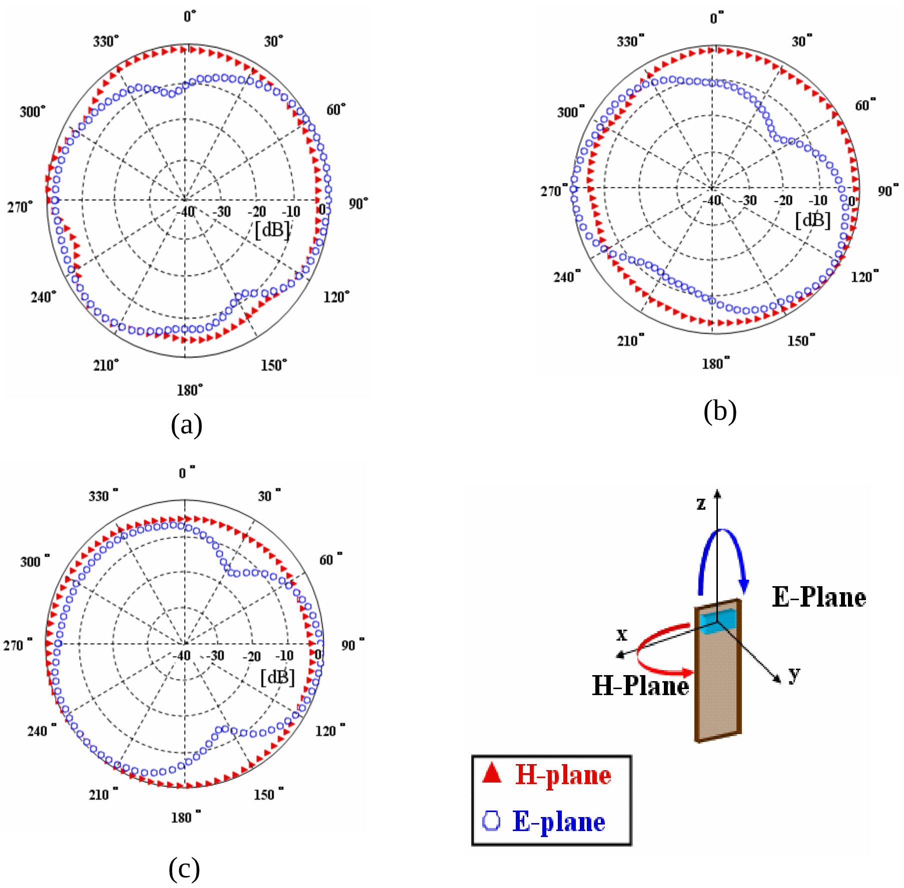


Fig. 4 Measured radiation pattern

(a) 920 [MHz] (b) 1795 [MHz] (c) 1920 [MHz]