Internal Meandered Loop Antenna for Multiband Mobile Phone with the User's Hand

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I. Introduction

Recently, the internal antennas for mobile devices are usually required to be capable of multiband operation. For this application, many planar inverted-F antenna (PIFA) designs for application in mobile phones have been reported [1]. However, all the operating bands of the multiband PIFAs are with unbalanced structures and will thus lead to larger excited surface currents on the system ground plane than the antennas with self-balanced structures. For achieving the self-balanced structures, the modified one-wavelength loop antennas suitable for application in the mobile phone have been presented [2]. These modified loop antennas, however, show mainly single-band operation. In this paper, we present a novel internal meandered loop antenna (MLA) capable of operating in the GSM/DCS/PCS bands for mobile phone applications. Design considerations of the proposed antenna and the user's hand effect on the antenna performance are also presented and studied.

II. Design considerations of the proposed meandered loop antenna

Fig. 1(a) shows the top view of the proposed MLA. The system ground plane is printed on a 0.8-mm thick FR4 substrate of size 45 × 100 mm2. The MLA has a symmetric metal-strip loop pattern cut from a 0.2-mm thick copper plate, and is fed by a 50 餶microstrip line printed on the back side of the grounded FR4 substrate in the study. Detailed dimensions of the metal-strip loop pattern in the planar structure are given in Fig. 1(b). For the meandered sections, they can effectively lower the antenna's third resonant mode (1.5-wavlength mode) to be close to the second resonant mode (one-wavelength mode) to form a wide bandwidth at about 1800 MHz to cover the DCS/PCS operation. In addition, by adjusting the width w of matching section 1 and the length t of matching section 2, enhanced impedance matching of the antenna's lower and upper bands can be obtained. Also note that, the unoccupied area of 15 × 13.5 mm2 in the central region of the MLA is used to accommodate the lens or the CCD (charge coupled device) element of a digital camera [3].

III. Experimental results and discussion

Fig. 2 shows the measured and simulated return loss of the constructed prototype enclosed by the plastic housing shown in Fig. 1(c). From the measured results, the antenna's lower band has a bandwidth of 98 MHz for the GSM operation. On the other hand, the antenna's upper band shows a large bandwidth of 480 MHz for the DCS/PCS operation. Next, in order to demonstrate the effects of the meandered sections in the proposed meandered loop antenna, a comparison of the simulated return loss for the proposed antenna, folded loop antenna, and simple loop antenna is shown in Fig. 3. It is seen that the antenna's third resonant mode can be adjusted to be

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very close to the second resonant mode to form a wide bandwidth by properly meandering the loop pattern to achieve the proposed antenna shown in Fig. 1. The experimental photo of the user's hand holding the mobile phone with the proposed antenna is shown in Fig. 4 in which the parameter d indicates the distance from the top edge of the mobile phone to the top of the user's thumb portion. It is seen that there is frequency detuning for all the antenna's three resonant modes, when a certain portion of the antenna is overlaid by the user's hand (d = 0 and 30 mm).

Also note that the radiation characteristics are analyzed by the simulation hand model, which is provided by the commercial EM simulation software, SEMCAD. The hand model mainly comprises the skin, muscle, and bones, whose relative permittivity and conductivity are obtained from Ref. [4]. The simulated three-dimensional radiation patterns at 925, 1795 and 1920 MHz are studied and shown in Fig. 5. It is observed that the radiation power is greatly absorbed by the user's hand in the forearm direction when the distance d is small, leading to a large distortion in the antenna's radiation patterns for both the unbalanced and balanced modes. Finally, the simulated radiation efficiency as a function of d is shown in Fig. 6 for comparison. With the presence of the user's hand, large efficiency drops at 925, 1795 and 1920 MHz are observed. However, it is noted that the radiation efficiency for d = 60 mm at 1795 MHz is only about 14.6% lower than that in free space, which is smaller than the corresponding values at 925 (23.1% decrease from 72.2% to 49.1%) and 1920 MHz (18.5% decrease from 56.6% to 38.1%). This behavior is probably owing to the smaller excited surface currents on the system ground plane for the proposed antenna operated in the self-balanced mode [2].

IV. Conclusion

A novel internal meandered loop antenna for multiband operation in the mobile phone has been proposed. Strong effects of the user's hand on the impedance and radiation characteristics of the antenna have been observed. Results indicate that, when the user's hand is close to or cover a certain portion of the antenna, large decrease in the antenna's radiation efficiency and great distortion in the antenna's radiation pattern for both the unbalanced and balanced modes will occur. On the other hand, when the user's hand holds the mobile phone with a large distance to the proposed antenna, smaller decrease in the radiation efficiency has been observed for the antenna's self-balanced mode than the antenna's two other unbalanced modes.

References

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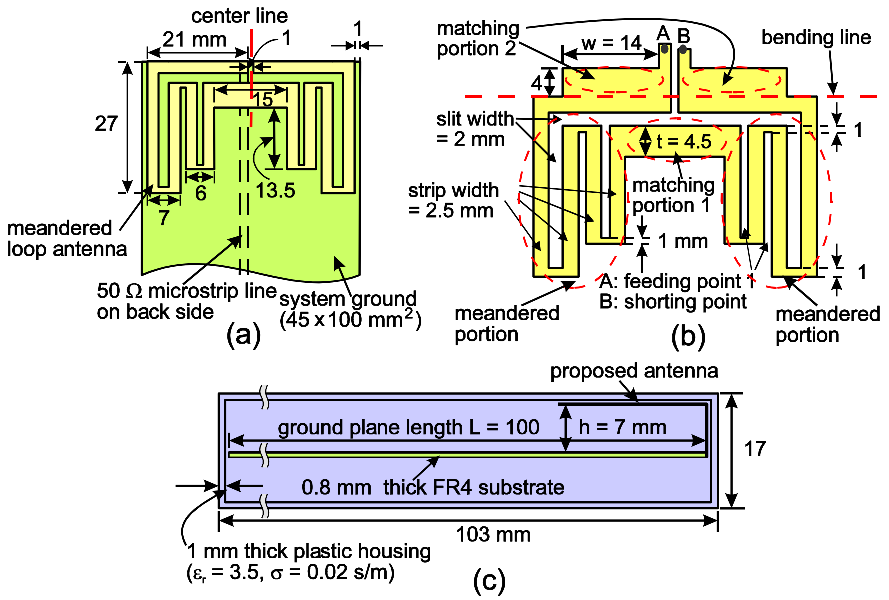

Fig. 1 (a) Top view of the proposed antenna. (b) Detailed dimensions of the antenna. (c) Side view of the antenna enclosed by a 1-mm thick plastic housing.

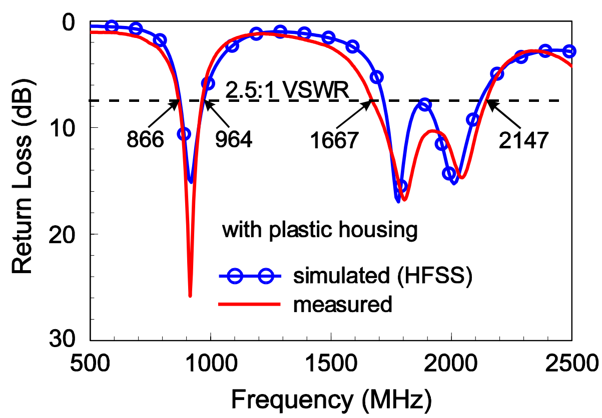

Fig. 2 Measured and simulated return loss for the proposed antenna; the 1-mm thick plastic housing is included in the study.

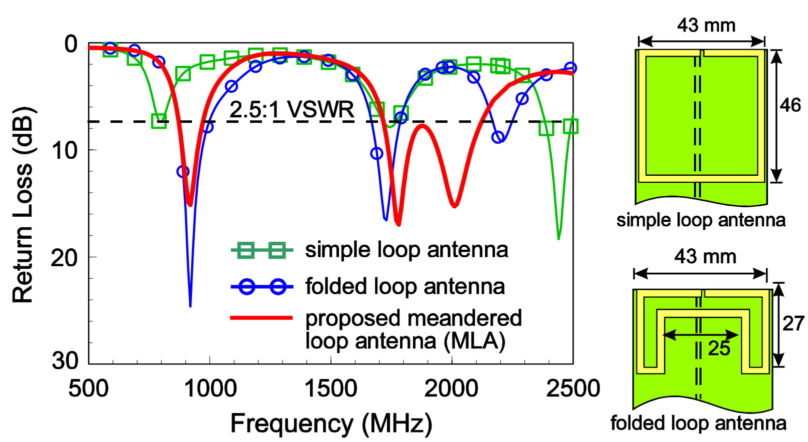

Fig. 3 Simulated (HFSS) return loss for the proposed antenna, folded loop antenna, and simple loop antenna.

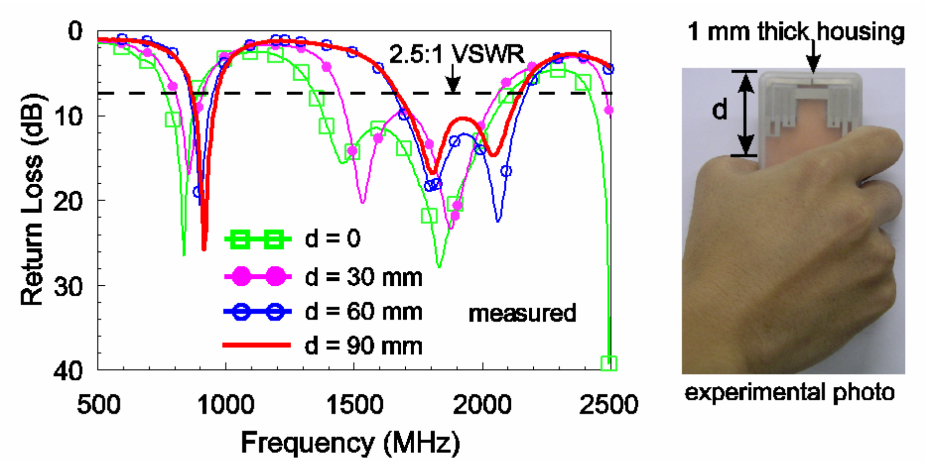

Fig. 4 Measured return loss for d = 0, 30, 60 and 90 mm for the proposed antenna with the user's hand.

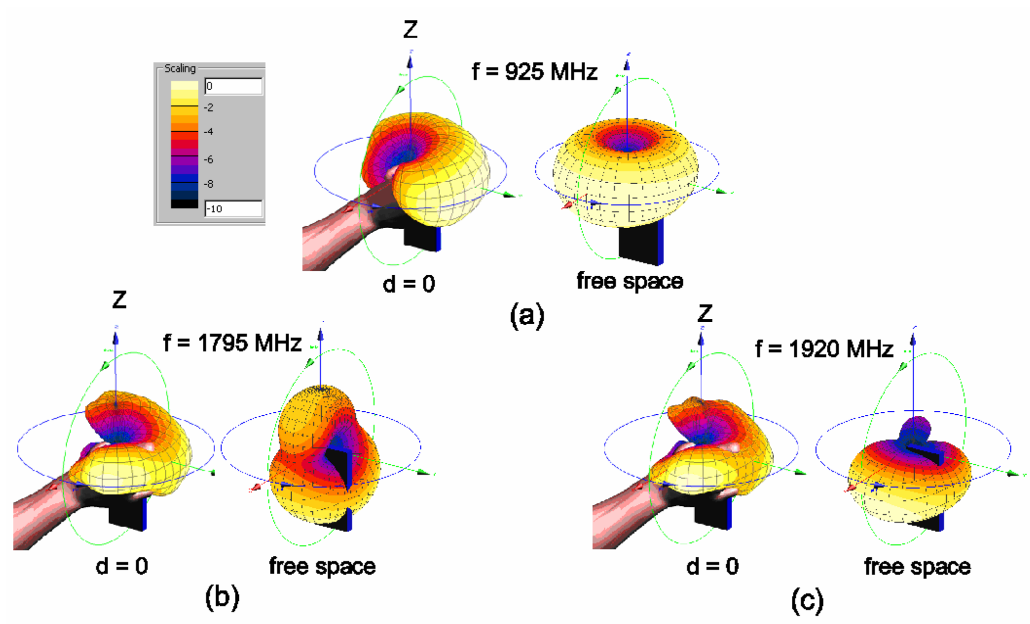

Fig. 5 Simulated (SEMCAD) radiation patterns at (a) 925, (b) 1795 and (c) 1920 MHz.

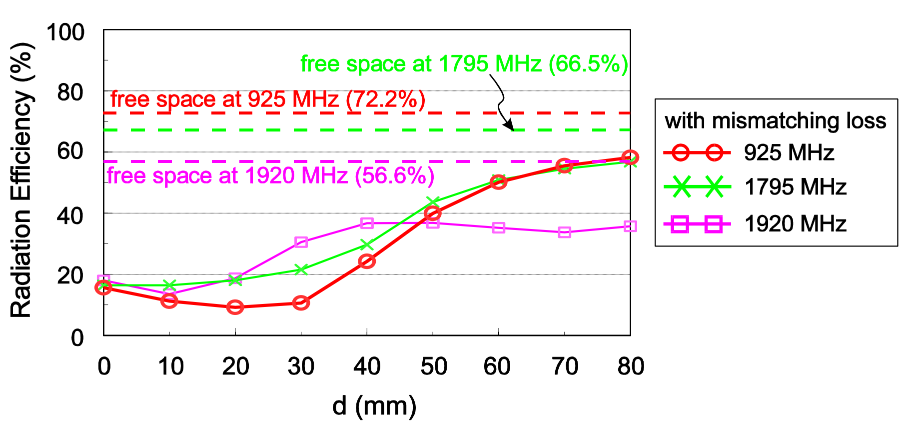

Fig. 6 Simulated (SAMCAD) radiation efficiency as a function of d.