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Multiband Hybrid Loop/Monopole Slot/Planar Monopole Antenna for Mobile Phone Application

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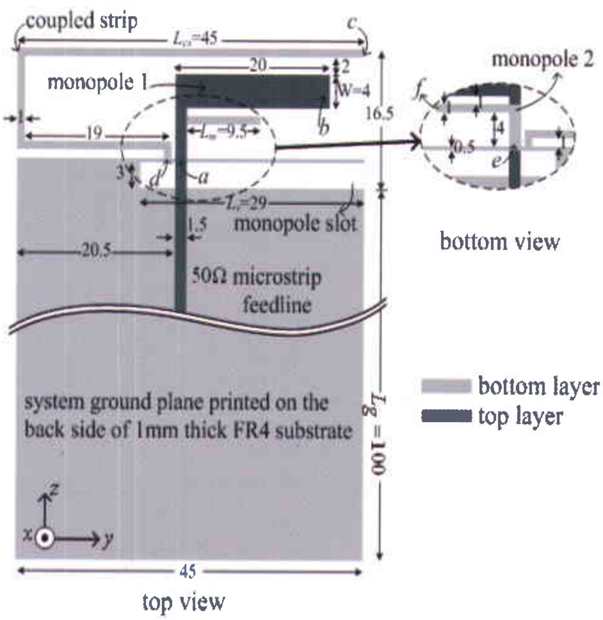
Abstract— **In this paper, a novel planar hybrid multiband antenna formed by a loop-type antenna, a monopole slot antenna, and a coupled planar monopole antenna for the mobile phone is proposed. The loop-type antenna comprises a driven monopole and a coupled strip that printed on the other side of the substrate and short-circuited to the ground. The 0.5λ and 1.0λ mode of the loop-type antenna are excited. Therefore, the 0.5λ mode of the loop-type antenna forms a wide bandwidth of 326 MHz to cover the GSM850/900 operation and the 0.25λ mode of the monopole slot antenna, the 1.0λ mode of the loop-type antenna, and the 0.25λ mode of the coupled monopole antenna provide a wide bandwidth of 1181 MHz to cover the GPS/DCS/PCS/UMTS/WLAN2.4/WiMAX operation. Finally, the 0.5λ mode of the coupled monopole antenna forms a wide bandwidth to cover the WLAN5.2 operation. Moreover, the hybrid antenna occupies a compact area of 16.5 × 45 mm^2 and it has good radiation characteristics over the operating bands.**

Keywords- mobile phone antennas; multiband antennas; planar monopole antennas; loop-type antennas; monopole slot antennas; hybrid antennas.

I. INTRODUCTION

With the growth of wireless communications, mobile handsets that can provide multiband operation have been attractive. To achieve it, several techniques have been proposed, such as Planar Inverted-F Antennas (PIFA) [1-3], planar monopole antennas [4], [5], loop-type antennas [6-8], and monopole slot antennas [9-11]. The planar monopole antenna has easy fabrication compared with the 3-D PIFA. Also, the loop-type and the monopole slot (open-end slot) antenna show an attractive feature of exciting smaller surface currents on the system ground plane of the mobile phone compared with the PIFA [12] which has unbalanced structure. Thus, dimension variations of the system ground plane and user's hand and head lead smaller effects on the antenna performances.

In this letter, we propose such a simple printed multiband hybrid antenna that consists of one loop-type antenna, one monopole slot antenna, and one planar monopole antenna. Therefore, by using of hybrid of three different antenna types, it is capable of multiband (nine-band) operation covering the Global System for Mobile communication: GSM850 or AMPS (824-894 MHz), GSM900 (890-960 MHz), Digital Communication System: DCS (1710-1880 MHz), Personal Communication Service: PCS or GSM1900 (1850-1990 MHZ), and Universal Telecommunication System: UMTS (1920-2170 MHz) for Wireless Wide Area Network (WWAN) operation and the Global Position System: GPS (1575.42 MHz) operation and the 2.4 GHz and the 5.2 GHz bands (2400-2484 MHz, 5100-5900 MHz) for Wireless Local Area Network (WLAN) operation and the 2.5 GHz band (2500-2690 MHz) for Worldwide interoperability for Microwave Access (WiMAX) operation [13]. In addition, the antenna occupies a compact area of 16.5 × 45 mm^2 only. Detailed design considerations of the hybrid antenna and the experimental results of the constructed prototype are presented and discussed.



(a)

(b)

Fig. 1. (a) Geometry and, (b) Experimental photo of the proposed planar antenna (unit: mm).

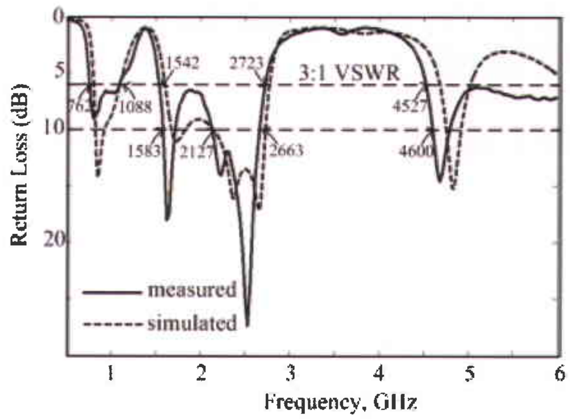


Fig. 2. Measured and simulated return losses of the proposed antenna.

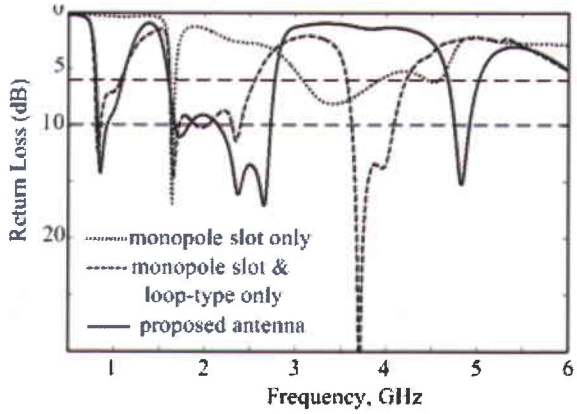


Fig. 3. Comparison of simulated return loss for the case with monopole slot only, the case with monopole slot and loop-type only, and the proposed hybrid antenna.

II. Antenna Configuration

The configuration of the proposed planar hybrid antenna printed on the top portion of the ground plane of the system circuit board is shown in Fig. 1(a) and the experimental photo of it is shown in Fig. 1(b). In this study the circuit board is fabricated by using a cheap 1-mm-thick FR4 substrate (ε_r= 4.4). The system ground plane having an area of 103.5×45 mm^2 is printed on the back side of the FR4 substrate.

The loop-type structure of the hybrid antenna is formed by a driven monopole antenna (monopole 1) that is connected to a 50Ω microstrip feedline and a coupled strip that is printed on the back side of the substrate. One of the ends of the coupled strip (point *c*) is electromagnetically coupled to the monopole 1 and in the other end is short-circuited to the ground (point *d*). Therefore, the coupled strip is capacitively excited by the monopole 1 and a loop-type structure is created with the total length of (from point *a* to *d*) 109-mm and the 0.5λ loop resonant mode at about 860 MHz and the 1.0λ loop resonant mode at about 2380 MHz are excited.

The length of the monopole slot antenna that is fed by 50Ω microstrip feedline is 29-mm (about 0.17λ in free space at 1740 MHz) which can provide a 0.25λ resonant mode [14] at about 1740 MHz. Also notice that decreasing of the resonance length is due to the presence of FR4 substrate. Finally, the coupled planar monopole (monopole 2) is printed on the back side of the substrate and short-circuited to the ground plane at point *e*. The length of it which is excited through the capacitive coupling by the monopole 1 is 16-mm (from point *e* to *f*) that can generate a 0.25λ resonant mode at about 2660 MHz and a 0.5λ resonant mode at about 4830 MHz.

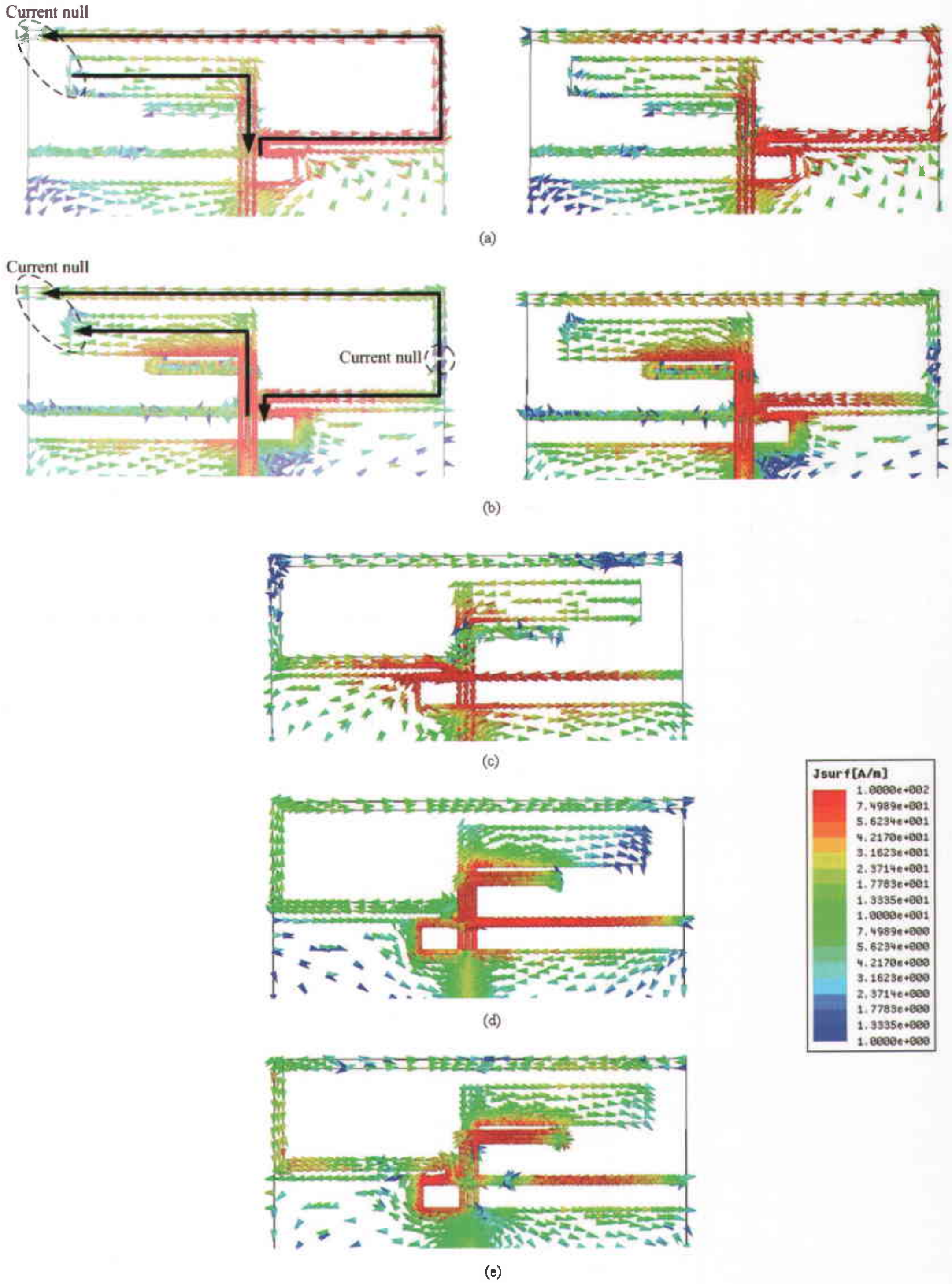


Fig.4. Simulated excited surface currents at (a) 860 MHz (top view) , (b) 1740 MHz (bottom view), (c) 2380 MHz (top view), (d) 2660 MHz (bottom view), and (e) 4830 MHz (bottom view).

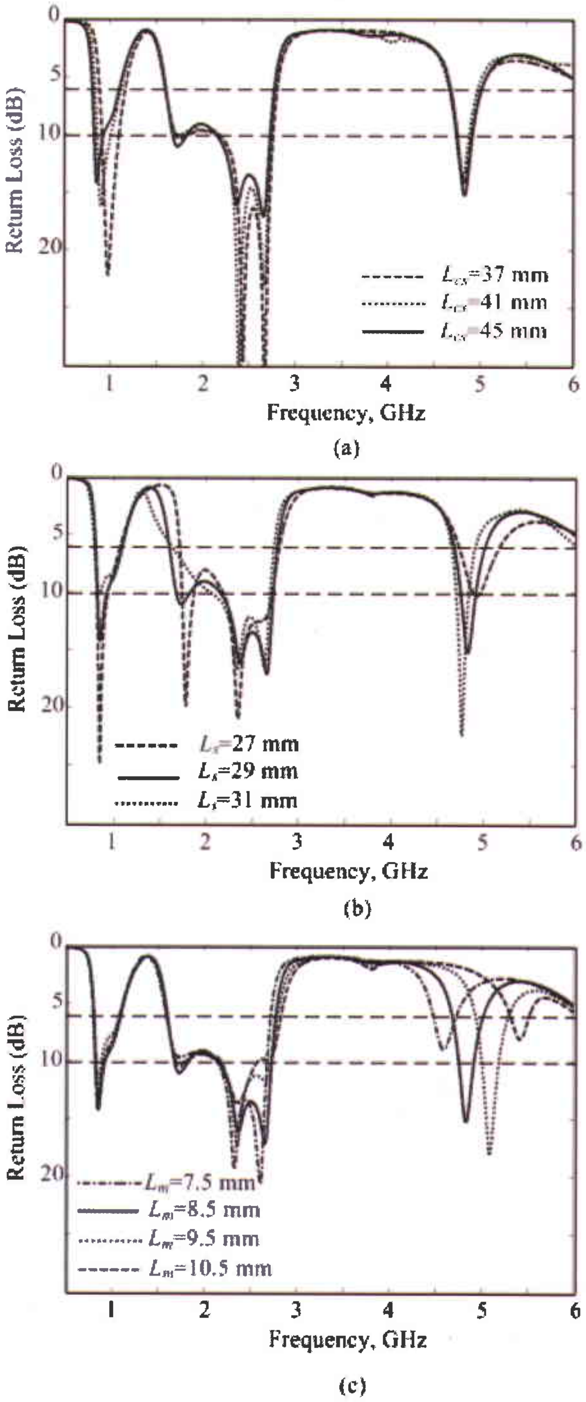


Fig. 5. Simulated return loss as a function of (a) the coupled strip length L_{cs} of the loop- type, (b) the monopole slot length L_s , and (c) the coupled monopole 2 length L_m. Other dimensions are the same as studied in Fig. 2.

III. RESULTS AND DISCUSSION

A prototype based on the design dimensions given in Fig. 1 was constructed and tested. Fig. 2 shows the measured and simulated return loss of it. The simulated results are obtained using HFSS [15], and good agreement between them can be observed. For the first band, the impedance bandwidth that is defined by 3:1 VSWR (6-dB return loss, note that the 3:1 VSWR bandwidth definition is generally accepted for practical applications [2]) reaches 326 MHz (762-1088 MHz), suitable for GSM850/900 operation and for the second band, it is 1181 MHz (1542-2723 MHz) and easily covers GPS/DCS/PCS/UMTS/ WLAN2.4/WiMAX and for the third band, it is 1473 MHz (4527-6000 MHz). In addition, the impedance matching for frequencies over the GPS, the WLAN, and the WiMAX is better than 8-dB return loss.

A comparison of simulated return loss of the proposed hybrid antenna, the case with monopole slot only, and the case with monopole slot and loop-type only is shown in Fig. 3. In the first case, the 0.25λ mode of monopole slot antenna is excited. In the second case, the 0.25λ and the 0.5λ mode of the monopole slot (at 1740 and 3710 MHz, respectively), the 0.5λ and the 1.0λ mode of the loop-type (at 850 and 1950 MHz, respectively), and the 0.25λ mode of the monopole 1 (at 2350 MHz) are excited. Notice that the monopole 1 has about 30-mm of length (from point *a* to *b*) and in this case, it alone can provide a 0.25λ resonant mode at about 2350 MHz. Therefore, without the monopole 2, the antenna easily covers GSM850/900/GPS/DCS/PCS/UMTS and with fine tuning may be covered WiMAX3.5 (3400-3600 MHz).

When monopole 2 is added, not only two additional resonant modes at about 2660 and 4830MHz are generated, but also the 1.0λ mode of the loop-type is shifted to upper frequency and excited at about 2380 MHz This shifting to upper frequency is because of decreasing of the resonance effective length of loop-type. In addition, the 0.5λ mode of monopole slot antenna isn't excited.

To study the excited resonant modes at 860, 1740, 2380, 2660, and 4830 MHz, Fig. 4 shows their simulated excited surface currents. In Fig. 4(a), it is seen that for the 0.5λ mode of loop-type antenna, there is one current null along the loop structure. Fig. 4(b) clearly indicates that the 0.25λ mode of the monopole slot antenna has been excited. In Fig. 4(c), it is observed that for the 1.0λ mode of the loop-type antenna, there are two current nulls along the loop structure. Fig. 4(d) and 4(e) show that the 0.25λ and the 0.5λ modes of the monopole 2 are excited at about 2660 and 4830 MHz, respectively.

Effects of the coupled strip length L_{cs}, are studied in Fig. 5(a). The results indicate that, by increasing L_{cs} the resonant modes of the loop-type antenna (i.e. 0.5λ at 860 MHz and 1.0λ at 2380 MHz) because of increasing of resonance effective length are decreased. Effects of the monopole slot on the performances are studied in Fig. 5(b). As expected, with an increase in the length L_s, the resonant mode of the monopole slot antenna (i.e. 0.25λ at 1740 MHz) is shifted to lower frequencies and the other resonant frequencies are almost not affected. For the effects of the length of monopole 2 L_m, the results are shown in Fig. 5(c). In this case, with an increase in the length L_m, the resonant modes of the monopole 2 (i.e. 0.25λ at 2660 MHz and 0.5λ at 4830 MHz) are shifted to lower frequencies and small variations in the other resonant modes are seen. These results (Fig. 5 (a), (b) and (c)) clearly confirm the presented discussion in section II.

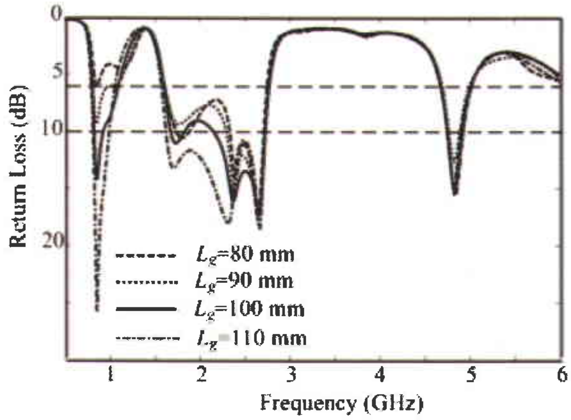


Fig. 6. Simulated return loss as a function of the ground plane length (L_g). Other dimensions are the same as studied in Fig. 2.

Effects of the ground length L_g on the return loss are also analyzed and shown in Fig. 6. It is observed that with decreasing in L_g, the lower band is degraded that is due to unbalanced resonance of 0.5λ mode in the loop-type antenna. As for the upper bands, smaller effects of the length L_g on the impedance matching of the antenna are seen. For L_g=90 mm, however, the obtained lower band can still cover GSM85/900 operation. However, the obtained bandwidths are generally about the same that suggests that the proposed antenna is suitable for application in the mobile phones with various possible ground plane lengths.

The radiation patterns of the proposed antenna are also studied and measured radiation patterns at 925, 1795, 2045, 2442, and 2595 MHz (center frequency of GSM900, DCS, PCS, UMTS, and WLAN bands, respectively) of the fabricated prototype are shown in Fig. 7. Monopole-like radiation patterns with good omnidirectional radiation in the azimuthal plane (*x-y* plane) at 925 MHz are obtained which is similar to those of the conventional internal mobile phone antennas operated in the GSM band [1]. For the upper band frequencies generally similar radiation patterns are observed, which indicates that stable radiation characteristics are obtained over the antenna's upper band. The simulated gains of the antenna at 859, 925, 1575, 1795, 1920, 2045, 2442, 2595, and 4830 MHz are 0.72, 0.69, 0.56, 1.22, 1.25, 1.25, 1.40, 1.32, and 2.5 dBi, respectively.

The measured input impedance on Smith chart for the proposed antenna is presented in Fig. 8. It shows four loops on Smith chart, corresponding to five nulls present on its return loss plot in Fig. 2.

Moreover, with the bending of the proposed antenna by 90° along to the lower edge of the monopole 1, it can occupy a smaller space in the mobile phone with negligible effects on the performance of antenna which a comparison of simulated return loss of it and the proposed planar antenna is also shown in Fig. 9.

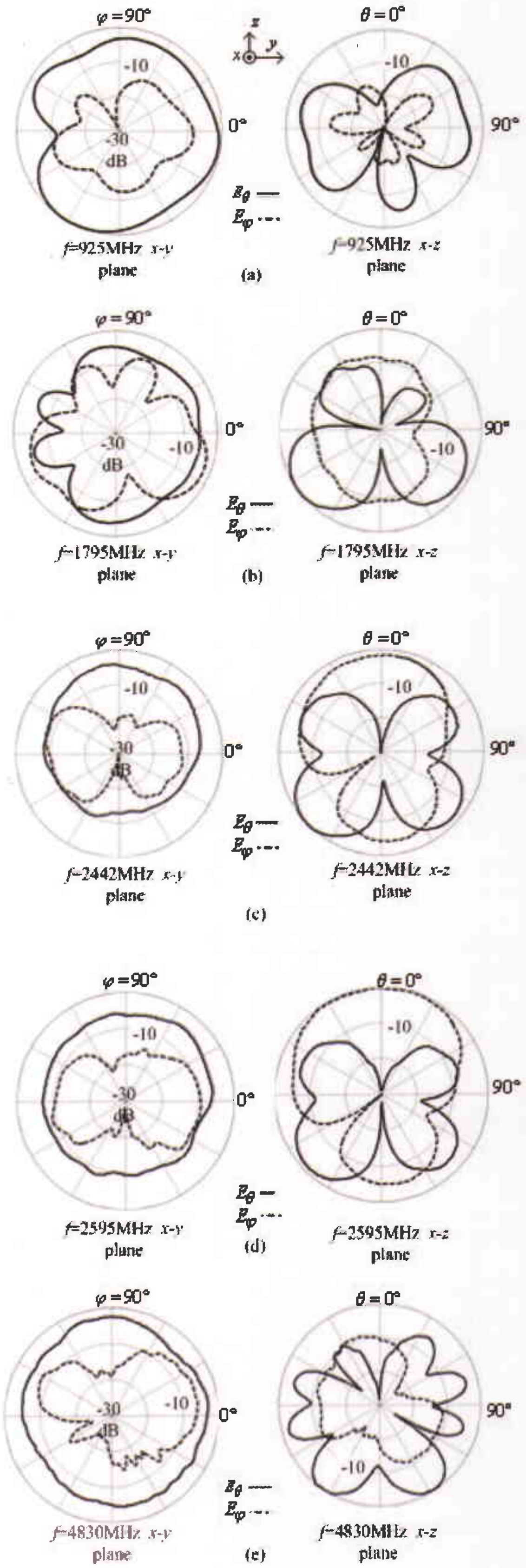


Fig. 7. Measured radiation patterns at center frequency of (a) GSM900, (b) DCS, (c) UMTS, (d) WLAN2.4, and (e) WiMAX.

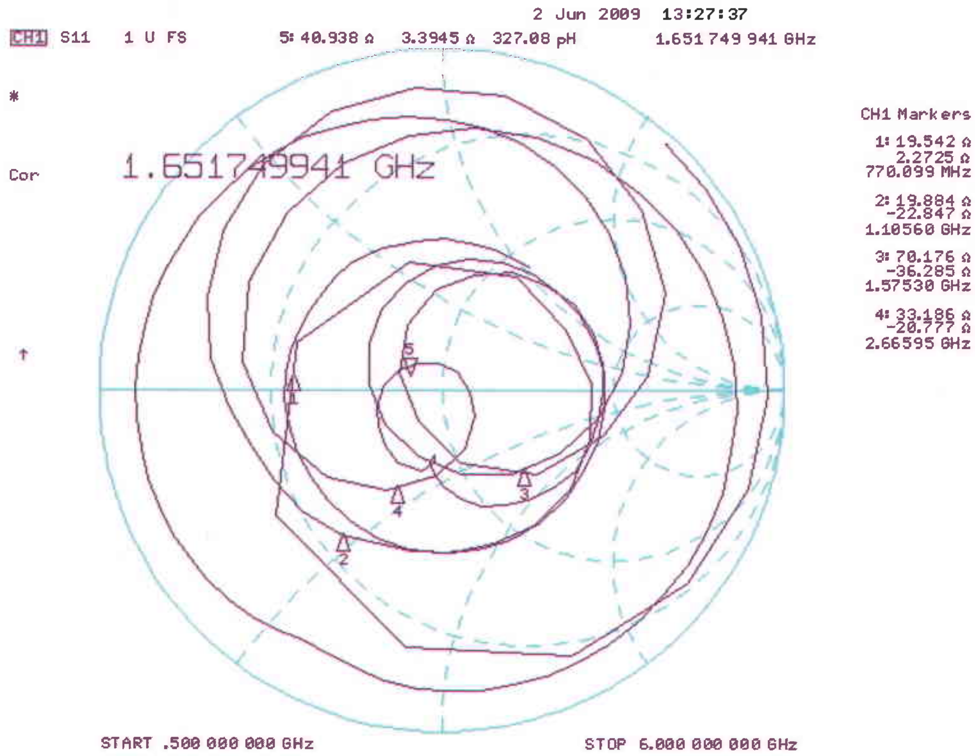


Fig. 8. Measured input impedance on Smith chart for the proposed planar antenna (start: 0.5GHz, stop: 6GHz). Notice that markers are on the edge of the different bands.

IV. Conclusion

A simple hybrid planar antenna capable of GSM850/900/GPS/DCS/PCS/UMTS/WLAN2.4/WiMAX/WLAN5.2 operation (nine-band) for mobile handsets applications has been proposed and studied. The proposed antenna has a simple planar structure and is easy to fabricate. Moreover, with bending of it, not only the antenna can occupy smaller space but also the effect of the bending on the performance of the antenna is negligible.

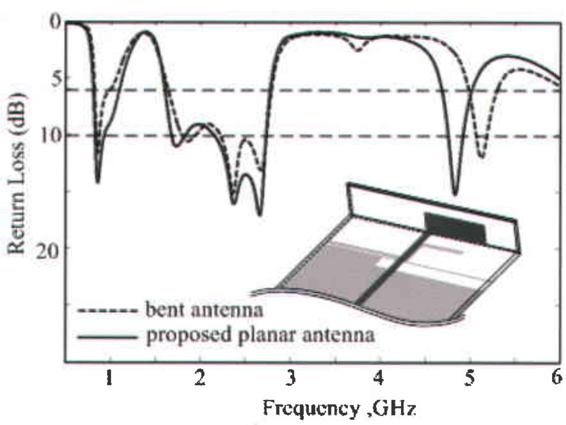


Fig. 9. Simulated return loss for the proposed planar antenna and the bent antenna.

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References

[1] Wong, K. L.: ‘Planar Antennas for Wireless Communications’. New York: Wiley, 2003, ch. 2.
[2] Wong, K. L. and Huang, Ch.: ‘Compact multiband PIFA with a coupling feed for internal mobile phone antenna’. *Microw. Opt. Technol. Lett.*, 2008, vol. 50, pp. 2487-2491.
[3] Nguyen V., Bhatti R., Park S.: ‘A simple PIFA-based tunable internal antenna for personal communication handsets’. *IEEE Antennas Wireless Propag. Lett.,* 2008, vol. 7, pp. 130-133.
[4] Jing, X. and Du, Z.: ‘A compact multiband planar antenna for mobile handsets’. *IEEE Antennas Wireless Propag. Lett.,* 2006,vol. 5, pp. 343-345.
[5] Zaker R., Ghobadi C., and Nourinia J.: ‘Novel modified UWB planar monopole antenna with variable frequency band-notch function’. *IEEE Antennas Wireless Propag. Lett.,* 2008, vol. 7, pp. 112-114.
[6] Lin C. and Wong K. L.: ‘Internal multiband loop antenna for GSM/DCS/PCS/UMTS operation in the small-size mobile device’. *Microw. Opt. Technol. Lett.*, 2008 vol. 50, pp. 1279-1285.
[7] Chi Y., Wong K. L.: ‘Internal compact dual-band printed loop antenna for mobile phone application’. *IEEE Trans. Antennas Propag.,* 2007, vol. 55, pp. 1457-1462.
[8] Wong K. L. and Tu S.: ‘Ultra-wideband loop antenna coupling-fed by a monopole feed for penta-band folder-type mobile phonea’. *Microw. Opt. Technol. Lett.*, 2008, vol. 50, pp. 2706-2712.

[9] Lin C. I. and Wong K. L.: 'Printed monopole slot antenna for internal multiband mobile phone antenna'. *IEEE Trans. Antennas Propag.*, 2007, vol. 55, pp. 3690-3697.

[10] Chang C. and Wong K. L.: 'Internal multiband surface-mount monopole slot chip antenna for mobile phone application'. *Microw. Opt. Technol. Lett.*, 2008, vol. 50, pp. 1273-1279.

[11] Zhao A. and Rahola J.: 'Quarter-wavelength wideband slot antenna for 3-5 GHz mobile applications'. *IEEE Antennas Wireless Propag. Lett.*, 2005, vol. 4, pp. 421-424.

[12] Wu C. H. and Wong K. L.: 'Internal hybrid loop/monopole slot antenna for quad-band operation in the mobile phone'. *Microw. Opt. Technol. Lett.*, 2008, vol. 50, pp. 795-801.

[13] http://www.wimaxforum.org, worldwide interoperability for microwave access forum or WiMAX forum.

[14] Latif S. L., Shafai L., and Sharma S. K.: 'Bandwidth enhancement and size reduction of microstrip slot antenna' *IEEE Trans. Antennas Propag.*, 2005, vol. 53, pp. 994-1002.

[15] http://www.ansoft.com/products/hf/hfss/Ansoft Corporation HFSS.

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