A Reconfigurable Folded Antenna for Mobile Phone Applications

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Abstract— A folded reconfigurable antenna using three PIN diodes is proposed for personal communication handset applications. In a compact volume of $60 \times 9 \times 8\,\text{mm}^3$, the antenna has a simple metal structure comprising a folded loop strip, a Y-shape folded strip and three PIN diodes. By independently controlling the on/off states of the three PIN diodes located on the radiating element, the proposed structure can operate in the inverted-F antenna (IFA) and loop modes, respectively. While operating in the IFA mode, the bandwidth is sufficient to cover the DCS (1710–1880 MHz), PCS (1850–1990 MHz) bands. Owing to the additional Y-shape folded strip, the bandwidth generated by multiple resonances of the loop mode covers GSM850 (824–894 MHz), GSM900 (880–960 MHz), GPS (1560–1590 MHz), UMTS (1920–2180 MHz), LTE2300 (2305–2400 MHz), WLAN (2400–2480 MHz) bands. Good radiation efficiency and antenna gain at frequencies over the desired operating bands are obtained. The proposed antenna is fabricated and all simulated results are confirmed with measured data.

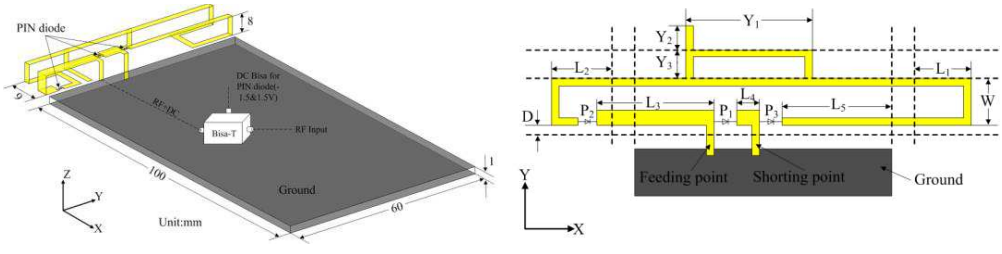
1. INTRODUCTION

With the rapid progress in wireless communication, the requirement of a single compact antenna covering multi-wireless radiation bands is increasing. Many antennas with wide bandwidth and compact structure have been introduced in [1, 2]. However, these conventional antennas mentioned above have relatively narrow operation bandwidth and are too large to be integrated into mobile terminals. Recent studies showed that the loop antennas are promising candidates for mobile phone application [3, 4]. However, good impedance matching of loop antenna is not easy to be achieved at its resonant mode.

In this paper, a novel folded reconfigurable antenna is presented for multifunctional wireless personal communication devices. The performance of the antenna is reconfigured in the IFA and loop modes by adjusting the states of the three PIN diodes. The proposed antenna generates very wide bandwidth to cover the DCS and PCS bands in the IFA mode. An additional strip connected to the main radiating element is utilized in the loop mode to widen the operating bandwidth. The four desired resonance at about 900 MHz, 1575 MHz, 1850 MHz and 2450 MHz can be excited for the proposed antenna of loop mode to cover GSM850, GSM900, GPS, UMTS, LTE2300 and WLAN bands.

2. DESIGN OF THE PROPOSED RECONFIGURABLE ANTENNA

Figures 1(a) and 1(b) show the geometry of the proposed reconfigurable antenna. A 1 mm thick FR4 substrate of relative permittivity 4.4 is used as the printed circuit board (PCB). The broadside of folded metal strip is divided into two parts. The length of the left part which plays a major role in IFA mode is 4 mm, while the length of the rest part is 2 mm to maintain the performance of loop mode. The additional Y-shape folded strip is attached to the main radiating element with the same width.



(a) (b)

Figure 1: Geometry of the proposed folded loop antenna. (a) 3-D view. (b) Detailed dimensions of the antenna unfolded into a planar structure.

Table 1: Optimized dimensions of the proposed antenna (mm)..

parameter	L_1	L_2	L_3	L_4	L_5
value	13	12	34	6	32
parameter	Y_1	Y_2	Y_3	W	D
value	22	8	7	9	2

The positions of PIN diodes (P_1, P_2 and P_3) are illustrated in Figs. 1(a) and 1(b). P_1 is located between the feed point and short point. P_2 and P_3 are placed on either end of the 4 mm-wide patch to adjust the length of the folded strip in IFA mode.

3. DISCUSSIONS AND OPTIMIZATION

The antenna is composed of a folded loop strip and a Y-shape folded strip when P_2 and P_3 are turned on and P_1 is turned off. The total length of the folded loop strip from the short point to the feed point is close to 0.5-wavelength of the frequency at 900 MHz, which makes it possible to generate a 0.5-wavlength resonant mode for GSM850/900 operation. Moreover, the loop antenna generates a 1.0-wavelength mode at about 1570 MHz. The 1.5-wavelength resonant mode is also excited at about 1950 MHz, which, however, cannot cover UMTS/LTE2300/WLAN operation for the antenna's upper band. By attaching an additional Y-shape folded strip to the main radiating element, the upper band can be formed together by the 1.5-wavelength resonant mode and the 2.0-wavelength resonant mode excited at about 2450 MHz.

Meanwhile when P_2 and P_3 are turned off and P_1 is turned on, the loop antenna can be divided to IFA by slicing the folded radiating element. For the inverted-L copper strip, the width is set to be 4 mm and the total length is about 40 mm which generates a 0.25-wavlength resonance at about 2000 MHz for DCS and PCS operations.

4. ANTENNA FABRICATION AND MEASUREMENT RESULTS

Antenna prototype was fabricated. In the bias circuit, the DC signal is isolated from the RF signal by an inductor and a chip capacitor. The blocking capacitor (C_b) is implemented between the port and main radiating element for DC blocking. On the other hand, an inductor (L_b) is located between DC signal and radiating element, which is used for RF choking.

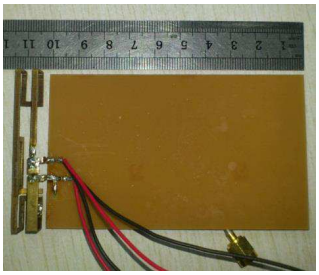


Figure 2: Photograph of the reconfigurable antenna.

Figure 3 shows the simulated and measured reflection coefficients of the proposed antenna in two operation modes. In the loop mode, the fabricated antenna covers the GSM850, GSM900 GPS, UMTS, LTE2300 and WLAN bands. For the IFA mode, the the measured bandwidth is 677 MHz which cover the DCS and PCS bands.

Figure 4 shows the gain radiation patterns of the reconfigurable antenna at 900 MHz, 1575 MHz, 1850 MHz, 2000 MHz and 2400 MHz, respectively. It is observed that the radiation patterns for the lower frequency band are similar to that of a conventional quarter-wavelength monopole antenna in the xy- and yz-planes, and omnidirectional radiation in the xz-plane. The main reason is that the antenna has a dominant operating current in the y-direction. The antenna radiation patterns cannot show complete omnidirectional pattern and linear polarization over the upper frequency bands for the existence of undesired weak surface currents in other directions. However, this is not a strict requirement for handheld devices antennas. The proposed antenna also has a high cross-polarization level of radiation patterns.

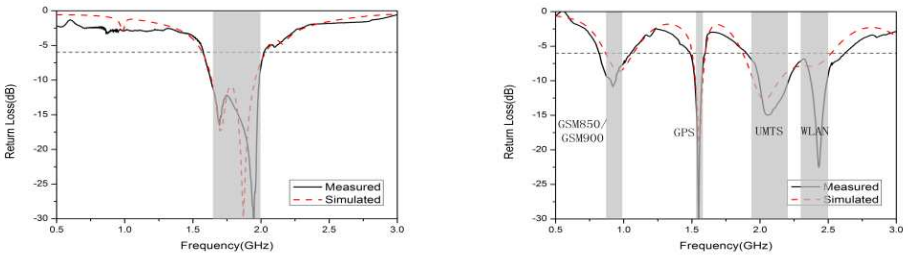


Figure 3: Simulated and measured reflection coefficients of (a) the IFA mode and (b) the loop mode.

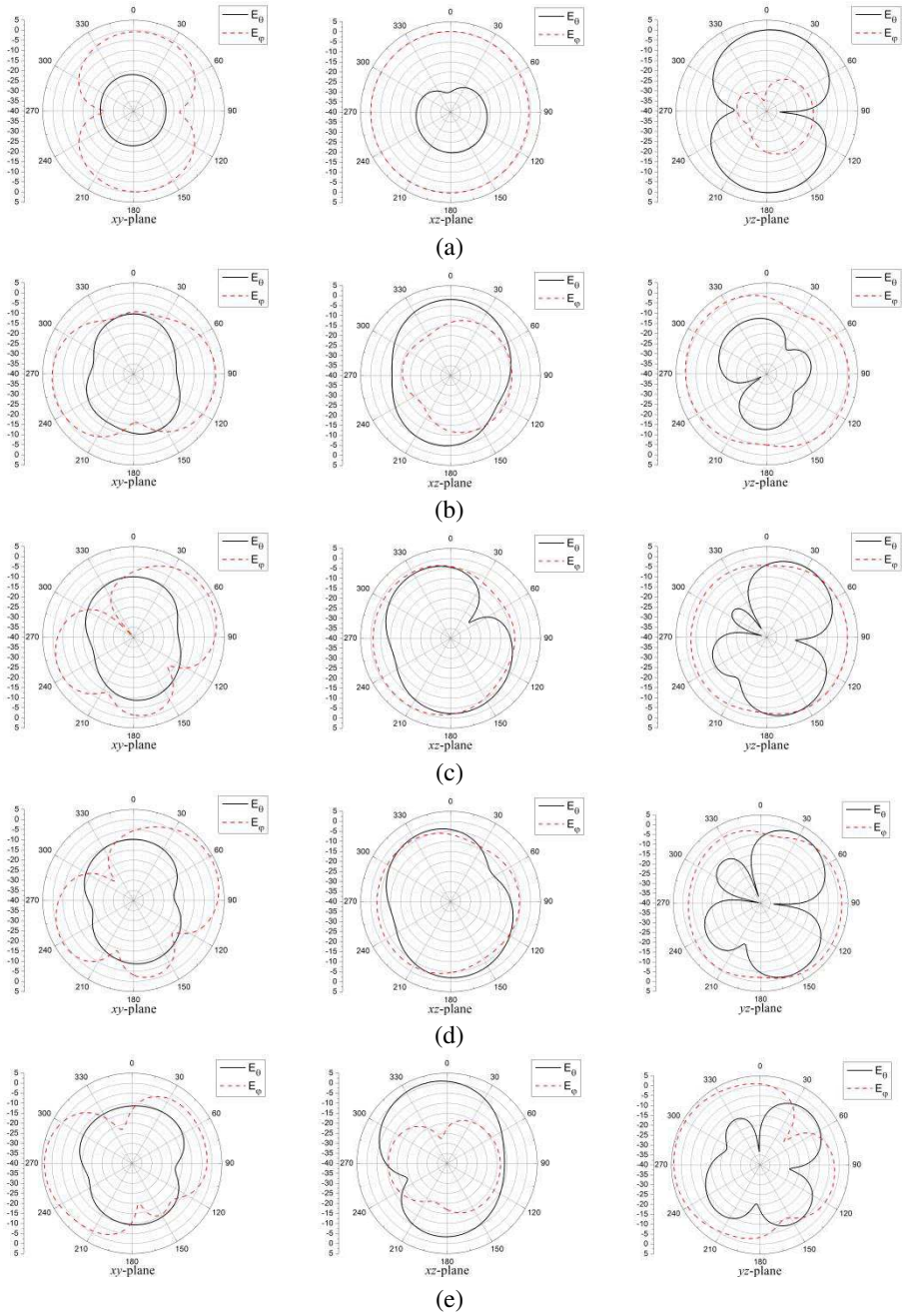


Figure 4: 2D-radiation pattern (co-polarization and cross-polarization) of the reconfigurable antenna in (a) 900 MHz, (b) 1575 MHz, (c) 1850 MHz, (d) 2000 MHz and (e) 2400 MHz.

Table 2 presents the simulated antenna gain and radiation efficiency for the proposed antenna in different frequency bands. The gains are about 0.66–0.84 dBi and the radiation efficiencies are higher than 50% over the GSM850/900 bands. Meanwhile, the gains for the GPS, DCS, PCS, UMTS, LTE2300 and WLAN bands range from 1.31 to 2.73 dBi and the radiation efficiencies are higher than 60%.

Table 2: The simulated gain and measured effciency of the proposed antenna at different frequencies.

Band	GSM 850	GSM 900	GPS	DCS	PCS	UMTS	LTE 2300	WLAN
Frequency (GHz)	0.85	0.9	1.575	1.8	1.9	2.05	2.35	2.45
Gain (dBi)	0.66	0.84	1.31	2.59	2.73	2.61	1.76	2.28
Total Effciency (%)	56.5	58.3	61.1	64.5	73	74.2	62.7	65.6

5. CONCLUSIONS

A folded loop antenna with reconfigurable characteristic for personal communication handset applications is presented. Wide bandwidth is achieved by merging the different working frequency bands generated in different operating modes. By adding a Y-shape folded strip, the impedance matching is improved for the upper bands in loop mode. The reconfigurable antenna can cover the following frequency bands: GSM850, GSM900, GPS, DCS, PCS, UMTS, LTE2300 and WLAN with a compact volume of $60 \times 9 \times 8\,\text{mm}^3$. Good radiation characteristics over the operating bands have been obtained.

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