A Novel Planar Inverted-F Antenna for 2G/3G/LTE Systems

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***Abstract*—In this paper, a novel planar inverted-F antenna (PIFA) operating at six bands (GSM850, GSM900, DCS1800, PCS1900, UMTS2100, LTE2300) is proposed. By adding a parasitic element and two slots in the patch of basic PIFA, the bandwidth on the upper frequency band can be improved to cover more communication systems. All the simulated and measured results show that the proposed PIFA possesses -6dB bandwidth 185 MHz (805 MHz to 990 MHz) at the lower frequency band and 815 MHz (1705 MHz to 2520 MHz) at the upper frequency band. Moreover, the proposed antenna exhibits good performance of total radiated power (TRP), (18 ~28 dBm) and total isotropic sensitivity (TIS), (-91 ~-107 dBm), under the free space environment. Thus, the novel PIFA is suitable for 2G/3G/LTE mobile communication systems.**

***Keywords*—PIFA; parasitic element; total radiated power (TRP); total isotropic sensitivity (TIS)**

I. INTRODUCTION

In recent years, with the rapid development of wireless communication systems, mobile phone antennas are constantly optimized to meet people's various requirements. It is important for us to design mobile phone antennas with miniaturization, low reflect coefficient and wide bandwidth, as well as high efficiency [1].

Most of handset antennas are planar inverted F antenna and ordinary monopole antenna, which are easy to design and manufacture. In addition, loop antenna is also important candidate for mobile phone because it can excite multi-resonant modes [2]. However, monopole antenna has poor performance and strict size, and loop antenna has a complex structure. Therefore, PIFA with small size and low profile is widely used in mobile phone, but PIFA has obvious disadvantage of narrow bandwidth [3]. Lots of studies on materials and structures for PIFA have been done to solve the problem of antennas [3]-[9]. It is common that slots on the ground have been used to increase impedance bandwidith of antenna [4], [5], [11],but the ground can not be slotted in many industrial design. The second one is to slot in the radiation patch [3], [10], [12]. Additionally, the third way is used to increase bandwidth by adding parasitic element next to antenna [6]- [9], but their sizes can not meet the requirement in some cases.

In this paper, a novel PIFA is proposed with a parasitic element and two slots to improve the radiation performance of antenna and enhance the bandwidth, which is enough silm and small size to be built in portable device. We compare the performance of the proposed antenna with and without parasitic element and two slots, in order to verify the effectiveness of this method. Finally, we use the over-the-air (OTA) test system to measure the performance of mobile phone antenna by total radiated power (TRP) and total isotropic sensitivity (TIS) [7] in ETS AMS chamber. Simulated and measured results show that the novel PIFA meet the modern mobile phone antenna design requirements, including -6dB bandwidth, stable radiation pattern at whole operating frequency and better values of TRP and TIS. Therefore, it can be used in portable handset to cover GSM850(820 ~894MHz), GSM900(880 ~960MHz), DCS(1710 ~1880MHz), PCS(1820 ~1990MHz), UMTS(1920 ~2170MHz), and LTE2300(2305 ~2400MHz).

This paper is organized as follows: section II shows the structure of the proposed antenna. Simulated and measured results are presented in Section III. Finally, a conclusion is drawn in Section IV.

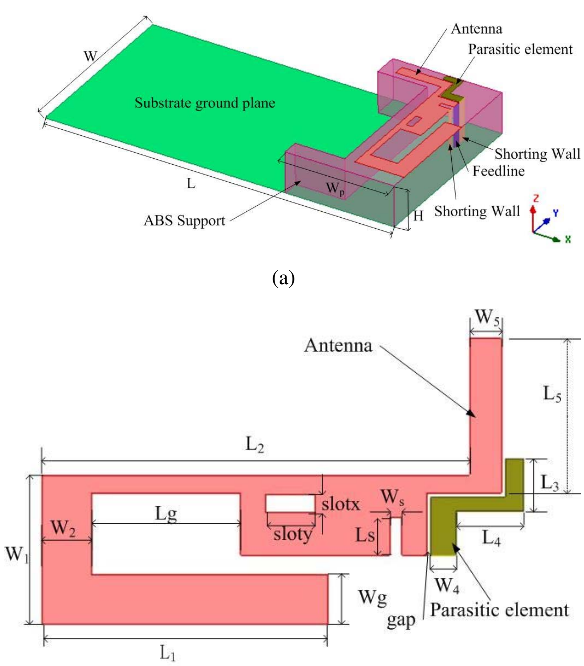
II. ANTENNA STRUCTURE

The proposed handset antenna with ground plane is shown in Fig. 1. The antenna elements are made of radiation patch, feedline, parasitic element, ABS support, as well as two shorting wall. The dimension of shorting wall is 10mm $\times$ 2mm $\times$ 0.1mm, and feedline is 10mm $\times$ 1.6mm $\times$ 0.1mm. The distance between shorting wall and feed is 1mm. Additionally, ground plane is made of FR4 material that has a permittivity of 4.4 with dielectric tangent loss δ of 0.02, and its dimensions are 82mm $\times$ 40mm $\times$ 1mm. The handset antenna support is made of acrylonitrite butadrene styrene with permittivity of 2.6 (ABS) [2], [4], which is widely used in mobile phone design. The radiated element with parasitic element is shown in Fig.1(b). The gap between the parasitic element with antenna is 0.5mm. What's more important, designing a parasitic element next to the antenna is beneficial to enhance bandwidth and improve radiation performance [6]- [9]. In addition, the proposed antenna here has two slots in its radiation patch, namely slots1 and slot2, which can change the current path in patch to influence the radiation performance. However, modern mobile phone has very limited volume for internal antenna and parasitic element. Hence all parameters of the proposed

TABLE I
DETAILED VALUES OF THE PROPOSED ANTENNA

Parameter	Value(mm)	Parameter	Value(mm)
L	82	$slotx$	1.5
W	40	$sloty$	4
H	10	L_s	3
L_1	23	W_s	1
W_1	12	L_5	11
L_g	12	W_5	2.5
W_g	4	L_4	5
L_2	34.5	W_4	2
W_2	4	L_3	4.2

phone antenna are optimized to get optimal results. Finally, the specific values of all parameters are listed in Table I.



(a)

(b)

Fig. 1. Configuration of the proposed antenna. (a) 3D antenna; (b) front antenna view

III. SIMULATION AND MEASUREMENT RESULTS

In this section, the model of the proposed mobile phone anatenna in Fig. 1 is simulated using the Ansoft HFSS 15, and then it is fabricated and tested to verify validity of the proposed antenna. Simulation results of reflect coefficient and radiation patterns of the proposed antenna have been obtained. Fig. 2 shows the reflect coefficient characteristics for proposed antenna with and without parasitic element. Although the bandwidth of the lower frequency band remains almost unchanged, the bandwidth for the upper frequency band has been greatly improved with the parasitic element so that it can cover PCS, UMTS, LTE systems. Simulated reflect coefficient of the proposed antenna with and without slot1 and

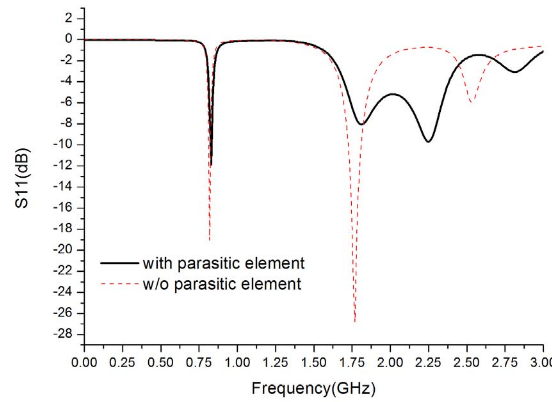


Fig. 2. Effects of parasitic element on the proposed antenna

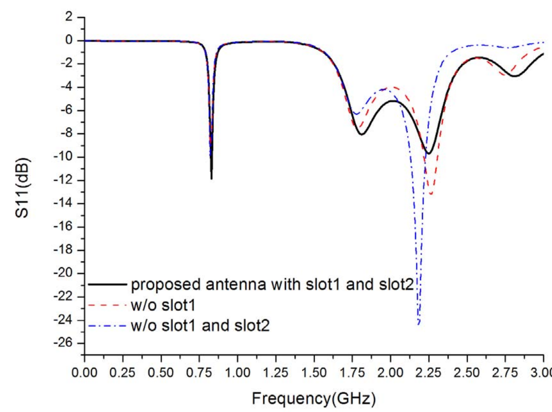


Fig. 3. Effects of slot1 and slot2 on the proposed antenna

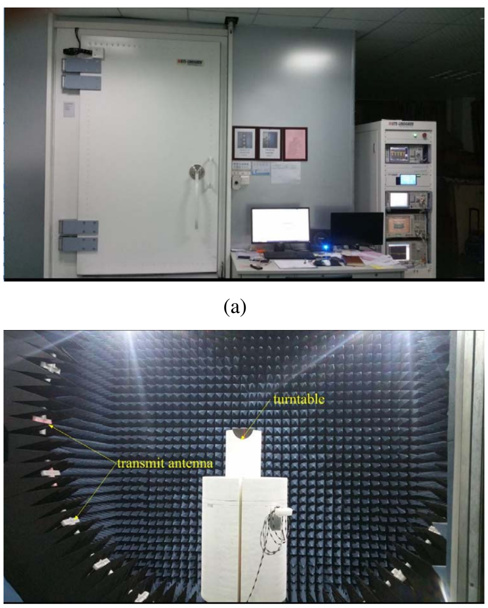
slot2 are also shown in Fig. 3. Simulated results demonstrate that slot1 and slot2 are beneficial to improve reflect coefficient and bandwidth in the upper frequency band while little impact on the lower frequency band.

Fig. 4 depicts the fabricated antenna prototype. Meanwhile, the fabricated antenna has also been measured using the antenna measurement chamber, ETS AMS chamber [10], as shown in Fig. 5, where it uses 24 transmit antennas to get accurate results. The Simulated and measured S_{11} are shown is Fig. 6. As shown in Fig. 6, measured result has some discrepancy with the simulated one. The discrepancy may result from fabrication and adjustment, but the measured -6dB bandwidth of the proposed antenna covers 0.805-0.99 GHz, 1.705-2.52 GHz, which can work in a communication multiband system.

Therefore, the proposed mobile phone antenna can operate at GSM850/900, DCS1800, PCS1900, UMTS2100, and LTE2300 to meet the requirements in modern mobile communications. Fig. 7 shows the measured 2D radiation patterns for xz and yz plane at 0.9 GHz, 1.8 GHz, 2.1 GHz and 2.3 GHz.

(a) (b)

Fig. 4. Manufactured antenna prototypes: (a) antenna on the support; (b) measured mobile phone



(a)

(b)

Fig. 5. The ETS AMS chamber: (a) external; (b) internal

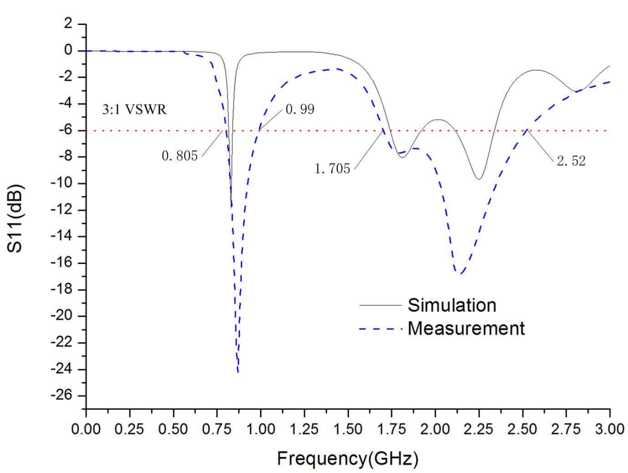


Fig. 6. Measured and simulated S_{11} for the proposed antenna

TABLE II
TRP AND TIS VALUES IN EACH BAND

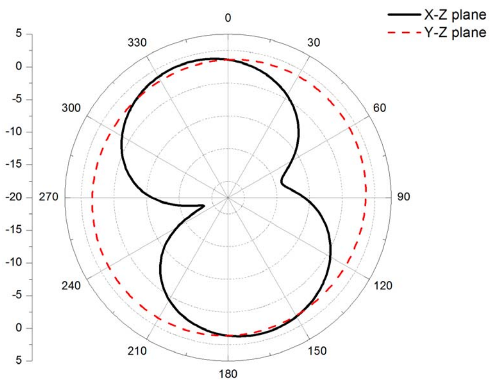
Band	Frequency (MHz)	TRP(dBm)	TIS(dBm)
EGSM850	824	27	-107
	836	27	
	848	28	
GSM900	890	24	-104
	902	25	
	914	26	
DCS1800	1710	23.4	-104
	1747	23	
	1784	22	
PCS1900	1850	23	-104
	1880	22	
	1909	22	
W2100	1922	19	-105
	1940	19	
	1977	19	
LTE2300	2302	18	-91
	2350	19	
	2397	19	

TABLE III
COMPARISON BETWEEN THIS WORK AND [7]

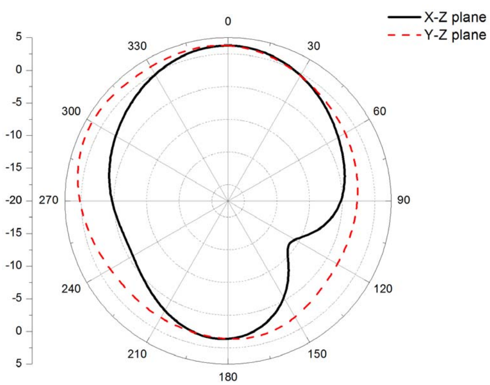
	this work		[7]	
	TRP (dBm)	TIS (dBm)	TRP (dBm)	TIS (dBm)
EGSM	28	-107	22.1	-98.2
DCS	23.4	-104	22.1	-101.9
PCS	23	-104	22.8	-101.7
WCDMA	19	-105	17.2	-104.9

The radiation pattern at 0.9GHz exhibits the similar pattern to the half-wave dipole. The obtained radiation patterns in Y-Z plane comfirm the omnidirectional characteristics in all operating frequency bands, which would meet the requirement of mobile communication handset.

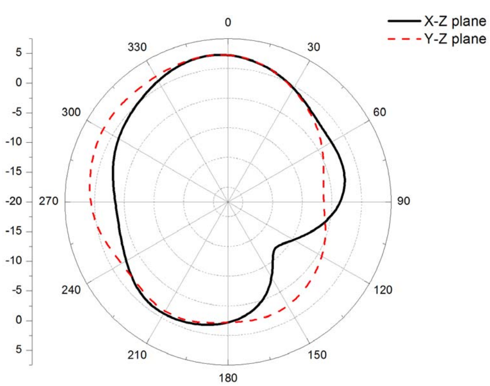
In addition, the mobile phone antenna has been measured for active test. Specific values of TRP and TIS in the free space are shown in Table 2. In general, mobile phone must meet a fixed standards for radiation performance so that it can be put into the market, and TRP and TIS are used to represent the radiation performance. The TRP represents total integrated radiated power, indicating the effectiveness of the antenna radiation system, and the TIS represents the ability to capture weak signals [7]. As shown in Table II, we can see that TRP is 18 ~28 dBm, and TIS is -91 ~-107 dBm. Generally, the greater TRP values means better radiation performance, and small TIS values represents better sensitivity. We compare this work with [7] to further illustrate the performance of the proposed antenna, and the results are shown in Table III. Compared results show that the proposed antenna outperforms the reference antenna [7]. Therefore the fabricated mobile phone antenna meets the requirements of commercial applications.



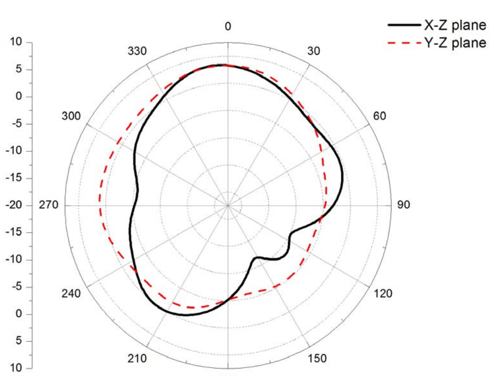
(a)



(b)



(c)



(d)

Fig. 7. X-Z and Y-Z radiation patterns of the proposed antenna at (a) 900 MHz, (b) 1800 MHz, (c) 2100 MHz, (d) 2300 MHz.

IV. CONCLUSION

The design of a novel six bands handset antenna for GSM/UMTS/LTE has been presented. The antenna consists of a radiating patch with two slots, a feedline, two shorting wall, and parasitic element. It should note that parasitic element and two slots are beneficial to improve radiation performance of the proposed antenna. Simulation and measurement have been used to study the performance, and all results show that the proposed antenna has excellent reflect coefficient, TRP(18 ~28 dBm), TIS(-91 ~-107 dBm), and stable radiation pattern on the whole operating band. Based on the ideal performance with compact size, low cost, easy fabrication, this proposed antenna is a good candidate for slim mobile phone applications.

ACKNOWLEDGEMENT

This work was supported in part by the NSFC under Grant 61372077, in part by the Shenzhen Science and Technology Programs under Grant ZDSYS 201507031550105, JCYJ20170302150411789, JCYJ20170302142515949 and GCZX2017040715180580, as well as in part by the Guangdong Provincial Science and Technology Program under Grant 2016B090918080.

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