Progress In Electromagnetics Research Letters, Vol. 14, 101–109, 2010

A MEANDER PDA ANTENNA FOR GSM/DCS/PCS/UMTS/WLAN APPLICATIONS

W.-S. Chen and B.-Y. Lee

Department of Electronic Engineering
Southern Taiwan University
Tainan County 710, Taiwan, R.O.C.

Abstract—This paper proposes a novel multi-band monopole antenna for PDA phone. A simple inverted-U-shaped driven element operates frequency bands centered at 1710 and 2350 MHz, which achieve a bandwidth based on 6-dB return loss from 1550 to 2490 MHz sufficient for DCS, PCS, UMTS, and WLAN applications. A low frequency meander path and an impedance matching stub with a truncated slit located at ground plane operates frequency band centered at 910 MHz. The bandwidth from 868 to 995 MHz covers the GSM 900 application band. The design procedures and both simulated and measured results are presented and discussed in this paper.

1. INTRODUCTION

In recent years, antenna developments have been fueled by the rapid development of modern wireless communication systems. In particular, products related to mobile phone and internet have become an indispensable part of people's daily lives. To integrate two or more functions into a single communication product, the designed antenna has to operate in multiple frequency bands. Variety antenna configurations for multi-band operation have been reported [1–5]. Conventional PIFA [3, 4] used currently are compact but have a relatively narrow bandwidth. The antenna design in [5] having two internal antennas on the edge of a circuit board achieves compact size, sufficient bandwidth, and acceptable radiation patterns. However, these antenna designs require extra clearance above the circuit board, leading to a more complex manufacturing process and therefore, higher cost.

Corresponding author: W.-S. Chen (chenws@mail.stut.edu.tw).

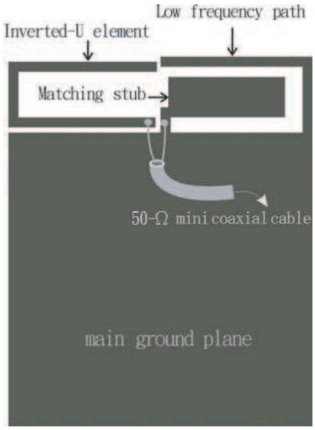
The printed planar antenna, which is fabricated on a single piece of FR4 substrate, has the advantages of low profile, lower production cost, and less complex fabrication. With these advantages, printed planar antenna is the optimal choice for manufacturer. The monopole antenna [6] is a widely employed planar antenna but suffers a major flaw of narrow bandwidth due to reducing antenna size. Many attempts have been made to extend the antenna bandwidth, such as adopting fractal geometries [7], adding parasitic elements [8], and using additional substrate [9]. In this proposed antenna, we use a simple inverted-U-shaped driven element, a low-frequency meander path, and a matching stub with a truncated slit to achieve the application requirements. By adjusting the gap between the inverted-U element and low-frequency meander path, the middle and high frequency bandwidth based on 6-dB return loss covers the DCS (1710–1880 MHz), PCS (1850–1990 MHz), UMTS (1920–2170 MHz), and WLAN (2400–2484 MHz) applications. The meander line and matching stub with a truncated slit, which are extended from the system ground, operate the bandwidth based on 6-dB return loss of the low frequency band sufficient for GSM 900 (890–960 MHz) applications.

2. ANTENNA DESIGN

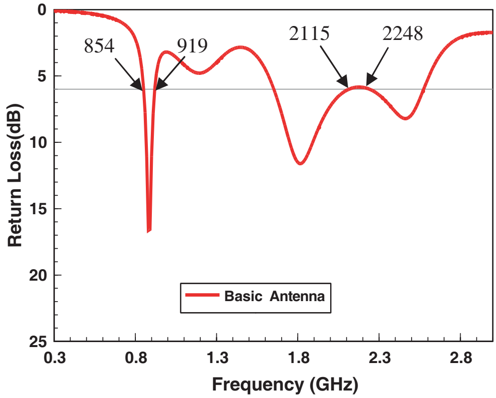
The profile of the proposed antenna is originated from a basic self-complementary antenna [10]. The basic antenna structure and simulated return loss are shown in Figures 1(a) and 1(b), respectively. The simulated results are obtained through the simulation software HFSS (High Frequency Structure Simulator) by Ansoft. From the result of return loss, the low frequency bandwidth from 854 to 919 MHz does not have sufficient bandwidth for GSM 900, and the impedance matching from 2115 to 2248 MHz is smaller than 6 dB. To solve the problems of insufficient bandwidth and poor impedance matching, the structure of the basic antenna needs to be modified into the proposed antenna shown in Figure 2. In [10], the insufficient low frequency bandwidth is increased by combining two low frequency paths, in which the first low frequency path is accomplished by adding a truncated slot in the system ground. To maintain the integrity of the system ground plane, this paper uses meander path and extended stub to increase the low frequency bandwidth. The detailed parameters of the proposed antenna are shown in Table 1. The overall dimensions of proposed antenna are 100 mm (length) $\times$ 61 mm (width) $\times$ 0.8 mm (thickness). A 50-Ω mini-cable is used to feed into the antenna.

To indicate the structure of the proposed antenna clearly, Figure 3 shows the integral elements of the proposed antenna. The inverted-

U element, which is located on the top left side of the proposed antenna, operates the middle- and high-frequency bands centered at 1710 MHz and 2350 MHz, respectively. The impedance matching of



(a)



(b)

Figure 1. (a) Basic antenna structure. (b) Simulated return loss of basic antenna.

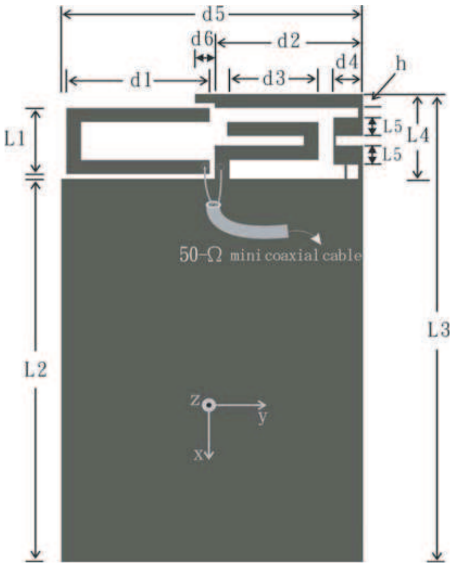


Figure 2. Structure of the proposed antenna.

Table 1. Parameters of the proposed antenna.

Parameters	L_1	L_2	L_3	L_4	L_5	d_1	d_2	d_3	d_4	d_5	d_6	h
Physical size (mm)	14	82	100	18	4	29	30	18.5	6	61	4	3

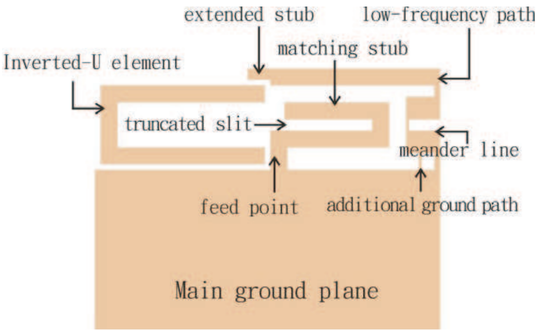


Figure 3. Elements of the proposed antenna.

the middle- and high-frequency bands is tuned by the size of the matching stub and the gap between the inverted-U-shape element and the extended stub. The gap between the inverted-U-shaped element and the main ground plane also influences the impedance matching of these frequency bands. The low-frequency path, which is comprised of a 4 mm long extended stub (d_6), a 30 mm long strip (d_2), a meander line strip, and a matching stub with a truncated slit, operates the low-frequency band centered at 920 MHz. The meander line on the low-frequency path and the truncated slit on the matching stub are used to extend the low-frequency path. The extended stub (D_6) used for increasing the coupling current can also increase this current path. The additional ground path located on the right end side of the low-frequency path is used for extending the bandwidth of low-frequency band. The gap between the low-frequency path and matching stub is used for adjusting the impedance matching of low-frequency band.

3. EXPERIMENTAL RESULTS AND DISCUSSION

Figure 4 shows the simulated and measured return losses of the proposed antenna. From Figure 4, the correspondences of the simulated and measured results can be seen. Besides, the bandwidth based on 6-dB return loss for low frequency band from 868 to 995 MHz can be applied to GSM 900 system, and that for high frequency band from 1550 to 2490 MHz can be used in DCS, PCS, UMTS, and WLAN applications.

The inverted-U driven element operates the middle- and high-frequency bands centered at 1710 and 2350 MHz, respectively. To verify these frequency bands, the lower and upper strips (d_1) of the inverted-U-shaped element were decreased in size from the left-hand side making the middle- and high-frequency paths shorter and moving these frequency bands to a higher band. The simulated return losses of different lengths of d_1 are shown in Figure 5. From the results, the low-frequency band located at 920 MHz was not affected by these changes; however, the middle-frequency band moved from 1710 MHz to 1840 MHz and the high-frequency band moved from 2350 MHz to 2770 MHz.

The low-frequency band centered at 920 MHz was resonated by the low-frequency path. To verify the low-frequency band, the upper

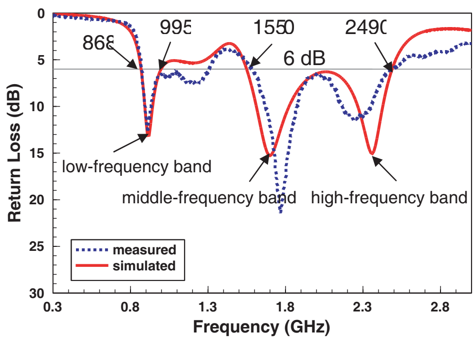


Figure 4. Simulated and measured return loss of the proposed antenna.

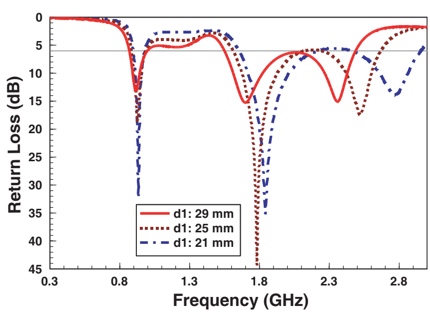


Figure 5. Simulated return losses for different lengths of d_1.

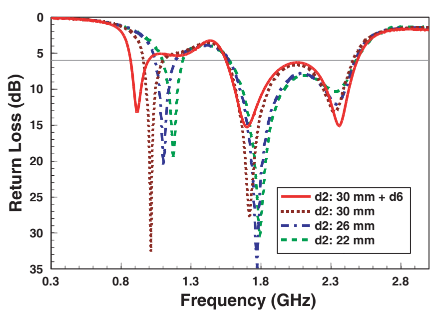


Figure 6. Simulated return losses for different lengths of d_2.

part ($d_2 + d_6$) of the low-frequency path was shortened from the left hand side. With a shorter low-frequency path, the low-frequency band moved to the higher band. Figure 6 shows the simulated return losses for different lengths of d_2. From the results, the middle- and high-frequency bands shifted slightly while the low-frequency band moved from 920 MHz to 1170 MHz.

The excited surface current distributions of the proposed antenna at 920 MHz, 1710 MHz, and 2350 MHz are shown in Figures 7(a), (b), and (c), respectively. It can be seen that the surface current distributions of 920 MHz is concentrated on the low-frequency path and the matching stub, while that of 1710 MHz and 2350 MHz is concentrated on the inverted-U-shaped element. The measured radiation patterns of x-y plane, y-z plane, and x-z plane for 900 MHz, 1800 MHz, and 2400 MHz are shown in Figures 8(a), (b), and (c),

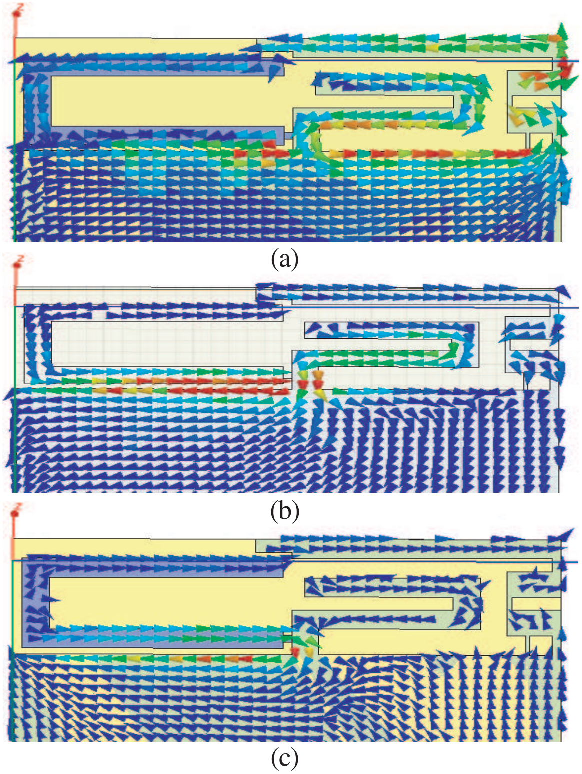


Figure 7. Current distributions of the proposed antenna at (a) 920 MHz, (b) 1710 MHz, and (c) 2350 MHz.

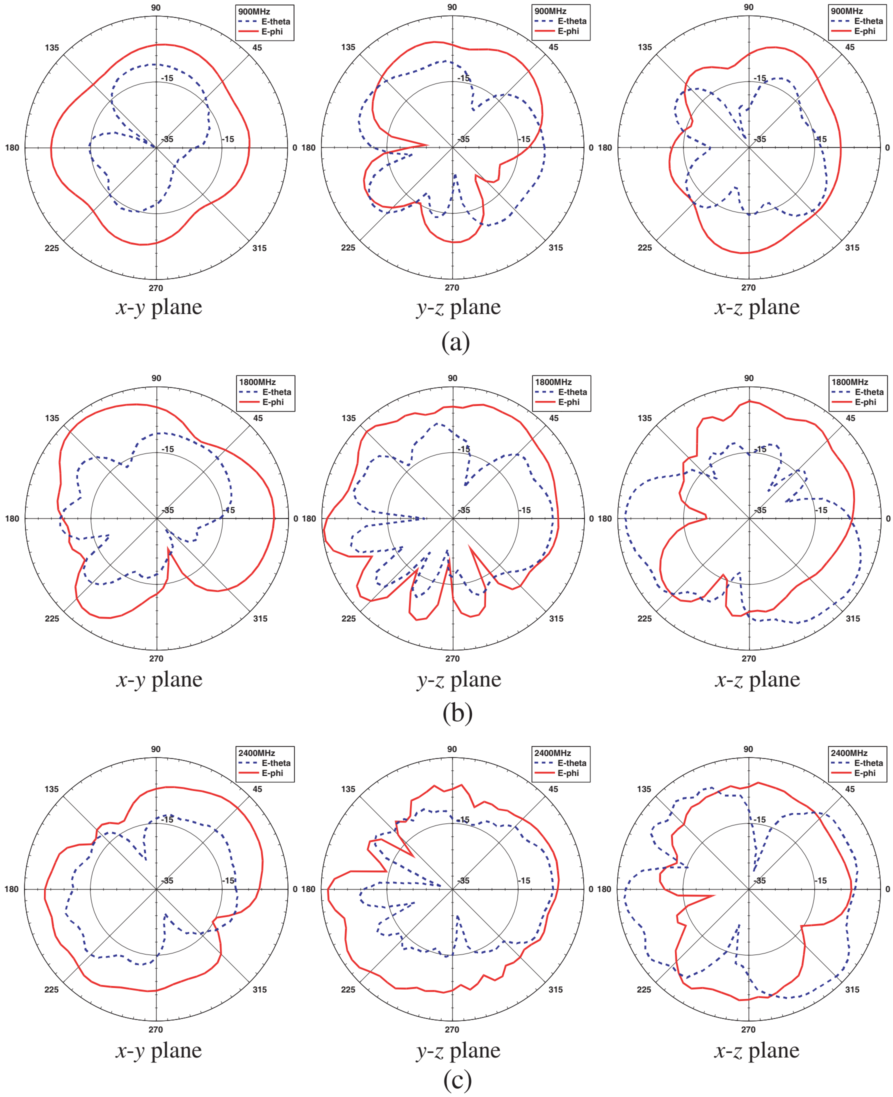
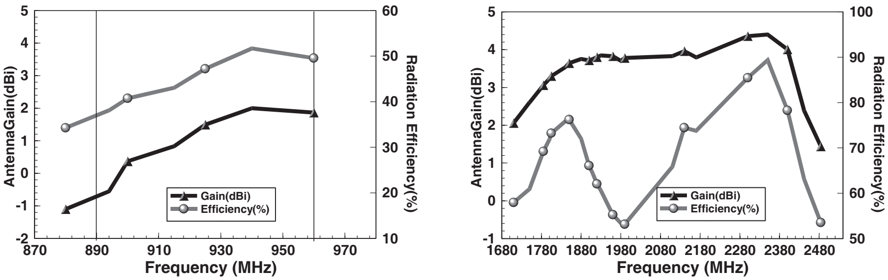


Figure 8. Measured radiation patterns of the proposed antenna at (a) 900 MHz, (b) 1800 MHz, and (c) 2400 MHz.

respectively. Although the obtained radiation patterns are not as good as those of simple conventional monopole antennas having a very good azimuth omni-directional pattern, the proposed antenna shows a monopole-like radiation pattern. Due to the passing of



(a) (b)

Figure 9. Measured gain and radiation efficiency of the proposed antenna at (a) 880–960 MHz and (b) 1710–2484 MHz.

the horizontal and vertical currents, there is a minute magnitude difference of col-pol and cross-pol. Figure 9 shows the measured antenna gain and radiation efficiency. For the GSM frequency band (880–960 MHz), the antenna gain is from -1.1 to 2 dBi, while that of the DCS/PCS/UMTS/WLAN (1710–2484 MHz) bands is from 1.45 to 4.4 dBi. The radiation efficiency of the GSM band (880–960 MHz) is from 34.5% to 52%, while that of the DCS/PCS/UMTS/WLAN (1710–2484 MHz) bands is from 53.5% to 89%.

4. CONCLUSION

A novel planar monopole antenna with an inverted-U-shaped element and a low-frequency path is developed and proposed. By adjusting the size of matching stub and the gap between the inverted-U-shaped element and extended stub, the high-frequency band can be applied to DCS1800, PCS1900, UMTS2000, and WLAN systems. The meander line, extended stub, and matching stub with a truncated slit are used for increasing the low-frequency path, which reaches the 920 MHz frequency band. Furthermore, by adding the additional ground path, the low-frequency band meets the GSM900 application band. The proposed antenna also has the advantages of low profile, lower fabrication costs, as well as the ease of manufacturing processes.

REFERENCES

1. Behera, S. and K. J. Vinoy, "Microstrip square ring antenna for dual-band operation," *Progress In Electromagnetics Research*, PIER 93, 41–56, 2009.

2. Mahatthanajatuphat, C., S. Saleekaw, P. Akkaraekthalin, and M. Krairiksh, "A rhombic patch monopole antenna with modified minkowski fractal geometry for UMTS, WLAN, and mobile WiMax application," *Progress In Electromagnetics Research*, PIER 89, 57–74, 2009.
3. Chen, W. S., T. W. Chiou, and K. L. Wong, "Compact PIFA for GSM/DCS/PCS triple-band mobile phone," *IEEE AP-S International Symposium and URSI Radio Science Meeting*, 528–531, 2002.
4. Kwak, W. I., S. O. Park, and J. S. Kim, "A folded planar inverted-F antenna for GSM/DCS/Bluetooth triple-band application," *IEEE Antennas and Wireless Propagat. Lett.*, Vol. 5, 18–21, 2006.
5. Wong, K. L., J. H. Chou, C. L. Tang, and S. H. Yeh, "Integrated internal GSM/DCS and WLAN antennas with optimized isolation for a PDA phone," *Microwave Opt. Technol. Lett.*, Vol. 46, 323–326, 2005.
6. Liang, J., C. C. Chiau, X. Chen, and C. G. Parini, "Study of a printed circular disc monopole antenna for UWB systems," *IEEE Transactions on Antennas and Propagation*, Vol. 53, 3500–3504, 2005.
7. Kordzadeh, A. and F. Hodjat-Kashani, "A new reduced size microstrip patch antenna with fractal shaped effects," *Progress In Electromagnetics Research B*, Vol. 11, 29–37, 2009.
8. Huang, C. Y. and P. Y. Chiu, "Dual-band monopole antenna with shorted parasitic element," *Electronic Letters*, Vol. 41, 1154–1155, 2005.
9. Guha, D., Y. M. M. Antar, A. Ittipiboon, A. Petosa, and D. Lee, "Improved design guidelines for the ultra wideband monopole dielectric resonator antenna," *IEEE Antennas and Wireless Propagation Letters*, Vol. 5, 373–376, 2006.
10. Chen, W. S. and B. Y. Lee, "Novel printed monopole antenna for PDA phone and WLAN applications," *Journal of Electromagnetic Waves and Applications*, Vol. 23, No. 14–15, 2073–2088, 2009.