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DESIGN OF A NOVEL WIDEBAND LOOP ANTENNA WITH PARASITIC RESONATORS

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Abstract—A novel coax-fed wideband loop antenna loaded with rectangular patches and U-shaped elements is presented and studied. By inserting a pair of rectangular patches inside the strip loops and employing a pair of U-shaped elements as the parasitic resonators, two additional resonances are excited and a good performance of bandwidth enhancement can be obtained. The measured results indicate that the impedance bandwidth (VSWR$\leq$2) is about 87.1% from 1.58 to 4.02 GHz, which covers the required operating bands of DCS1800 (1710–1880 MHz), PCS1900 (1850–1990 MHz), UMTS2100 (1920–2170 MHz), WLAN2400 (2400–2484 MHz), LTE2300/2500 (2300–2690 MHz) and WiMAX3500 (3300–3690 MHz). In addition, good radiation characteristics such as symmetrical radiation pattern, moderate peak gain, low back radiation, and low cross-polarization are observed over the entire operating band.

1. INTRODUCTION

With the rapid development of modern wireless communications, there has been increased interest in multiband and wideband antenna designs because of their capability and flexibility of meeting the demands of multiple communication standards. Omnidirectional antennas are often required in modern wireless communication systems [1–5], but

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the directional antennas are more favorable in some applications [6]. There are several ways to design an antenna with a directional radiation pattern. The directed electric dipole is simple in structure but poor in radiation pattern stability over the operating band. The microstrip patch antenna is considered to be a typical structure to realize directional radiation pattern with low profile, but they commonly yield a narrow bandwidth. Recently, some directional wideband antennas with low profile have been investigated [7–12], such as the circular patch antenna [7] fed by a coaxial probe with a three-dimensional transition structure, the L-shaped patch antenna [8] fed with Γ-shaped strip, and the antennas [9–12] fed by coaxial probes with capacitor patches. However, these antennas are very complex in structure.

In this paper, a novel coax-fed [13, 14] wideband loop antenna with the features of low profile, simple structure, and directional radiation is presented. By inserting a pair of rectangular patches inside the strip loops [15] and employing a pair of U-shaped elements as the parasitic resonators, a good wideband performance is obtained. Details of the antenna design and experimental results are presented and discussed as follows.

2. ANTENNA DESIGN

The geometry of the proposed wideband loop antenna is shown in Figure 1. The antenna consists of a printed radiating patch, a coax feed-line and a rectangular ground plane. The radiating patch is printed on a 0.8 mm-thick FR4 substrate with relative dielectric constant of 4.4 and area of $75\times75\,\text{mm}^2$. The coax feed-line is incorporated along the centerline of the radiating patch and located at a distance of $D/2$ from the center of the patch. The ground plane with size of $160\times160\,\text{mm}^2$ is placed below the patch for directional radiation. The radiating patch is connected with the ground plane by a short pin and the height H approximately equals a quarter of the free space wavelength. This configuration is utilized for balanced excitation and high gains [9]. An SMA connector located underneath the ground plane is connected to the end of the coax feed-line.

The design evolution of the proposed antenna is shown in Figure 2, and the corresponding simulated VSWR curves are plotted in Figure 3. In the detailed design, all parameters of the antennas are studied with the aid of ANSYS High Frequency Structure Simulator (HFSS) software, and the optimum design parameters are shown in Table 1.

As shown in Figure 2(a), Ant. 1 is a modified loop antenna which is composed of a pair of rectangular strip loops. The effective

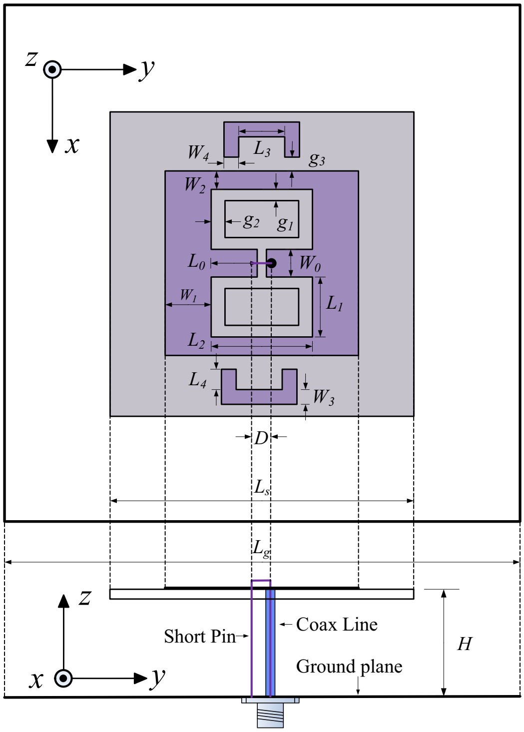

Figure 1. Geometry of the proposed antenna.

length of the strip loop is taken as one operating wavelength at the fundamental operating frequency [15]. As expected, the operating frequency decreases with increasing L_0, L_1, and L_2, and the impedance matching mainly depends on the arm widths W_0, W_1, and W_2. By properly choosing these parameters, an operating bandwidth of 40% from 1.6 to 2.4 GHz can be obtained. Based on the design of Ant. 1, a pair of rectangular patches is inserted symmetrically inside the strip loops in the design of Ant. 2, as shown in Figure 2(b). This configuration forms a pair of additional slot loops confined by the inner patches and outer strips. Each of the slot loops with a circumference of one operating wavelength operates at its resonant frequency [15]. The coupling strength between the inner patch and outer strip depends on the slot widths g_1 and g_2. By introducing a resonant mode of the slot loop at around 2.7 GHz, the impedance bandwidth can be enhanced to 61.8% ranging from 1.61 to 3.05 GHz. Moreover, a pair of U-shaped elements is adopted in Ant. 3 as the parasitic resonators, as shown in Figure 2(c). The gap g_3 determines the coupling strength and the

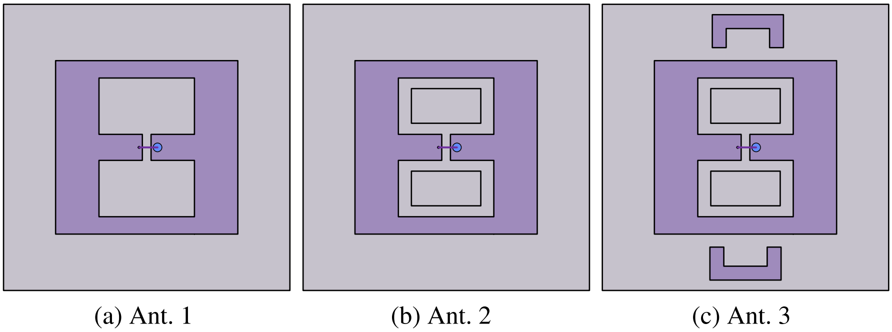

Figure 2. Design evolution of the proposed antenna.

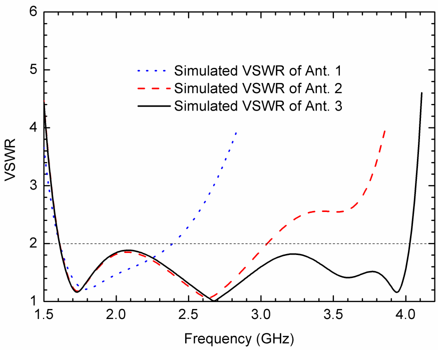

Figure 3. Simulated VSWRs of various antennas involved.

lengths L_3 and L_4 determine the resonant frequency. By appropriately adjusting the values of g_3, L_3, andL_4, the impedance matching at 3–4 GHz can be improved, and the broadened impedance bandwidth is about 87%, from 1.6 to 4 GHz.

3. EXPERIMENTAL RESULTS AND DISCUSSION

To verify the simulated results, a prototype of the proposed antenna is fabricated and measured based on the detailed values given in Table 1. Figure 4 presents the photograph of the proposed antenna. Experimental results are measured using the Agilent E8363B vector network analyzer and the Near Field Antenna Measurement System, Satimo.

The simulated and measured results for VSWR are plotted in

Table 1. Optimal parameters of various antennas involved.

Ant. 1															
Parameter	L_0	W_0	L_1	W_1	L_2	W_2	D	H	g_1	g_2	L_3	W_3	L_4	W_4	g_3
Value/mm	12.5	30	18	11	26	0.5	5	30	–	–	–	–	–	–	–
Ant. 2															
Parameter	L_0	W_0	L_1	W_1	L_2	W_2	D	H	g_1	g_2	L_3	W_3	L_4	W_4	g_3
Value/mm	12.5	17	18	11	26	0.5	5	30	2	1.7	–	–	–	–	–
Ant. 3															
Parameter	L_0	W_0	L_1	W_1	L_2	W_2	D	H	g_1	g_2	L_3	W_3	L_4	W_4	g_3
Value/mm	12.5	17	18	11	26	0.5	5	30	2	1.7	8.5	3	5.2	3	1

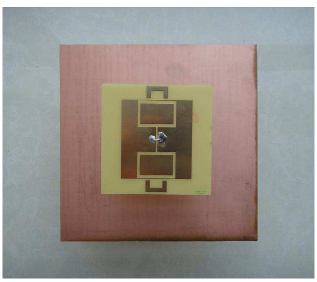

Figure 4. Photograph of the proposed antenna.

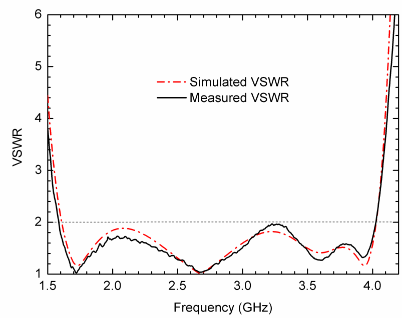

Figure 5. Simulated and measured VSWRs of the proposed antenna.

Figure 5. As expected, the measurement shows a good agreement with the simulation. The measured impedance bandwidth (VSWR$\leq$ 2) is about 87.1% from 1.58 to 4.02 GHz, successfully covering the required bands of DCS1800, PCS1900, UMTS2100, WLAN2400, LTE2300/2500 and WiMAX3500.

The simulated and measured far-field radiation patterns in the E-plane (yoz-plane) and H-plane (xoz-plane) at 1.8/2.5/3.5 GHz are plotted in Figure 6. The antenna radiates at broadside direction and has symmetrical radiation patterns in both E-plane and H-plane. Low back radiation and low cross-polarization are also obtained at the two principal planes. Figure 7 depicts the measured peak gain of the proposed antenna versus frequency. The gains range from 5.1 to 8.2 dBi across the operating frequency band.

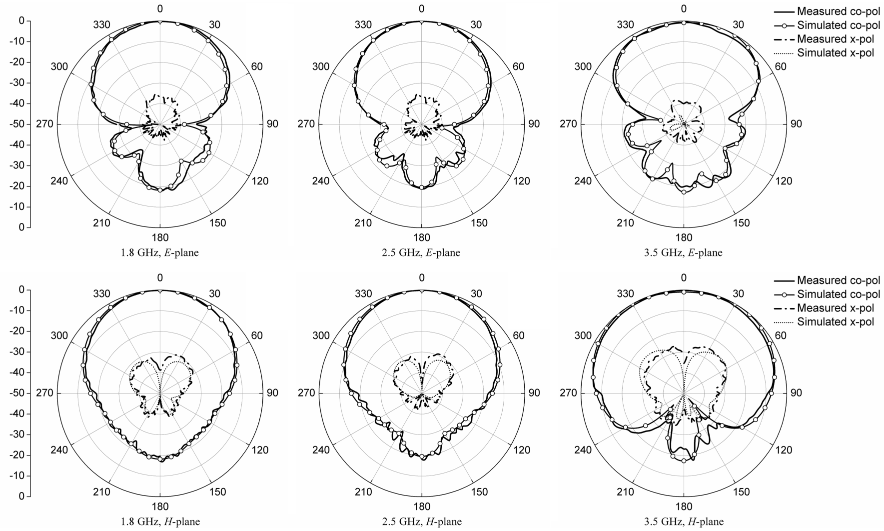

Figure 6. Simulated and measured far-field radiation patterns.

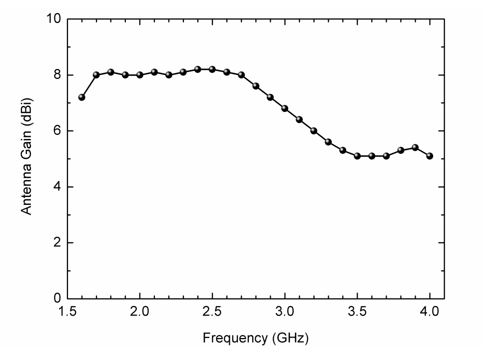

Figure 7. Measured antenna gain.

4. CONCLUSION

A novel coax-fed wideband loop antenna with low profile, simple structure, and directional radiation pattern has been designed, manufactured and measured successfully. By inserting a pair of rectangular patches inside the strip loops and employing a pair of U-shaped elements as the parasitic resonators, a wide impedance bandwidth of 87.1% from 1.58 to 4.02 GHz is obtained. Moreover, the proposed antenna exhibits good radiation characteristics over the entire operating band, such as symmetrical radiation pattern, moderate peak gain, low back radiation, and low cross-polarization. So a conclusion can be drawn that the proposed antenna is a good candidate for modern wireless communications.

REFERENCES

1. Azim, R. and M. T. Islam, "Compact planar UWB antenna with band notch characteristics for WLAN and DSRC," *Progress In Electromagnetics Research*, Vol. 133, 391–406, 2013.
2. Quan, X. L., R. L. Li, J. Y. Wang, and Y. H. Cui, "Development of a broadband horizontally polarized omnidirectional planar antenna and its array for base stations," *Progress In Electromagnetics Research*, Vol. 128, 441–456, 2012.
3. Zhu, F., S. Gao, A. T. S. Ho, C. H. See, R. A. Abd-Alhameed, J. Li, and J. Xu, "Design and analysis of planar ultra-wideband antenna with dual band-notched function," *Progress In Electromagnetics Research*, Vol. 127, 523–536, 2012.
4. Chen, A., T. Jiang, Z. Chen, and D. Su, "A novel low-profile wideband UHF antenna," *Progress In Electromagnetics Research*, Vol. 121, 75–88, 2011.
5. Xu, H. Y., H. Zhang, K. Lu, and X. F. Zeng, "A holly-leaf-shaped monopole antenna with low RCS for UWB application," *Progress In Electromagnetics Research*, Vol. 117, 35–50, 2011.
6. Klemm, M., I. Z. Kovcs, G. F. Pedersen, and G. Troster, "Novel small size directional antenna for UWB WBAN/WPAN applications," *IEEE Trans. Antennas Propag.*, Vol. 53, No. 12, 3884–3896, 2005.
7. Huang, Y. H., Q. Z. Liu, and S. G. Zhu, "A wideband and dual frequency three-dimensional transition-fed circular patch antenna for indoor base station application," *Progress In Electromagnetics Research Letters*, Vol. 11, 47–54, 2009.
8. An, W. X., H. Wong, K. L. Lau, S. F. Li, and Q. Xue, "Design of broadband dual-band dipole for base station antenna," *IEEE Trans. Antennas Propag.*, Vol. 60, No. 3, 1592–1595, 2012.
9. Malekpoor, H., and S. Jam, "Ultra-wideband shorted patch antennas fed by folded-patch with multi resonances," *Progress In Electromagnetics Research B*, Vol. 44, 309–326, 2012.
10. Lotfi Neyestanak, A. A., "Ultra wideband rose leaf microstrip patch antenna," *Progress In Electromagnetics Research*, Vol. 86, 155–168, 2008.

11. Abbaspour, M., and H. R. Hassani, "Wideband star-shaped microstrip patch antenna," *Progress In Electromagnetics Research Letters*, Vol. 1, 61–68, 2008.
12. Wang, F. J., and J. S. Zhang, "Wide band cavity-backed patch antenna for PCS/IMI2000/2.4 GHz WLAN," *Progress In Electromagnetics Research*, Vol. 74, 39–46, 2007.
13. Liu, C., J. L. Guo, Y. H. Huang, and L. Y. Zhou, "A novel dual-polarized antenna with high isolation and low cross polarization for wireless communication," *Progress In Electromagnetics Research Letters*, Vol. 32, 129–136, 2012.
14. Hu, W., Y. Z. Yin, P. Fei, and S. F. Zheng, "Design of a dual-polarized slot antenna with high isolation and low cross-polarization for wireless communication," *Journal of Electromagnetic Waves and Applications*, Vol. 26, No. 16, 2185–2191, 2012.
15. Mandal, M. K., and Z. N. Chen, "Compact dual-band and ultra-wideband loop antennas," *IEEE Trans. Antennas Propag.*, Vol. 59, No. 8, 2774–2779, 2011.