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Research Article

A Dual-Broadband Printed Dipole Antenna for 2G/3G/4G Base Station Applications

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A new dual-broadband printed dipole antenna for base station applications is proposed in this communication. This antenna has three different dipoles with the same feed point and an extra parasitic strip. The two arms of the three dipoles are printed on opposite sides of the substrate and symmetrical on the centerline, but the parasitic strip at the end of the dipole is just put on one side. Besides, a U-shaped reflector is designed at the bottom of the antenna to realize good radiation characteristics in the working frequency. The simulated and measured results show good agreement. The two studied bands are both broadened which, respectively, achieve 36.7% (690–1000MHz) and 47.3% (1710–2770MHz) for the lower and higher bands so as to satisfy the 2G/3G/4G wireless communication, and the corresponding gains of 4-5dBi and 5-6dBi are also obtained.

1. Introduction

With the development of the wireless communication, the requirement of the bandwidth of the antenna for the base station applications becomes more and more wide. This trend is so clear from its development process; the bands of 690-960MHz and the 1710-1850MHz were used for the 2G systems, and the band was broadened to be 265MHz from 1880 to 2145MHz for 3G communication, and then the wider bands of both the 1745-1900 MHz and the 2300MHz-2655MHz were developed for 4G systems [1–3]. Nowadays, to integrate easily, the antenna covering all the bands of 2G/3G/4G has attracted researchers' interest which should have the bands 32% (690-960MHz) and 45% (1710-2700MHz). This can reduce the number of antenna units, the complexity of RF, and minimization of the installation area, and they are also able to support multistandard system.

Several such dual-broadband antennas have been reported [4–7], where both the three-dimensional and the irregular multimetal structures were adopted for the lower and upper bands, respectively. To do this, the antenna would have complex resonant and feed structures so that the increase of both the large volume and the difficulties for the fabrication. In contrast, only in [8] the antenna had a simple planar microstrip structure to cover all frequencies. However, the upper and the lower-band elements were independent and then dual port feedings were required, and an extra power divider was designed to feed the two elements of the upper-band section. On the other hand, the gating lobe appeared when the frequency is higher than 2500MHz. Some other antennas were studied as well in [9–14], which only cover part of the 2G/3G/4G bands.

In this paper, a dual-band broadband printed dipole with only one feed for the base station applications is proposed whose −10 dB impedance bandwidths are 36.7% (690-1000MHz) and 47.3% (1710-2770MHz) for the lower and the upper bands, respectively. Here, several different series-fed dipoles were designed to realize the dual-broadband characteristics. And owing to the double-side symmetrical structure, the strip dipoles excitation can be easily reversed so that the corresponding two bands can be adjusted independently without influencing each other, and both the stable half-power beamwidth and the good cross-polarization discrimination are obtained over the entire operating frequency. Structures of all patches of the antenna are simple rectangular patches, which are fabricated by printing circuit board (PCB) processing, and

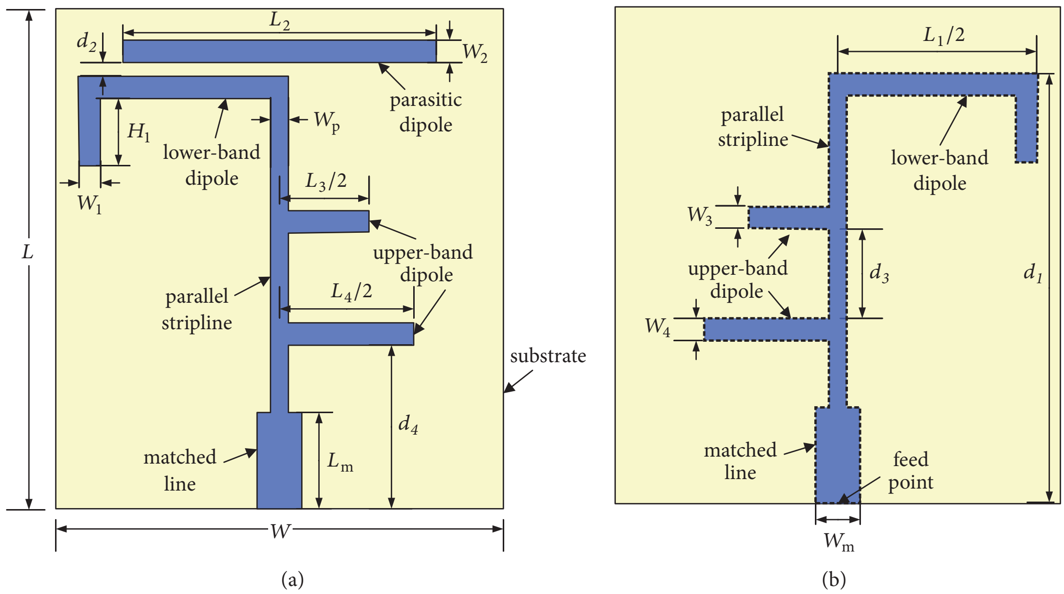


Figure 1: The top view of the proposed antenna. (a) Front. (b) Back.

only one feed port is needed. It has obvious advantages of simple structure and easy to fabricate at low cost.

2. Design of A Dual-Broadband Printed Dipole Antenna

2.1. Configuration. The top view of basic geometry of the proposed antenna is shown in Figure 1. The solid line in Figure 1(a) represents the outline of the front patch and the dashed line in Figure 1(b) represents the outline of the patch on the back side. They are in an axisymmetric structure and all the sizes are the same, except for the independent printed parasitic patch. It clearly presents the three series-fed printed strip dipoles and an extra printed parasitic patch. The three printed strip dipoles of different lengths, with the arms printed on opposite sides of the dielectric substrate, are connected through a parallel stripline. The parallel stripline consists of two broadside-coupled strips with a width of W_p. The antenna is fed by a conventional coaxial connector through a matched transmission line. The extra parasitic patch is designed at the end of the antenna and is fed by the terminal printed strip dipoles.

In this design, the width W_p of the feeding strip is kept the same, and the total length is mainly determined by the distances d_1 and d_2 to decrease the mutual couplings. The radiation of the antenna is divided into two parts, the shorter dipoles with lengths L_3 and L_4 are responsible for the higher frequencies while the longer length L_1 is for the lower frequency, and the parasitic patch is used to broaden the bandwidth of the lower frequency with the longer dipole. In order to reduce the size of the antenna, a folded part vertical to the dipole is added to the longest dipole whose length is $H_{1,}$ and thus the total length of the lower-band antenna becomes L_1+ H_1+ H_1. Besides, the width of the longest dipole is studied as W_1 considering the impedance matching. The parameters of the related parasitic patch to the longest dipole are length L_2, width W_2, and the distance between the parasitic patch and the dipole d_2. After using the parasitic element, the bandwidth is broadened about three times.

On the other hand, the upper frequency band is provided by the two sets of upper-band dipoles. To achieve broadband work for high frequency segments, the resonant frequency of the shorter dipole is higher than the nominal center frequency of the high frequency band while the longer one generates the lower part. But both dipoles can radiate effectively in the upper-band. These corresponding parameters are L_3 and W_3 and L_4 and W_4 for the shorter and longer dipoles, respectively. The distance between the two dipoles is d_3, and the dipoles are directly connected by the parallel stripline. By increasing the length difference of the two dipoles and selecting an optimal distance between them, the widest bandwidth can be obtained for the antenna [15]. Meanwhile, the distance between the upper-band diploe and the bottom of the antenna is d_4.

The line polarity between the lower-band dipole and the upper-band dipoles is reversed and the antenna fed is at the longer element of the upper-band dipoles through a matched transmission line at the end of the antenna. All of the printed strip dipoles are directly connected by a parallel stripline, and the corresponding phases of current of the connecting stripline are delayed sequentially resulting in end-fire radiation in the direction of propagation. This structure can achieve wideband impedance characteristics and operate at two frequency bands that are relatively far apart.

As we know, each dipole generates omnidirectional radiation at its H-plane. However, in this design the radiation of one dipole directed to the other two will distort. Thus, to realize the directional radiation, a U-shaped reflector is designed to reflect the electromagnetic wave of the dipoles as shown in Figure 2. It shows that the bottom of the reflector is vertical to the substrate, and the direction is parallel to that of the width of the substrate. The tilt angle between the bottom and tilt side should be adjusted carefully to get the good radiation in the whole frequency band. Finally, the optimized

Table 1: The optimized parameters of the antenna and the reflector.

Parameter	Value	Parameter	Value
L_1	140mm	W_p	2mm
L_2	112mm	d_1	122mm
L_3	40mm	d_2	4mm
L_4	64mm	d_3	27mm
L_m	33mm	d_4	40mm
W_1	6mm	H_1	23mm
W_2	4mm	W_r	47mm
W_3	8mm	L_r	63mm
W_4	8mm	H_r	10mm
W_m	4mm	θ	70°

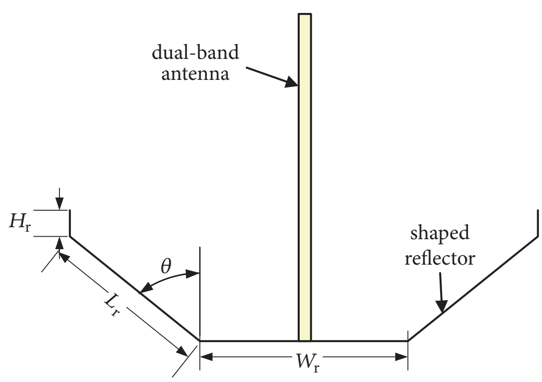


Figure 2: The antenna and the shaped reflector.

parameters of the antenna including those of the reflector are listed in Table 1.

2.2. Parametric Study. To get good impedance matching, many parameters of the dipoles should be considered, especially for the lengths L_1 and L_2, the length difference L_d between L_3 and L_4, and the distance d_3. Their influences are obtained by the 3D electromagnetic package High Frequency Structure Simulator (HFSS) and discussed as follows. The parameters in the following discussions are consistent with that in Table 1; that is, we just change the discussed parameter and keep the rest.

Figure 3 shows the influence of different L_1 on the S-parameter. It can be clearly seen that the lower-band diploe only affects the lowest frequency response of the antenna and remains stable in the high frequency band. Moreover, the increase of the lower-band diploe leads to the decrease of resonance frequency and the antenna becomes mismatched when L_1 is longer than 148 mm.

The influence of the parasitic patch length L_2 is shown in Figure 4. Its influence on the bandwidth is so obvious; if the is no parasitic patch, the bandwidth of lower frequency is only 70MHz, but it becomes 310MHz (690-1000MHz) after adding the parasitic strip because an additional resonance is introduced then in the low frequency to widen the original bandwidth. It is likely that, with the low-band diploe, the parasitic diploe length only affects the low-frequency response of the antenna and remains stable in the high frequency band.

And Figures 5 and 6 present the influences of L_d and d_3, respectively. Their influences on the impedance bandwidth are clear to the upper frequency range, while the lower are not

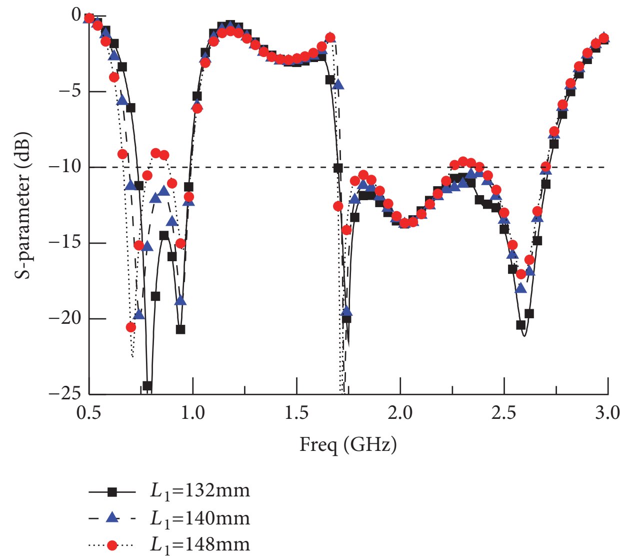


Figure 3: S-parameter versus frequency with different L_1.

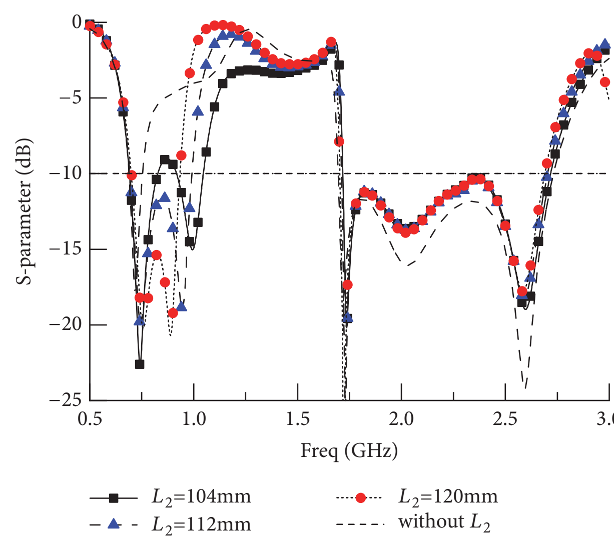


Figure 4: S-parameter versus frequency with different L_2.

so clear. This is because there exists mutual coupling between the two upper-band dipoles owing to the short distance comparing to the wavelength. Therefore, changing L_d and d_3 will alter the coupling to lead to the change of the corresponding inductance and the capacitance; then the resonant frequency and impedance bandwidth for the upper-band are being adjusted. In one word, all parameters of the upper-band should be optimized to obtain an expected bandwidth.

3. Results and Discussion

The proposed antenna is manufactured and shown in Figure 7. The Teflon is used as the substrate whose dielectric constant, loss tangent, and dimension are 2.65, 0.02, and 144mm×132mm×2mm, respectively. And the aluminum material is used for the reflector with a thickness of 3mm.

The measured and simulated S-parameter and gain versus frequency after optimization are shown in Figure 8 where

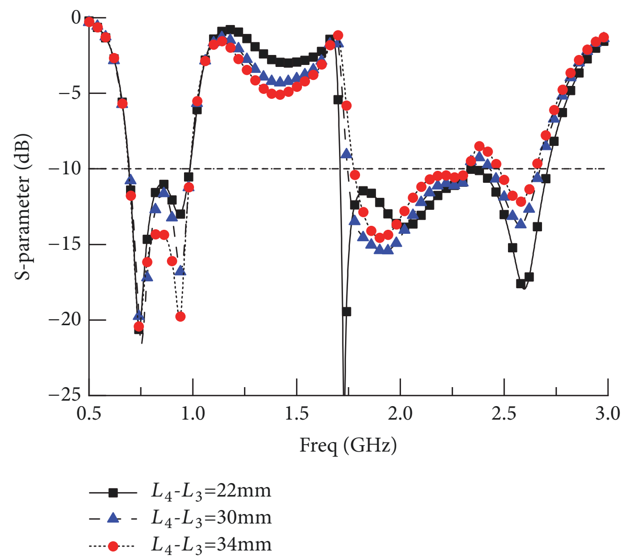


FIGURE 5: S-parameter versus frequency with different L_d.

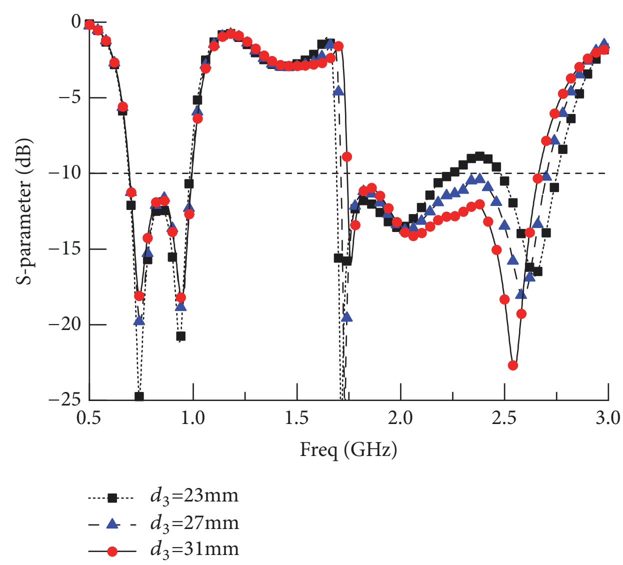
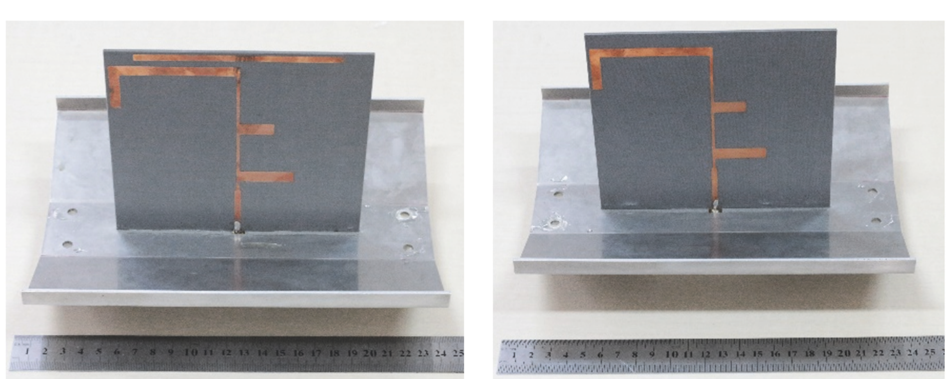


FIGURE 6: S-parameter versus frequency with different d_3.



(a) (b)

FIGURE 7: The prototype of the dual-broadband antenna. (a) Front view. (b) Back view.

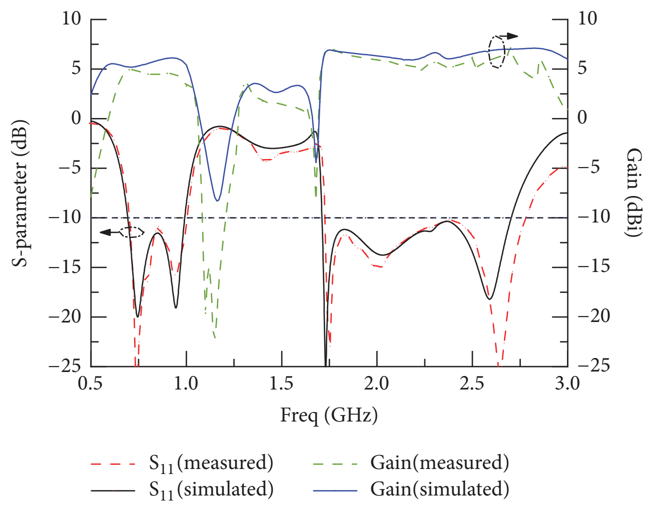
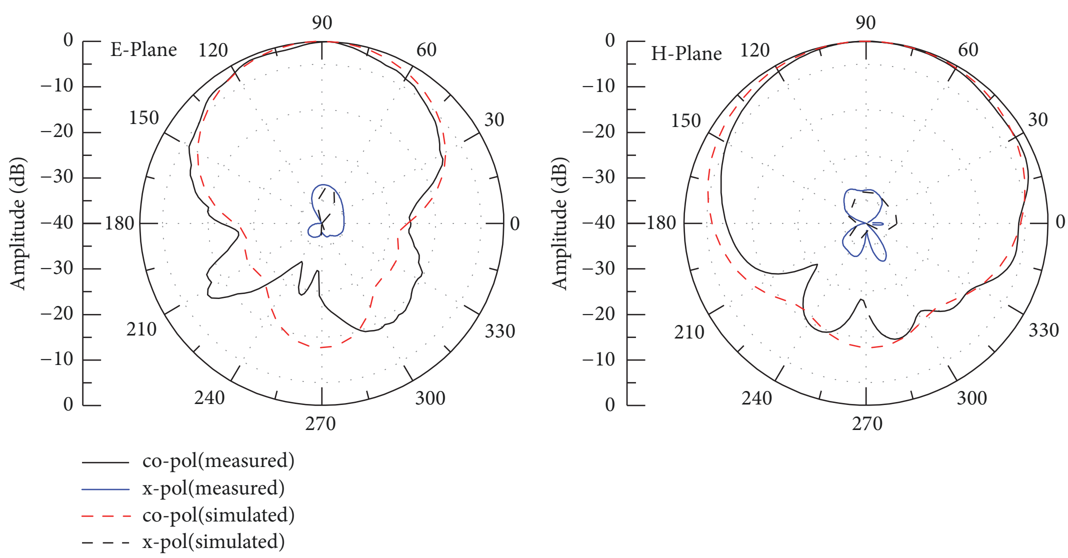
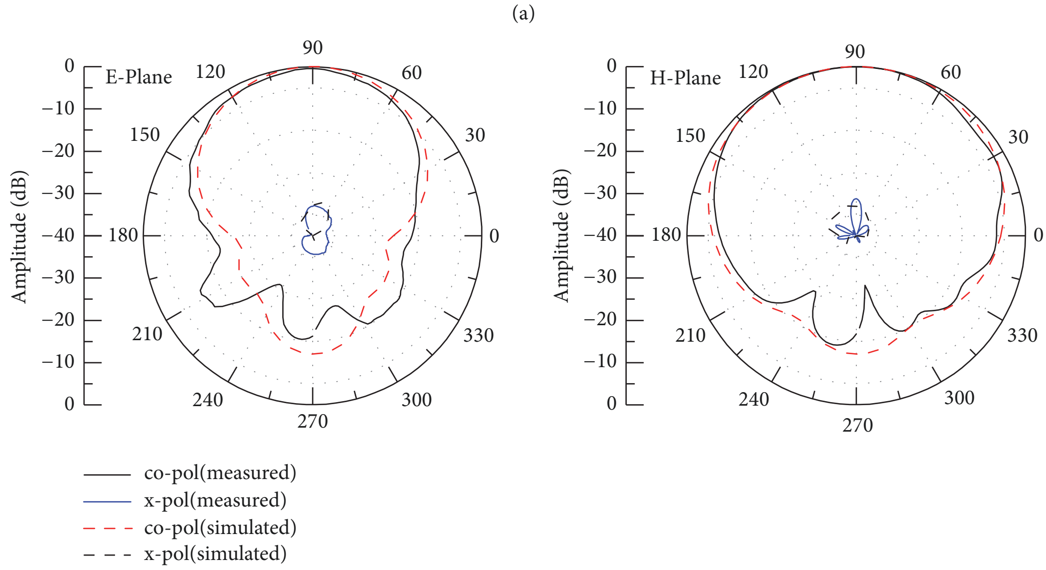


Figure 8: Measured and simulated S-parameter and Gain.

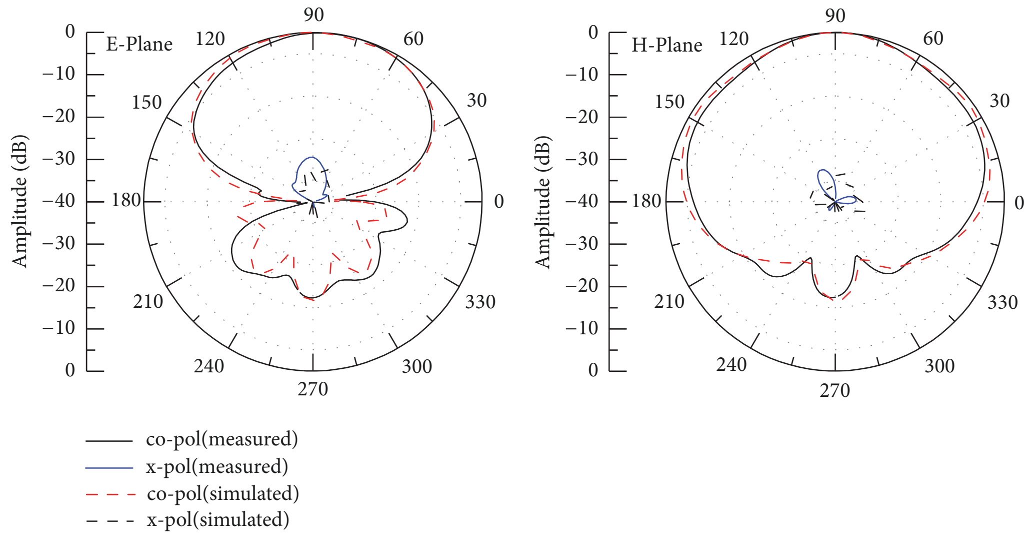


(a)

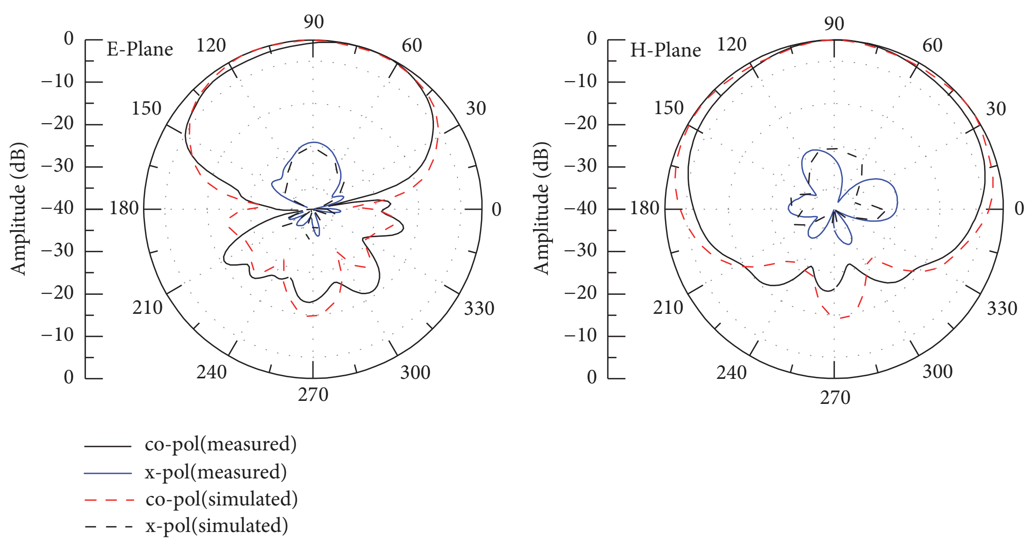


(b)

Figure 9: Continued.



(c)



(d)

Figure 9: Measured and simulated radiation patterns. (a) 907MHz. (b) 952MHz. (c)1885MHz. (d) 2015MHz.

both show the good agreements. Measured results show that the proposed antenna has dual-band characteristics. Both frequency bands are broadband and have stable gain and stable matching performance in both frequency bands. Besides, the percentage bandwidths is 36.7% (690-1000MHz) and 47.3% (1710-2770MHz) at the lower and higher frequencies, respectively. According to the measured results, the antenna gain is 4-5dBi in the lower frequency band and 5-6dBi in the higher frequency band. The measured results of antenna gain are lower than the simulation results and may be attributed to the losses of both the coaxial line and the SMA joint, influences of the testing surrounding, and fabrication inaccuracy.

To validate the design further, the comparisons of both the measured and the simulated radiation patterns at 907MHz, 952MHz, 1885MHz, and 2015MHz are plotted and shown in Figure 9, where all are in good agreement. The measured results show that the antenna has good direction and low cross-polarization. For the lower and the higher frequencies, the cross-polarization is less than 30dB and 22dB, the measured half-power beamwidths (HPBWs) of the H-plane are about 120° and 140°, and the front-to-back ratio is less than 15dB and 17dB, respectively.

4. Conclusions

A novel broadband dual-band dipole antenna has been proposed. Both the simulation and test results showed that it has dual wideband characteristics and the working frequency band which can cover all the frequency bands for 2G/3G/4G wireless communications is 36.7% and 47.3% in the lower bands 690-1000 MHz and upper bands 1710-2770MHz, respectively. The antenna has stable radiation characteristics including gain, good directivity, low cross-polarization, and high front-to-back ratio in the whole band. In addition, it also had the advantages of simple structure, easy processing, low cost, and single port feed. All these properties make it possible as a strong candidate for the wireless communication system.

Data Availability

The data used to support the findings of this study are included within the article.

Conflicts of Interest

There are no conflicts of interest regarding the publication of this paper.

Acknowledgments

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References

[1] A. Moleiro, J. Rosa, R. Nunes, and C. Peixeiro, “Dual band microstrip patch antenna element with parasitic for GSM,” in *Proceedings of the IEEE Antennas and Propagation Society International Symposium. Transmitting Waves of Progress to the Next Millennium. 2000 Digest. Held in conjunction with: USNC/URSI National Radio Science Meeting*, vol. 4, pp. 2188–2191, IEEE, Salt Lake City, UT, USA.

[2] M. Barba, “A high-isolation, wideband and dual-linear polarization patch antenna,” *IEEE Transactions on Antennas and Propagation*, vol. 56, no. 5, pp. 1472–1476, 2008.

[3] K. M. Mak, X. Gao, and H. W. Lai, “Low cost dual polarized base station element for long term evolution,” *IEEE Transactions on Antennas and Propagation*, vol. 62, no. 11, pp. 5861–5865, 2014.

[4] B. Feng, W. Hong, S. Li, W. An, and S. Yin, “A dual-wideband double-layer magnetoelectric dipole antenna with a modified horned reflector for 2G/3G/LTE applications,” *International Journal of Antennas and Propagation*, vol. 2013, Article ID 509589, 9 pages, 2013.

[5] W. X. An, H. Wong, K. L. Lau, S. F. Li, and Q. Xue, “Design of broadband dual-band dipole for base station antenna,” *IEEE Transactions on Antennas and Propagation*, vol. 60, no. 3, pp. 1592–1595, 2012.

[6] H. Huang, Y. Liu, and S. Gong, “A dual-broadband, dual-polarized base station antenna for 2G/3G/4G applications,” *IEEE Antennas and Wireless Propagation Letters*, vol. 16, pp. 1111–1114, 2017.

[7] H. Zhai, Q. Gao, C. Liang, R. Yu, and S. Liu, “A dual-band high-gain base-station antenna for WLAN and WiMAX applications,” *IEEE Antennas and Wireless Propagation Letters*, vol. 13, pp. 876–879, 2014.

[8] Y. Cui, R. Li, and P. Wang, “Novel dual-broadband planar antenna and its array for 2G/3G/LTE base stations,” *IEEE Transactions on Antennas and Propagation*, vol. 61, no. 3, pp. 1132–1139, 2013.

[9] M. Zeng, Z. Li, A. S. Andrenko, Y. Zeng, and H.-Z. Tan, “A compact dual-band rectenna for GSM900 and GSM1800 energy harvesting,” *International Journal of Antennas and Propagation*, vol. 2018, Article ID 4781465, 9 pages, 2018.

[10] Y. He, Z. Pan, X. Cheng, Y. He, J. Qiao, and M. M. Tentzeris, “A novel dual-band, dual-polarized, miniaturized and low-profile base station antenna,” *IEEE Transactions on Antennas and Propagation*, vol. 63, no. 12, pp. 5399–5408, 2015.

[11] M. Li, Q. Li, B. Wang, C. Zhou, and S. Cheung, “A miniaturized dual-band base station array antenna using band notch dipole antenna elements and AMC reflectors,” *IEEE Transactions on Antennas and Propagation*, vol. 66, no. 6, pp. 3189–3194, 2018.

[12] G. Cui, S.-G. Zhou, G. Zhao, and S.-X. Gong, “A compact dual-band dual-polarized antenna for base station application,” *Progress in Electromagnetics Research C*, vol. 64, pp. 61–70, 2016.

[13] Y. Zhang, X. Y. Zhang, L.-H. Ye, and Y.-M. Pan, “Dual-band base station array using filtering antenna elements for mutual coupling suppression,” *IEEE Transactions on Antennas and Propagation*, vol. 64, no. 8, pp. 3423–3430, 2016.

[14] Y. Wang and Z. Du, “Dual-polarized dual-band microstrip antenna with similar-shaped radiation pattern,” *IEEE Transactions on Antennas and Propagation*, vol. 63, no. 12, pp. 5923–5928, 2015.

[15] F. Tefiku, “A broadband antenna of double-sided printed strip dipoles,” in *Proceedings of the International Symposium on Antennas and Propagation Japan*, vol. 2, pp. 361–364, 1996.