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A Wideband Dual-Polarized Dipole Antenna for Base Station Applications

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Abstract—In this letter, a wideband dual-polarized dipole antenna is proposed for base station applications. By bending the arms of the dipole, the radiator size is reduced. Meanwhile, a new resonant mode occurs at high frequency. Besides, four shorting stubs are employed to improve the impedance matching. Finally, a wide operating bandwidth is realized by combining all resonant modes. A prototype of the proposed antenna is fabricated and tested. Experimental results show that the antenna has a wide impedance bandwidth of 53% (1.65–2.84 GHz) for VSWR < 1.5 at two ports and a high port isolation of 26 dB. Also, a stable antenna gain around 7.9 ± 0.5 dBi and a stable radiation pattern with 3-dB beamwidth of $67.5° \pm 3.5°$ are obtained within the entire band of operation.

1. INTRODUCTION

In recent years, dual-polarized antennas have been widely applied in the 2G/3G/LTE communication systems because they have superior features of restraining the multipath fading effect and raising the channel capacity [1]. In addition, designing an antenna with a wide impedance bandwidth can reduce the cost and installation space. As a result, a dual-polarized antenna with a wide band of 1.71–2.69 GHz is important for wireless communication systems.

Different kinds of dual-polarized antennas have been proposed by antenna researchers, including crossed dipole antennas in [2, 3], patch antennas in [4, 5], and slot antennas in [6, 7]. However, the operating impedance bandwidths of the antennas mentioned above cannot cover the desired band of 1710–2690 MHz. In the design of [8], a relative bandwidth of 45% (1.71–2.69 GHz) is obtained for VSWR < 1.5 by loading long and short dipoles. Besides, the proposed antenna has a high port isolation, a stable gain, and a stable radiation pattern across the whole operating bandwidth. Nevertheless, it is unsuited to massive assembly due to its 3-D structure. In [9], combining magnetic and electric dipoles, a new type of dipole antenna is developed. Although it has a broad impedance bandwidth of 65.9% (1.7185–3.409 GHz) for VSWR < 2 and a high port isolation of 36 dB, the weight of the antenna is too heavy because of its all-metal structure.

In this letter, a wideband dual-polarized dipole antenna is developed for base station applications. The radiator size is reduced by bending the arms of the dipole. Meanwhile, a new resonant mode is induced at high frequency band. In addition, four shorting stubs are adopted to perform the impedance matching. Combining all resonant modes, a wide operating bandwidth is realized at last. A prototype is fabricated and measured to validate the design principle. Measured results illustrate that the proposed antenna features wide impedance bandwidth, high port isolation, stable antenna gain and stable radiation pattern.

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2. ANTENNA DESIGN AND ANALYSIS

Figure 1 shows the configuration of the proposed antenna. The antenna consists of a pair of orthogonal dipoles, two Y-shaped feeding lines, two 50-Ω coaxial cables, two metal pins, and a metal ground plane. Note that the dipoles are printed on the bottom side of a square FR4 substrate ($\varepsilon_r = 4.4$, $\tan\delta = 0.02$, and thickness = 0.8 mm) while the Y-shaped feeding lines are etched on the top side of the same substrate. As shown in Figure 1(c), one of two feeding lines is divided into three parts and one part of them is moved down to the back side of the substrate to avoid overlapping between the feeding lines. Two metal vias are utilized to connect three parts. Two ports are employed to excite the radiating element via coaxial cables. The inner conductors of coaxial cables are soldered on the Y-shaped feeding lines while their outer conductors are connected to the dipoles and ground plane, respectively. Two metal pins are introduced to act as balun structures for balance-to-unbalance transformer. In addition, the antenna is fixed above a metal ground plane to obtain a unidirectional radiation. A commercial simulation software Ansys HFSS v.16 is carried out to design the antenna, and the optimized dimensions

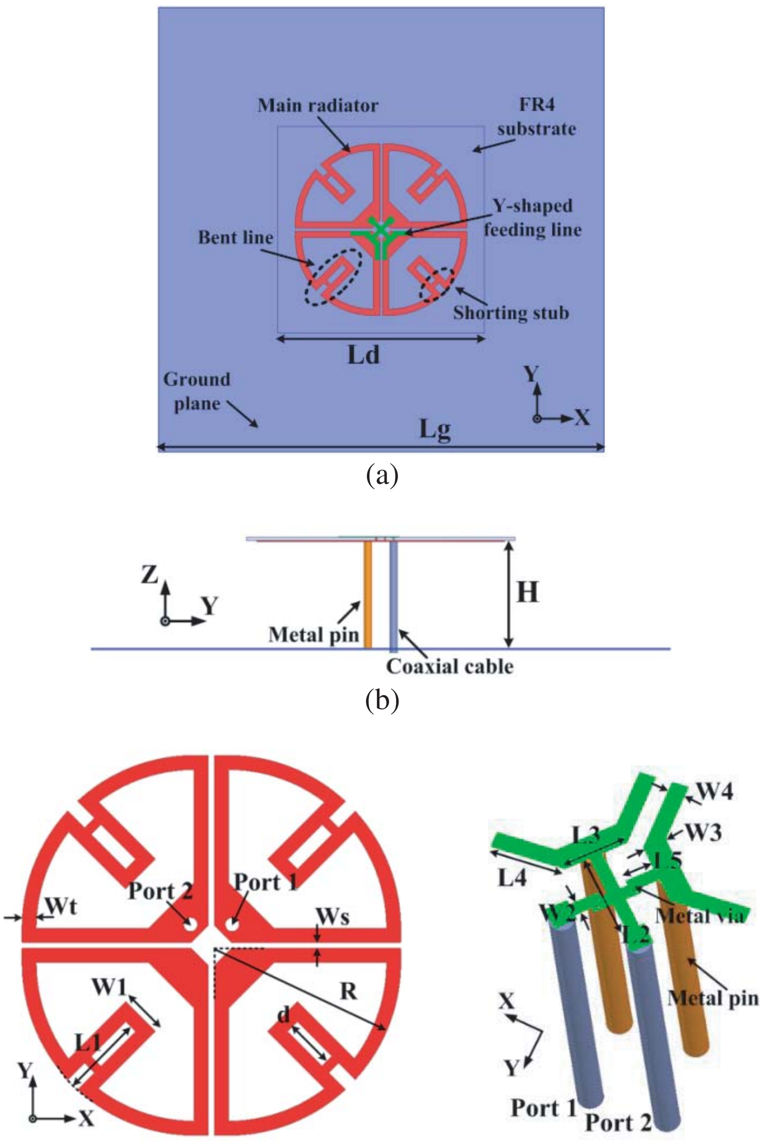


Figure 1. Configuration of the proposed antenna: (a) top view, (b) side view, (c) detailed view.

are listed as follows: $R = 26.6\,\text{mm}$, $L1 = 12\,\text{mm}$, $L2 = 7\,\text{mm}$, $L3 = 4.9\,\text{mm}$, $L4 = 5.4\,\text{mm}$, $L5 = 2.4\,\text{mm}$, $Lg = 140\,\text{mm}$, $Ld = 65\,\text{mm}$, $Wt = 2\,\text{mm}$, $Ws = 0.8\,\text{mm}$, $W1 = 6\,\text{mm}$, $W2 = 1.3\,\text{mm}$, $W3 = 1.8\,\text{mm}$, $W4 = 1.3\,\text{mm}$, $H = 36\,\text{mm}$, $d = 7\,\text{mm}$.

Figure 2 shows the evolution of the proposed antenna, and the corresponding VSWRs are depicted in Figure 3. First, an antenna with a pair of orthogonal dipoles, marked as Ant 1, is designed. In this case, the operating impedance bandwidth is of 30.1% (1.64–2.22 GHz) for VSWR < 1.5, and the radiator size is of $60 \times 60\,\text{mm}^2$. By bending the arms of the dipole, as done in Ant 2, the radiator size is reduced to $54 \times 54\,\text{mm}^2$. At the same time, a new resonant mode occurs at 3 GHz. In Ant 3, four shorting stubs are introduced. It can be seen that the resonant mode at high frequency moves down, and the impedance matching is improved. Finally, a wide operating impedance bandwidth is obtained by combining all resonant modes.

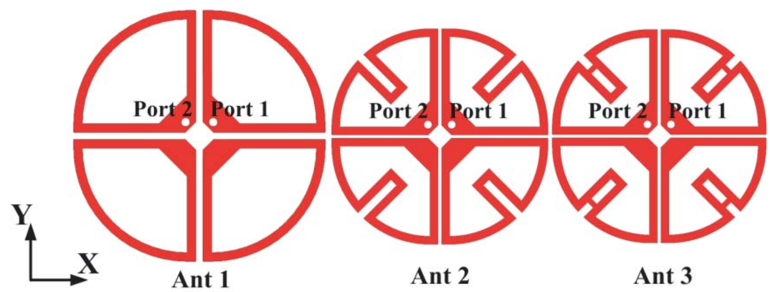


Figure 2. Evolution of the proposed antenna.

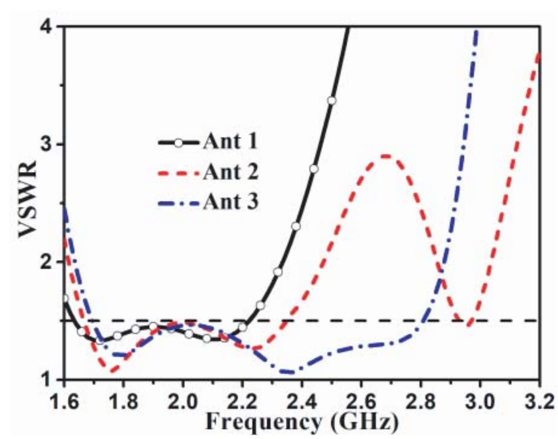


Figure 3. Simulated VSWRs of the antennas in the evolution.

Figure 4 shows a comparison of the simulated input impedance with and without shorting stubs. It can be observed that the resistance gets closer to $50\,\Omega$ while the reactance gets closer to $0\,\Omega$ in the high frequency band when four shorting stubs are utilized, which indicates that the impedance matching is accomplished.

Figure 5 shows the effect of the parameter R on the impedance bandwidth. It can be seen that the two resonant modes at lower and middle frequencies move toward the low frequency band as R increases. The reason for it is that the parameter R represents the radius of the fan-shaped dipole, and it extends the current lengths of the resonant modes as R increases. In addition, the curves at high frequency band rise gradually, which means that the impedance matching becomes worse. Finally, $R = 26.6\,\text{mm}$ is selected to obtain a wide operating bandwidth with good impedance matching.

Figure 6 shows the effect of the parameter $L1$ on the impedance bandwidth. We can see that the resonant mode at high frequency band shifts down to the low frequency band as $L1$ increases. Moreover, it has little effect on the lower and middle resonant modes. It can be concluded that the parameter $L1$

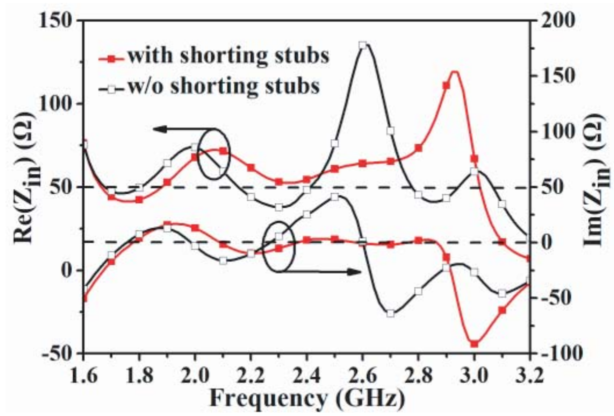


Figure 4. Comparison of the simulated input impedance with and w/o shorting stubs.

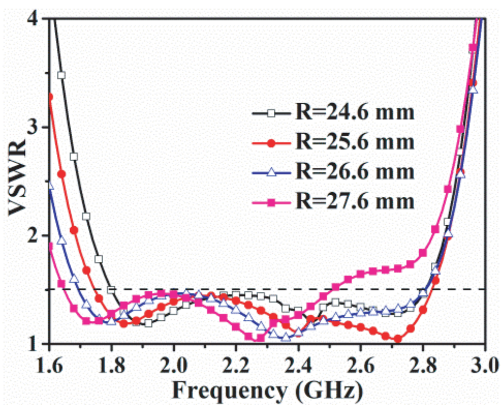


Figure 5. Simulated VSWRs versus parameter R.

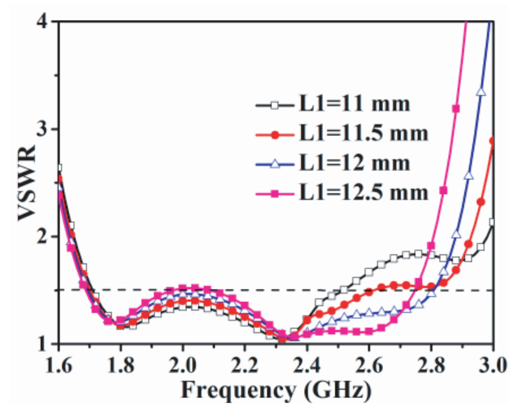


Figure 6. Simulated VSWRs versus parameter $L1$.

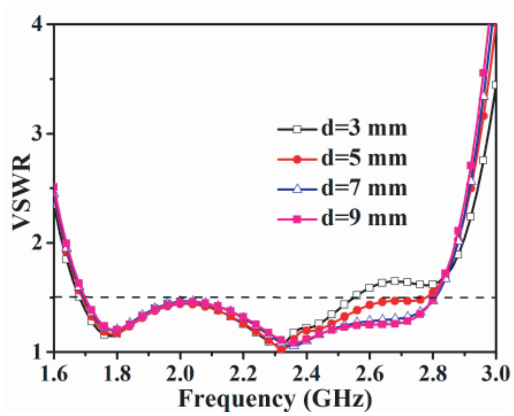


Figure 7. Simulated VSWRs versus parameter d.

can control the higher resonant mode. At last, $L1 = 12\,\text{mm}$ is chosen.

Figure 7 shows the effect of the parameter d on the impedance bandwidth. As can be seen, the resonant mode at high frequency gradually moves down to the low frequency band as d increases, and the impedance bandwidth declines. In addition, the curves at high frequency band gradually go down, which means that the impedance matching becomes better. Finally, $d = 7\,\text{mm}$ is chosen to obtain a wide operating bandwidth.

3. EXPERIMENTAL RESULTS

A prototype of the proposed antenna is fabricated and measured. Figure 8 shows the simulated and measured VSWRs and isolations of the antenna. It can be seen that the simulated and measured results are in fair agreement. The antenna has a wide impedance bandwidth of 53% (1.65–2.84 GHz) for VSWR < 1.5 at two ports, successfully covering the desired band of 1.71–2.69 GHz. Moreover, the measured port isolation is better than 26 dB within the band of operation.

Figure 9 shows the simulated and measured radiation patterns of the antenna. Based on the position of the base station antenna in practical application, the xz-plane and yz-plane are designated as the horizontal plane (H-plane) and vertical plane (V-plane), respectively. In addition, we just give

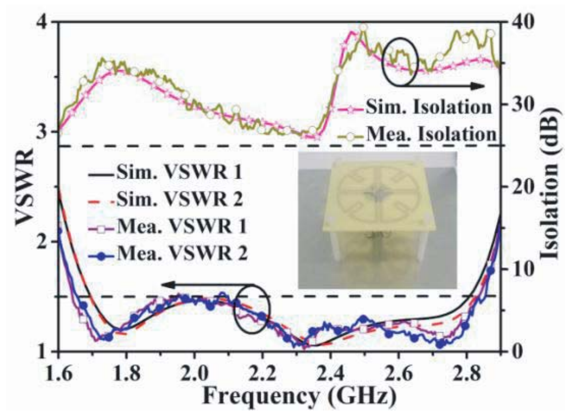
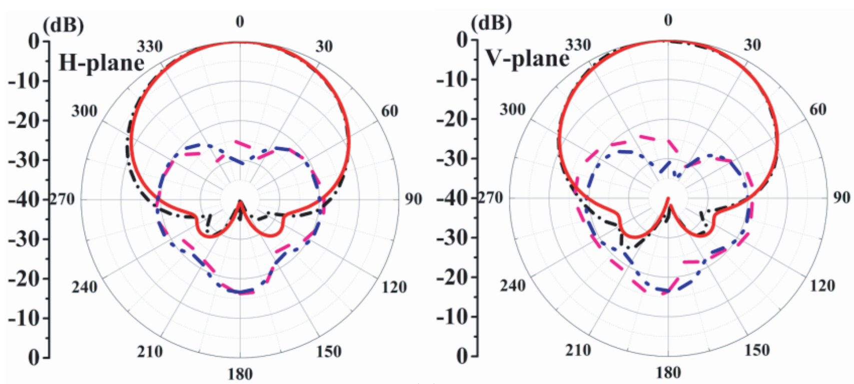
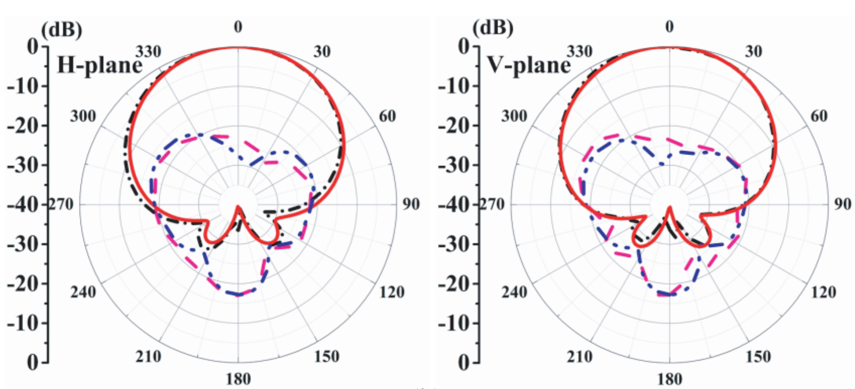


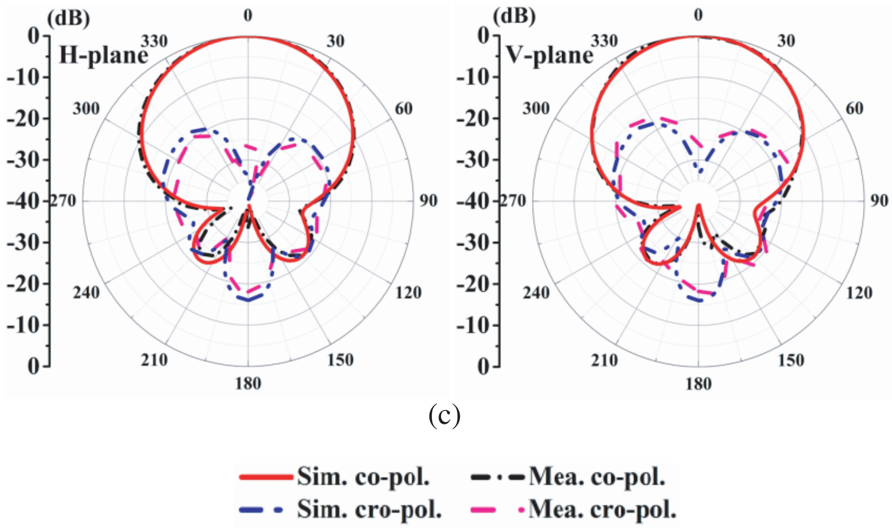
Figure 8. Simulated and measured VSWRs and isolations of the antenna.



(a)

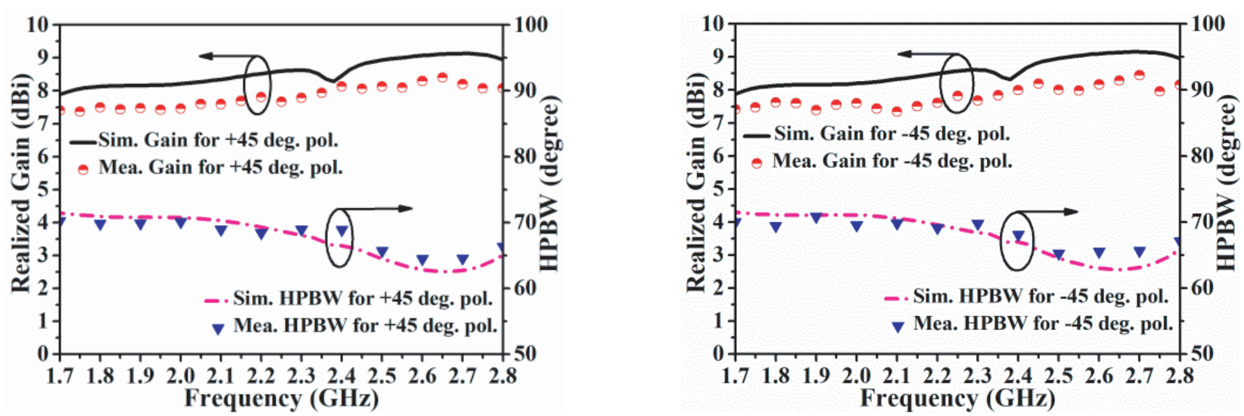


(b)



(c)

Figure 9. Simulated and measured radiation patterns of the antenna at (a) 1.7 GHz, (b) 2.2 GHz, and (c) 2.7 GHz.



(a) (b)

Figure 10. Simulated and measured gains and HPBWs of the antenna at (a) port 1 and (b) port 2.

the radiation pattern of the +45° polarization due to the symmetric structure of the antenna. As displayed in Figure 9, the stable and symmetrical radiation pattern is obtained across the entire band of operation.

Figure 10 shows the simulated and measured antenna gains and half-power beamwidths (HPBWs) in the *H*-plane for dual polarizations. It can be observed that the antenna gain around 7.9 ± 0.5 dBi and the 3-dB HPBWs of $67.5° \pm 3.5°$ are implemented over the operating band of 1.7–2.8 GHz.

4. CONCLUSION

A wideband dual-polarized dipole antenna is proposed for base station applications in this letter. By bending the arms of the dipole, the radiator size is reduced. Meanwhile, a new resonant mode occurs at high frequency. Then, four additional shorting stubs are used to improve the impedance matching. Finally, a wide impedance bandwidth is achieved by combining all resonant modes. A prototype of the proposed antenna is fabricated and measured. Experimental results show that the antenna possesses wide impedance bandwidth, high isolation, stable gain, and stable radiation pattern, indicating its promising use for base station applications.

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