An Improved Design of Dipole Antenna Array for Base Station Applications

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Abstract. To meet the high requirements of base station antennas, such as broadband, wide beamwidth and high gain, an improved dipole antenna array is proposed. Generally, the working frequency range of the conventional unidirectional dipole element cannot cover the 2G, 3G and 4G band (1.71-2.69GHz) at the same time. To solve this problem, two parasitic dipoles are added on both sides of the conventional dipole. The simulated results show that the return loss of the improved element is less than -10dB from 1.62GHz to 2.85GHz, which has a complete coverage of 2G, 3G and 4G band. And its beamwidth is more than 120° in the whole band. Apart from it, the gain of the element is levelling out at around 6.9dBi. To enhance the gain further, a 1×4 antenna array is designed and it can obtain a gain of more than 11.7dBi. Therefore, the proposed array is more profitable for the wireless mobile communication systems.

Introduction

Due to tremendous developments of various generations of wireless mobile communication systems, base station antennas have achieved dozens of milestones for a series of standards [1], such as 2G base station antennas for GSM and CDMA system [2], 3G base station antennas for TD-SCDMA, WCDMA, CDMA2000 [3], and 4G base station antennas for LTE/ LTE-Advanced [4].

As a mounting number of users are involved in wireless networks, an ever increasing capacity and more base station antennas are in urgent demand. In order to optimize the resource utilization efficiency, base station antenna having functional characteristics such as broad impedance bandwidth and stable gain are highly desired.

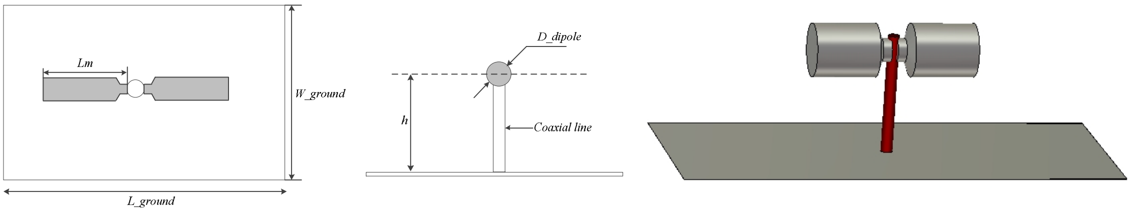
To satisfy such functional characteristics, a magneto-electric dipole antenna was proposed in [5]. This antenna had a bandwidth of 40% (1.82-2.73GHz). A broadband dual-polarized planar antenna, composed of two perpendicularly crossed bowtie dipoles, is proposed in [6]. This antenna has a bandwidth of 45% (1.7-2.7GHz) and a half power beamwidth (HPBW) of around 65°. In [7], a broadband asymmetric folded dipole antenna with high front-to-back ratio for LTE base stations is designed. The impedance bandwidth is 58.2% (1.62-2.95GHz) and the HPBW is greater than 65° at both principal planes in the frequency range from 1.7 to 2.7GHz. In [8], a ±45° linear-polarized cross-dipole with an operating band from 1.7GHz to 2.7 GHz is designed. And the HPBW is controlled by encircling the antenna with a conducting wall and placing cross-directors above the antenna, respectively, and a steady HPBW of 67°±3° is obtained.

However, in many cases, wide beamwidth in the main azimuth plane and narrow ones in the elevation plane are required for base station antennas, so that the efficiency and coverage quality of the antenna can be enhanced [9].

Under this circumstance, a dipole element with a beamwidth of more than 120° is proposed in this paper. Subsequently, the element is improved to obtain a broader impedance bandwidth, and the frequency range ($|S_{11}|$<-10dB) of the improved antenna element covers the 2G, 3G and 4G band. At last, a 1×4 array is designed to achieve a higher gain of over 12.1dBi, which can meet the demand for broadband, wide beamwidth and high gain in the wireless mobile communication systems.

The Design of Dipole Element

The geometry of the conventional unidirectional dipole element is shown in Fig. 1.



(a) Top view (b) Side view (c) 3D view

Fig. 1 Geometry of the conventional unidirectional dipole element

In order to realize the unidirectional radiation characteristic, the dipole is placed above the metallic ground plane with height *h*, which is about a quarter of the wavelength of the center frequency (2.2GHz). For base station applications, the optimized parameters of this element are displayed in Table 1.

Table 1 The optimized parameters of the conventional unidirectional dipole element

Parameter	*Lm*	*D_dipole*	*L_ground*	*W_ground*	*h*
Value(mm)	26.5	18	150	65	35

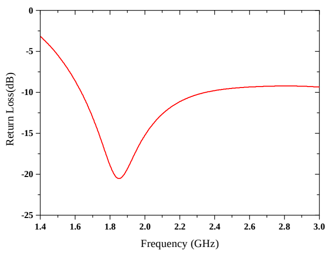
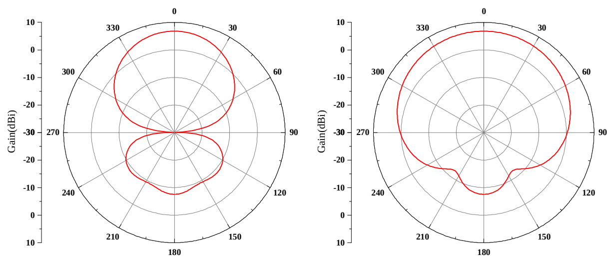


Fig. 2 Simulated return loss of the conventional unidirectional dipole element



(a) E-plane (b) H-plane

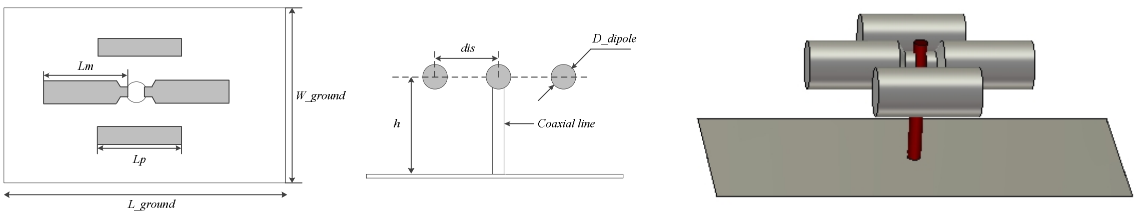
Fig. 3 Simulated radiation pattern at 2.2 GHz

Fig. 2 shows the return loss of the conventional unidirectional dipole. The return loss is less than -10dB from 1.63GHz to 2.35GHz and its impedance bandwidth is 36.18%. Besides, it is obvious that the impedance bandwidth can be widened by enlarging the diameter of the dipole, but the conventional unidirectional dipole cannot fully cover the 2G, 3G and 4G band.

The simulated radiation pattern at the center frequency 2.2GHz is shown in Fig. 3. As can be seen, the beamwidth of H-plane and E-plane are 127.8° and 58.5° respectively. Compared to the base station antennas whose H-plane beamwidth is about 65°, an omnidirectional pattern in the horizontal plane can be realized by using 3 antennas instead of 6 or more, which is beneficial to reduce the cost of construction on a large scale. Moreover, the maximum gain of this element is 6.79dBi, which happens at 2.2GHz.

The Design of Improved Antenna

A. An Improved Dipole Element



(a) Top view (b) Side view (c) 3D view

Fig. 4 Geometry of the improved dipole element

Generally, to reduce the complexity of the mobile communication system, base station antennas need to own the feature of broadband, but the bandwidth of the conventional unidirectional dipole element proposed in part Ⅰ cannot meet this requirement. Through the study of the geometry of this element, it is found that a broader band can be realized by adding two parasitic dipoles on both sides of the conventional dipole. Therefore, an improved dipole element is put forward, and its structure is shown in Fig. 4. Apart from the length of parasitic dipoles *Lp* is 30mm, the other parameters are identical to Table 1.

Fig. 5 displays the return loss of the improved dipole element. As can be seen, the return loss is less than -10dB from 1.62GHz to 2.85GHz, which fully covers the 2G, 3G and 4G band. And its impedance bandwidth is 55.03%, which is 18.85% wider than the conventional dipole element.

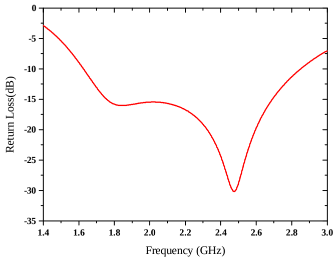
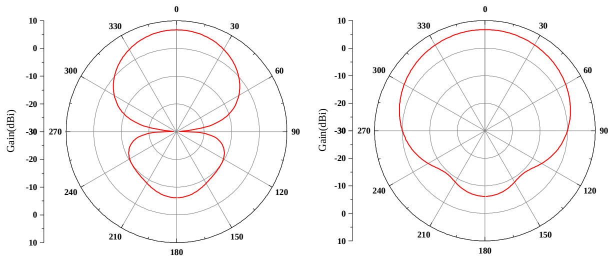
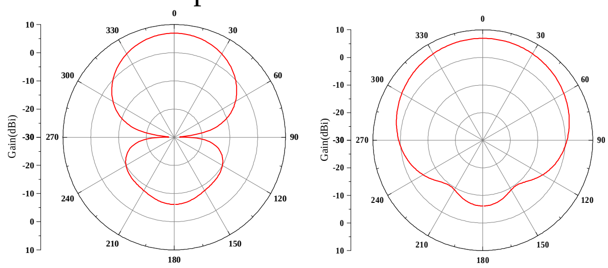


Fig. 5 Simulated return loss of the improved dipole element



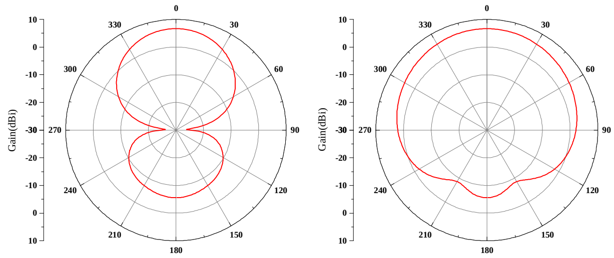
(a) E-plane (b) H-plane

Fig. 6 Simulated radiation pattern at 1.7GHz



(a) E-plane (b) H-plane

Fig. 7 Simulated radiation pattern at 2.2GHz



(a) E-plane (b) H-plane

Fig.8 Simulated radiation pattern at 2.7GHz

Fig. 6-Fig. 8 illustrate the radiation pattern of the improved dipole element at 1.7GHz, 2.2GHz and 2.7GHz, respectively. As can be seen, the beamwidth of H-plane is more than 120°. In addition, the gain of the improved antenna is still around 6.9dBi, and the radiation patterns are stable, which ranges from 6.65 to 6.92dBi in 1.7-2.7GHz.

B. An Array of the Improved Dipole

To satisfy the demand of high gain in mobile communication systems, a 1×4 antenna array is designed. As displayed in Fig. 9, the spacing between adjacent antenna elements is 120mm to avoid grating lobe at high frequency. To maintain the wideband property, the antenna elements are fed by an equal-power splitter.

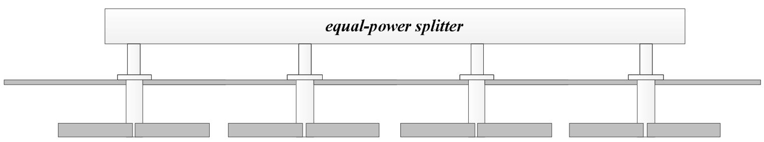
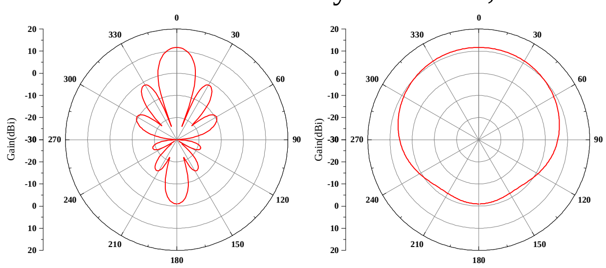


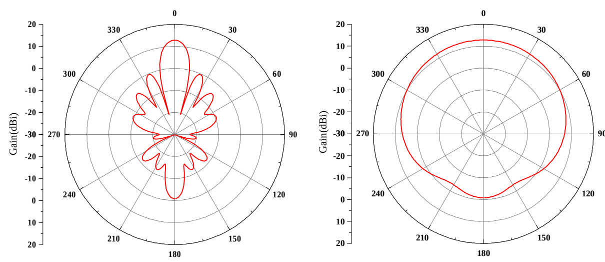
Fig. 9 Geometry of the 1×4 antenna array

The return loss of the array can fully cover the 2G, 3G and 4G band (1.71GHz-2.69GHz) as well. Here the pattern features are paid more attention. Fig.10-Fig.12 shows the simulated radiation patterns of the antenna array at 1.7GHz, 2.2GHz and 2.7GHz.



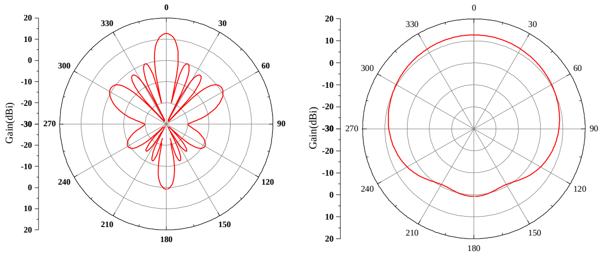
(a) E-plane (b) H-plane

Fig. 10 Simulated radiation pattern at 1.7GHz



(a) E-plane (b) H-plane

Fig. 11 Simulated radiation pattern at 2.2GHz



(a) E-plane (b) H-plane

Fig. 12 Simulated radiation pattern at 2.7GHz

The beamwidth of the H-plane keeps wide, which is still more than 120°. And the gain varies from 11.7dBi to 12.8dBi in the whole band. Consequently, the gain of the antenna is improved without affecting the impedance bandwidth and beamwidth in azimuth plane.

Conclusions

Base station antennas are expected to have broadband, high gain and wide beamwidth characteristics. However these three characteristics are contradictory. To cope with this problem, an improved dipole antenna is proposed. Compared with other work, the proposed antenna owns a broadband of 55.03%, a wide beamwidth of no less than 120° in azimuth plane, and a high gain of more than 6.65dBi. Though the gain is not enough for the actual systems, it can be improved by arraying, and the simulated results of a 1×4 array have demonstrated it. With the benefits of the designed antenna, the mobile communication system can be simpler and the cost of the system will also be reduced, so this antenna is a good candidate for base station applications.

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