An Improved Design of L-probe Feeding Microstrip Antenna Array for 4G Applications

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Keywords: microstrip antenna, broadband, wide beamwidth, high gain, 4G mobile communication systems.

Abstract. To meet the high requirements of 4G mobile communication systems, such as broadband, wide beamwidth and high gain, an improved microstrip antenna array fed by L-probe is proposed. Generally, most of the 4G antenna array elements have wide band and a gain of 3-5dBi. But the beamwidth in the horizontal plane is narrow, which is less than 70 °usually. To solve this problem, an improved design of the patch ground is introduced. Then an improved patch antenna and its array are designed. The simulated results show that the return loss of the improved patch is less than -10dB from 1.88GHz to 2.65GHz, which has a complete coverage of TD-LTE 4G band. And the beamwidth expands to almost 120 °at the same time. Though the gain of the patch is only above 5dBi, a 1×4 antenna array can get a gain of 11.85 dBi at the center frequency. Therefore, the proposed array is more profitable for the mobile communication systems.

1 Introduction

With the development of mobile communication systems, the characteristics of antenna are attached much more importance, such as size, impedance bandwidth, gain and beamwidth. According to the features of low profile, light weight and the conformity to mounting structures, patch antennas are the prior option to tackle the size problem [1]. As the evolution of 3G mobile networks, TD-LTE is the primary technology behind 4G [2]. Recently, operating permission for TD-LTE was awarded by Chinese government to the three major mobile operators in China. China Mobile has been authorized to operate TD-LTE on three frequency bands- 1880-1900MHz, 2320-2370MHz and 2575-2635MHz. China Unicom obtains two bands-they are 2300-2320MHz and 2555-2575MHz. For China Telecom, it has a dual band of 2370-2390MHz and 2635-2655MHz [3]. However, the bandwidth of traditional patch antennas is too narrow to cover the whole TD-LTE frequency band, so the monopole planar antennas are proposed [4]. In general, their gain is about 3dBi, and the beamwidth is up to 70 °. In order to realize the omnidirectional radiation in the horizontal plane, more than six antenna elements are needed. Therefore, antennas with a wide beamwidth can decrease the number of element to some extent. Then the patch antenna fed by L-probe is put forward [5]. Owing to its simple structure, broadband, moderate gain and wide bandwidth [6], it is quite suitable for the 4G mobile communication applications.

In this paper, we put forward a patch antenna element fed by L-probe. The frequency range ($|S_{11}|$<-10dB) of the designed antenna covers the 4G band of TDD-LTE. Then the element is improved to obtain a broader beamwidth of 114°. And finally, a 1×4 array is designed to achieve a higher gain of 11.85dBi, which can meet the demand for broadband, wide beamwidth and high gain in the mobile communication systems.

2 The Design of L-probe Feeding Microstrip Patch

As shown in Fig. 1, a conventional L-probe feeding microstrip patch consists of three components.

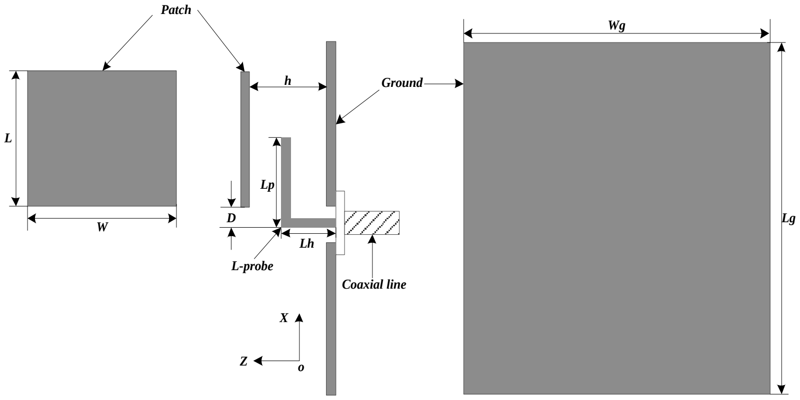


Fig. 1 Geometry of the conventional patch

On the top of the antenna is a rectangular radiation patch, which is fed by an L-shaped coaxial probe, so the normal TM_{01} mode of the patch can be excited. The size of the patch is about half of the wavelength. At the bottom of the antenna is the metallic ground plane. And the feeding probe penetrates through the ground by a hole. Between the rectangular radiation patch and the ground is filled with air, which may broaden the bandwidth. We can adjust the size of the probe and the height of the air layer to get a wide bandwidth. For 4G applications the optimized parameters of this antenna are displayed in Table 1.

Table 1 The optimized parameters of the conventional patch

Parameter	*L*	*W*	*Lg*	*Wg*	*h*	*Lp*	*Lh*	*D*
Value(mm)	51.1	61.3	245.4	204.5	13.5	23.5	10.5	5.1

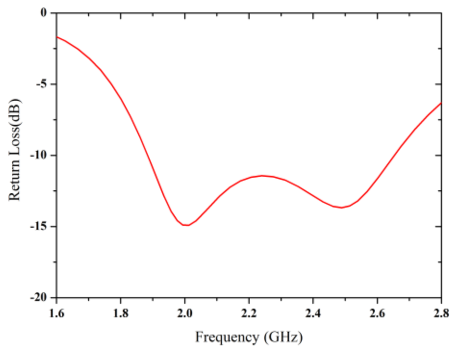
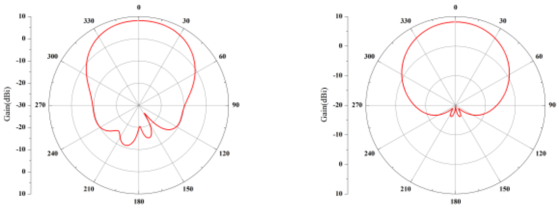


Fig. 2 Simulated return loss of the conventional patch

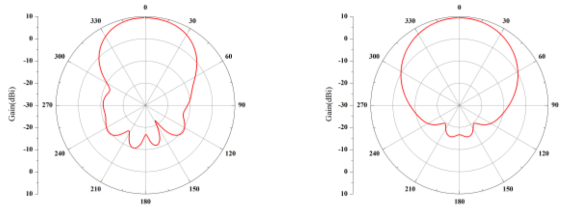
Fig. 2 shows the return loss of the conventional L-probe feeding microstrip patch. And the return loss is less than -10dB from 1.88GHz to 2.66GHz, which fully covers the TD-LTE 4G band (1.88GHz-2.655GHz). And the fractional bandwidth is 34.36%. Because the capacitance introduced by the L-probe suppresses some of the inductance brought by the feed probe, the wide bandwidth is obtained.

The simulated radiation patterns of the antenna at 1.9GHz, 2.25GHz and 2.6GHz are shown in Fig. 3, Fig. 4 and Fig. 5, respectively.



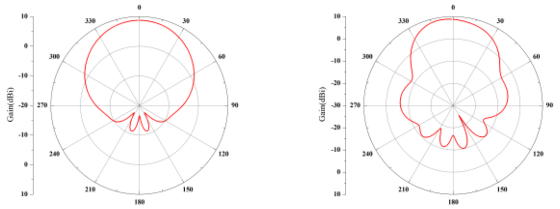
(a) XOZ € plane (b) XOY (H) plane

Fig. 3 Simulated radiation pattern at 1.9GHz



(a) XOZ € plane (b) XOY (H) plane

Fig. 4 Simulated radiation pattern at 2.25GHz



(a) XOZ € plane (b) XOY (H) plane

Fig. 5 Simulated radiation pattern at 2.6GHz

As can be seen, the beamwidth of H-plane is about 70 °, which is almost not changed through the whole band. And the beamwidth of E-plane varies from about 70 °to 50 °, when the frequency changes from 1.9GHz to 2.6GHz. Besides, the beamwidth of H-plane is always a little wider than that of E-plane. If an omnidirectional pattern in the horizontal plane is required by this antenna, 5 or 6 antennas should be used. The gain is above 7.5dBi over 1.88GHz-2.65GHz. Moreover, the maximum gain is 9.2dBi, which happens at 2.22GHz.

3 The Design of The Improved Antenna

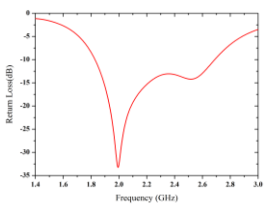
A. An improved L-probe feeding microstrip patch

Generally, to reduce the complexity of the mobile communication system, the antennas need to own the feature of wide beamwidth in the horizontal plane. Unfortunately the beamwidth of the conventional antenna can't satisfy this requirement in many cases. Through the study of all parameters designed in part Ⅰ, it is found that we can realize the purpose of wide beamwidth by only adjusting the size of the ground. Therefore, an improved antenna is proposed, which structure is identical to the conventional patch as shown in Fig.1. And the optimized parameters of the improved antenna are displayed in Table 2.

Table 2 The optimized parameters of the improved patch

Parameter	*L*	*W*	*Lg*	*Wg*	*h*	*Lp*	*Lh*	*D*
Value(mm)	51.1	61.4	245.4	28.0	13.5	23.5	10.5	5.1

Fig. 6 shows the return loss of the improved L-probe feeding microstrip patch. And the return loss is less than -10dB from 1.82GHz to 2.68GHz, which fully covers the TD-LTE 4G band (1.88GHz-2.655GHz) too. And the fractional bandwidth is 38.22%, which is 3.86% wider than the conventional patch.



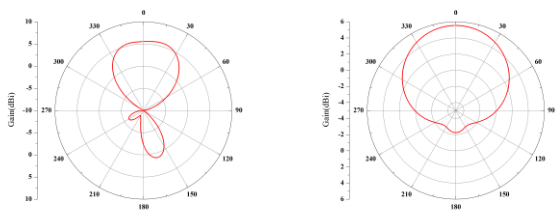
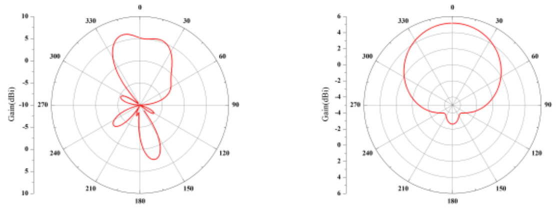


Fig. 6 Simulated return loss of the improved patch

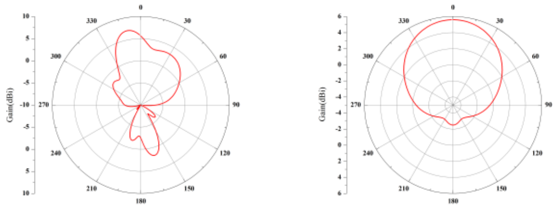
(a) XOZ (E) plane (b) XOY (H) plane

Fig. 7 Simulated radiation pattern at 1.9GHz



(a) XOZ (E) plane (b) XOY (H) plane

Fig. 8 Simulated radiation pattern at 2.25GHz



(a) XOZ (E) plane (b) XOY (H) plane

Fig. 9 Simulated radiation pattern at 2.6GHz

Fig. 7-Fig. 9 show the radiation pattern of the improved L-probe feeding patch at 1.9GHz, 2.25GHz and 2.6GHz, respectively.

As can be seen, the beamwidth of H-plane is obviously expanded, which is almost 120°in the whole band. So we can use only three antennas of the improved type to get an omnidirectional coverage in the horizontal plane. The amount of antennas is half of the conventional form, which is very attractive in engineering. Compared with the conventional form, the gain of the improved antenna decreases about 3dBi. This is mainly because the H-plane beamwidth of the improved antenna is about two times than the former. But the gain of the improved patch is still above 5dBi in the whole band, which is higher than most common base-station antennas.

B. An array of the improved patch

To further verify the wide beamwidth performance of the improved patch and considering the need of high gain in actual system, a 1×4 antenna array is also simulated. As shown in Fig. 10, the spacing between adjacent antenna elements is 67mm to avoid grating lobe at high frequency. To maintain the wideband property, the antenna elements are fed by an equal-power splitter.

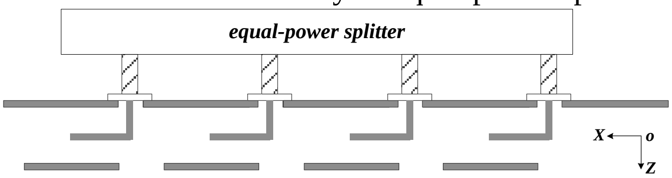
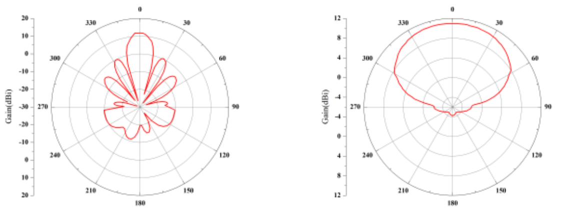


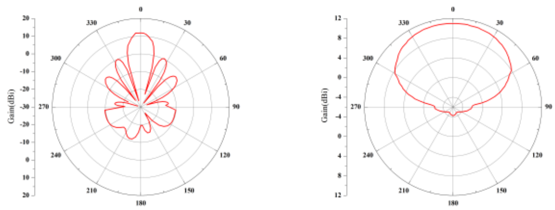
Fig. 10 Geometry of the 1×4 antenna array

The return loss can fully cover the TD-LTE 4G band (1.88GHz-2.655GHz) as well. Here we focus on the pattern feature. Fig.11-Fig.13 shows the simulated radiation patterns of the antenna array at 1.9GHz, 2.25GHz and 2.6GHz.



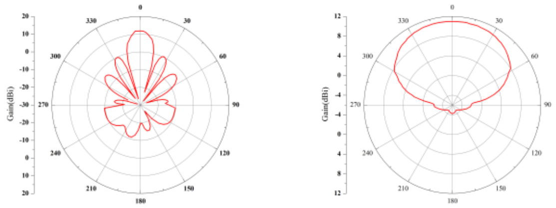
(a) XOZ (E) plane (b) XOY (H) plane

Fig. 11 Simulated radiation pattern at 1.9GHz



(a) XOZ (E) plane (b) XOY (H) plane

Fig. 12 Simulated radiation pattern at 2.25GHz



(a) XOZ (E) plane (b) XOY (H) plane

Fig. 13 Simulated radiation pattern at 2.6GHz

The beamwidth of the H-plane keeps wide, which is still about 120 °. The gain is 11.85dBi at the center frequency 2.25GHz. As a result, the gain of the antenna is improved without affecting the bandwidth and beamwidth character.

4 Summary

The ideal characteristic of the base-station antenna is to have broadband, high gain and wide beamwidth at the same time. However these three characteristics are contradictory. To tackle the problem, an improved L-probe feeding patch antenna is proposed. Compared with other work, the proposed antenna broadened beamwidth without affecting the wide band character. Though the gain is not high, it can be improved by antenna array. And the simulated results of a 1×4 array have demonstrated it. With the benefits of wide beamwidth, the mobile communication system can be simpler and the cost of the system will also be reduced. These make our proposed antenna more attractive in 4G applications.

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