Design of a High Isolation Dual-band MIMO Antenna for LTE Terminal

Lili Wang[1], Chongyu Wei[2], Weichen Wei[3]
[1,2]Qingdao University of Science and Technology, Qingdao, 266061, P.R.China
[3]Melbourne University, VIC, Australia
Email:youranjinsh@163.com

***Abstract*-This paper presents a dual-band MIMO array antenna working in LTE frequency band. A dual-band PIFA antenna is used for every single antenna element. The PIFA antenna is achieved by using the slotted technology. Using coupling feed and adding a capacitive patch to the short wall to reduce the coupling between two antenna elements can improve the isolation of the MIMO system. The designed antenna can work on the LTE 2.3GHz and LTE 2.6GHz bands synchronously, corresponding band widths are 2300MHz-2400MHz and 2570MHz-2620MHz respectively. Simulation results show that within the operating frequency bands, isolation can be less than -25dB without significantly affecting the radiation characteristics, which demonstrates the feasibility of this design.**

***Keywords*-LTE, MIMO, Isolation, Dual-band, PIFA**

I. INTRODUCTION

LTE (Long Term Evolution) is a key technology for the evolution of the wireless communication system from 3G to 4G. In order to meet requirements of high data rate, LTE system uses the multi-antenna technology. Multiple-input multiple-output (MIMO) wireless communication has become one of the most critical technologies in LTE and future 4G system. By using multiple antennas for receiving and transmitting, it can greatly improve the capacity of the communication system. However, there is often mutual-coupling between the antenna elements, which reduces the independence of the antenna elements, thus severely limiting the improvement of the capacity of the communication system. Therefore, the multi-antenna decoupling technology has become one of the key issues in mobile terminals.

This paper only discusses MIMO antenna for LTE terminal that consists of dual antenna elements. Reference [1] increases the isolation between antennas by changing the antenna polarization characteristics and slotting on the ground plane. Reference [2] uses the DGS (Defected Ground Structure), which means reducing the permittivity of the dielectric plate or digging up part of the media below the antenna. Or add PBG (Photonic Band Gap) material or EBG (Electromagnetic Band Gap) material between the antennas such as Reference [3]. Reference [4] uses DMN (Decoupling Matching Networks) structure to achieve decoupling. Reference [5] applies microstrip line to link the two antenna elements, to achieve the purpose of offsetting the coupling effects as some of the energy will transfers to another antenna.

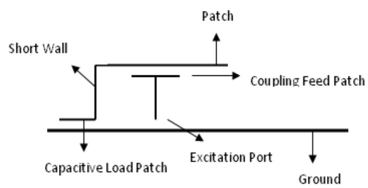
Antenna elements that are array compactly often have stronger coupling. One of the reasons is that there is strong common currents distribution on the ground plane. Thus, low coupling between antenna elements can be achieved by reducing the currents or changing the currents distribution on the ground plane. When introduce DGS structure, currents on the ground plane will be weaken due to the action of the stop band and thereby increasing the isolation Reference [6]. This technology to some extent is undesirable for practical application, since the ground plane structure of the actual mobile terminals may not allow such a change. However, lower the coupling between antennas elements by reducing the currents on the ground plane is a desirable manner. The method proposed in Reference [7] can significantly improve the isolation between antenna elements in MIMO system. In this paper, both the capacitive feed and capacitive load structures can be used to prevent currents on the radiation patch flowing directly to the ground plane through short wall and feed point, taking a step forward from an antenna port flows into another antenna port. Thereby reducing the coupling between antenna elements and lowering the correlation between antennas. Its essence is achieving the low coupling of MIMO multi-antenna system by reducing the currents on the ground plane.

II. ANTENNA MODELING AND ANALYSIS

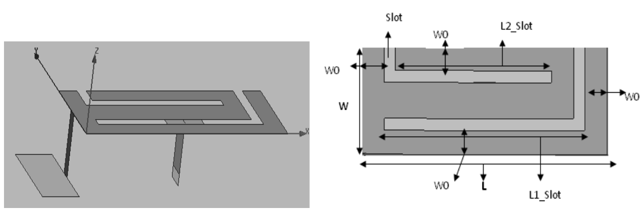
PIFA antenna has simple structure, small size and can achieve a wide bandwidth as well as achieve multi-band. The single antenna element of the MIMO system proposed in this paper also uses PIFA antenna. In the literatures that introduce how to reduce the mutual coupling, to a great extent, single-frequency antennas are researched. This is because the structure of a single-frequency antenna is simple and easy to decouple. Here we achieve the dual-band characteristics by using meander technology based on PIFA antenna. The operating frequency of the antenna is from 2300MHz to 2400MHz and from 2570MHz to 2620MHz, both of them are LTE bands. Resonant frequencies are about 2.35GHz and 2.6GHz respectively. In order to reduce the coupling between the two antenna elements, capacitive coupling feed and capacitive load technology are used at the same time.

A Antenna Design

Figure 1(a) is the side view of a single antenna element .The two antenna elements are placed at the same top edge of the ground plane, keeping 2mm and 6mm respectively from the long side and the short side of the ground plane. The radiation patch dimensions are (L, W) = (22mm, 9mm). The antenna height from the ground is 6mm. Instead of coaxial feed, the currents will be fed to the metal microstrip through coaxial, then the metal microstrip feed line will feed the currents to the radiation patch. The feed line is not directly connected to the radiation patch, but a capacitive feed patch is used at the top of the feed line to achieve currents feed using coupling feed method. The capacitive feed patch has length of 4mm along the X-axis and 3mm along the Y-axis direction. The distance between the feed patch and the radiation patch is 0.5mm. The metal microstrip feed line with a width of 2mm places in the center of the feed patch, and parallels to the short wall. The width of the short wall is 1mm, and a capacitive load patch which has length of 4mm along the X-axis and 9mm along the Y-axis direction is connected to the short wall. The distance between the load patch and the ground plane is 0.5mm. By using slotted structure, the dual-band characteristics will be realized. Slot gap structure and relative parameters are shown in Figure 1 (b). The gap width Slot = 1mm, and the gap keep distance of W0 = 2mm with each edge of the patch, L1_Slot = 18mm, L2_Slot = 14mm.



(a) Side view of the antenna element



(b) Antenna element structure and structural parameters

Fig.1 Geometry of the antenna structure

B Antenna Structure Analysis

The so-called coupling feed is to retain an adjustable gap between the feed patch and the radiation patch. Capacitive coupling feed can offset the sensitivity brought by the feed line and increase the degree of freedom in debugging and matching, and this can also be used as a mean of increasing bandwidth. Here, it also can reduce the currents that flow directly to the ground plane through the feed line. As a result, the isolation between the antenna elements to some extent will be improved.

Currents flowing to the ground plane through the short wall is one of the important reasons resulting in strong coupling between antenna elements. Add a capacitive load patch to the short wall can reduce currents that flows directly through the short wall to the ground plane obviously, which can play a good role in improving the isolation.

The coupling feed patch and the capacitive load patch constitute an adjustable capacitor with the radiation patch and the ground plane respectively. To the feed patch, the capacitor value can be adjusted by changing the distance between the feed patch and the radiation patch and the feed patch area. And to the load patch, there are the same methods to change the capacitor value. The change of the capacitor value will affect the characteristics of a single antenna and the isolation between the antenna elements.

To achieve a dual-band PIFA antenna and taking into account the coupling feed structure at the same time, design a gap structure on the radiation patch shown in figure1(b). The capacitive coupling feed patch placed on the middle of the short side of the radiation patch connected to the microstrip line. Adjust the position of the feed point and the short wall and the capacitance of the two parallel plate capacitors can be used to achieve impedance matching. As a result, a good antenna property can be implemented.

III. SIMULATION RESULTS AND ANALYSIS

HFSS electromagnetic simulation software is used in this paper for simulating and analyzing the designed MIMO antenna. The related simulation results are shown in figure 2, 3 and 4.

Figure 2 is the simulation result of the return loss of the MIMO antenna. As shown in figure 2, the resonance characteristics of the two antennas change little and there is only small difference at the low frequency resonant point. Put the reflection coefficient S11 ≤ -6 dB as a standard, we can measure that the return loss over the frequency range from 2.28GH-2.46GHz is less than -6dB which covering LTE 2300GHz-2400GHz band with a bandwidth of 180MHz. And the return loss of 2.54GHz—2.63GHz also covers LTE 2570GHz—2620GHz band with a bandwidth of 90MHz. Their center frequencies are approximately 2.35GH and 2.6GHz. The return loss is up to -25dB or so.

Figure 3 is the simulation result of the isolation between the two ports of the antenna system. To the MIMO system consists of the traditional FIFA antenna elements, isolation is far from the requirement by MIMO. However, to the new designed dual-band MIMO antenna system, the isolation within working bands can up to -25dB or less. Within 2.3GHz band, the minimum isolation is -26.6dB and the maximum isolation can up to -35.9dB. The isolation of the 2.6GH band ranges from a minimum isolation of -28.4dB to a maximum isolation of -30.8dB. In the case of affecting the radiation characteristics little, the isolation of the MIMO antenna system is effectively improved.

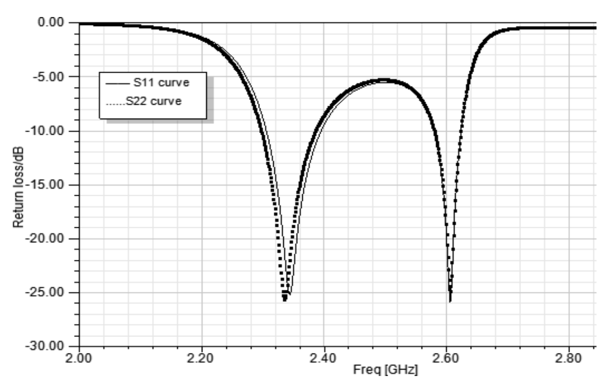


Fig. 2 Simulated return loss curve of MIMO antenna

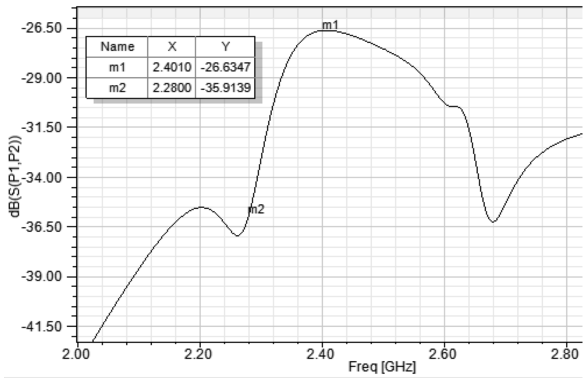
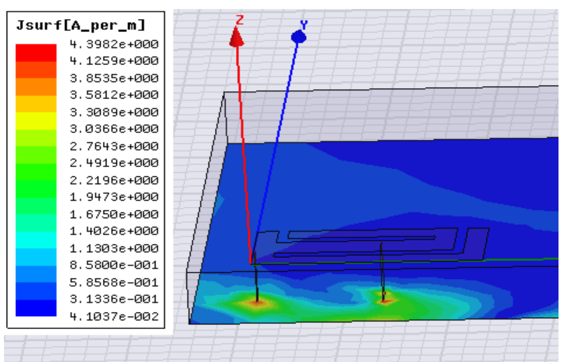
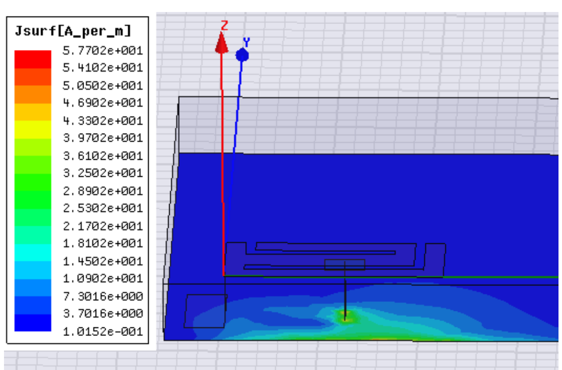


Fig. 3 Simulated isolation curve of MIMO antenna

Figure 4 is the current distribution on the ground plane. Figure (a) is the situation without capacitive feed patch and capacitive load patch. Figure (b) is the antenna structure that this paper proposed.



(a) Current distribution on the ground plane of the traditional PIFA antenna



(b) Current distribution on the ground plane of the PIFA antenna proposed in this paper

Fig. 4 Current distribution on the ground plane

It can be clearly seen that when capacitive load patch is added, the current density on the nearby region of the short wall on the ground plane is significantly reduced. The current density on the nearby region under the feed patch to some extent is also decreased. This result proves that short wall has played a significant role in guiding the current flowing. And when the capacitive load patch is added, it can significantly prevent the currents flows to the ground plane through the short wall. Current on the ground plane that is located under the radiation patch significantly larger than other positions of the ground which proves that the ground plane as an important part of the antenna plays a key role in guiding the flow of currents and involved in the electromagnetic radiation.

IV. MEASUREMENT RESULTS

The designed antenna is fabricated and measured (As shown in Figure 5). The measurement results of the dual-band MIMO antenna are shown in Figure 6. As can be seen from the measurement curves, the resonant points are basically consistent with the simulation results. However, the return loss values, in particular for the low frequency resonant point, have slight difference compared with the simulation results. Overall, the bandwidth can meet the requirements. It can also be seen from Figure 6, the measurement result of the isolation can not be fully consistent with the simulation curve. However, the trend of the two curves is identical and the measurement result of the isolation can achieve the range of values of the simulation. The measurement results show that the antenna has a good practicability.

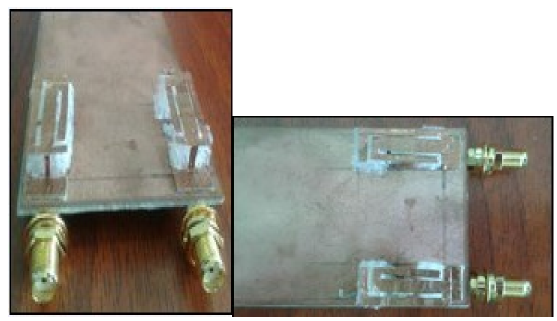


Fig. 5 Photograph of the dual-band MIMO antenna

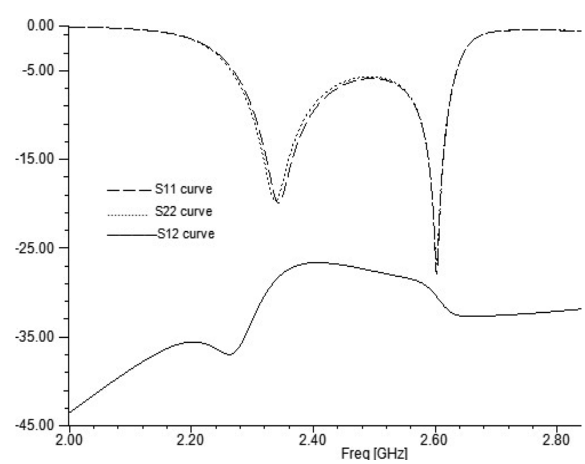


Fig. 6 Return loss curves and isolation curve of the measurement results

V. CONCLUSIONS

This paper presents a dual-band MIMO array antenna working in LTE frequency band. Coupling feed patch and capacitive load patch are used to reduce the current density on the ground plane, so that improving the isolation between the antenna elements. Focus on the design of a high isolation and dual-band MIMO antenna system, a PIFA antenna structure is used for every single antenna element. The slotted technology is used to achieve the dual-band. The simulation and measurement results proof that within the operating frequency bands, less than-25dB isolation can be obtained in this MIMO antenna system without significantly affecting the radiation characteristics. Therefore, this antenna structure has a good reference value to the design and application of the MIMO antenna for the terminal in the future.

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