Printed Inverted-F MIMO Antenna for TD-LTE Mobile Terminal

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Abstract— With the rapid growth and development of the mobile communication technologies in recent years, many mobile communication technologies appeared one after another, of particular concern is 3GPP long term evolution (LTE). TD-LTE is growing rapidly in China and is also widely considered in the forth generation (4G) mobile communication now. MIMO technology, which utilizes multiple antenna to improve spectrum efficiency and increase the system channel capacity, is one of the 4G key technologies.

In this paper a MIMO antenna, operating on TD-LTE frequency band for TD-LTE mobile terminal is designed. The proposed MIMO antenna consists of two modified IFA structures has the advantage of compact structure and multiband for 4G handheld devices. The antenna designed to cover the TD-LTE frequency band of 1880 −1900 MHz and 2575–2635 MHz for China Mobile. The simulated and test results show that the isolation and S_{11} parameters of the proposed MIMO antenna can meet TD-LTE mobile communication requirements.

1. INTRODUCTION

The 4th generation in the wireless evolution is called the Long Term Evolution (LTE) which will provide higher peak data rates, higher spectral efficiency and lower latency taking advantage of the latest enabling technologies such as Orthogonal Frequency Division Multiple Access (OFDMA), Adaptive modulation and coding (AMC) and Multiple-Input Multiple-Output (MIMO) technologies.

The 1.8 GHz and 2.6 GHz band is used for China Mobile's LTE systems in mainland China. Due to the small size of LTE mobile terminal, the design of Multiple-Input Multiple-Output (MIMO) antenna with broadband or multiband on small handsets is a real challenge. And due to the integration of multiple antennas on a single portable device with very limited space, mutual coupling between multiple antennas is severe, and the MIMO antenna for mobile terminal systems with high isolation is of great importance to bring 4G capabilities to reality.

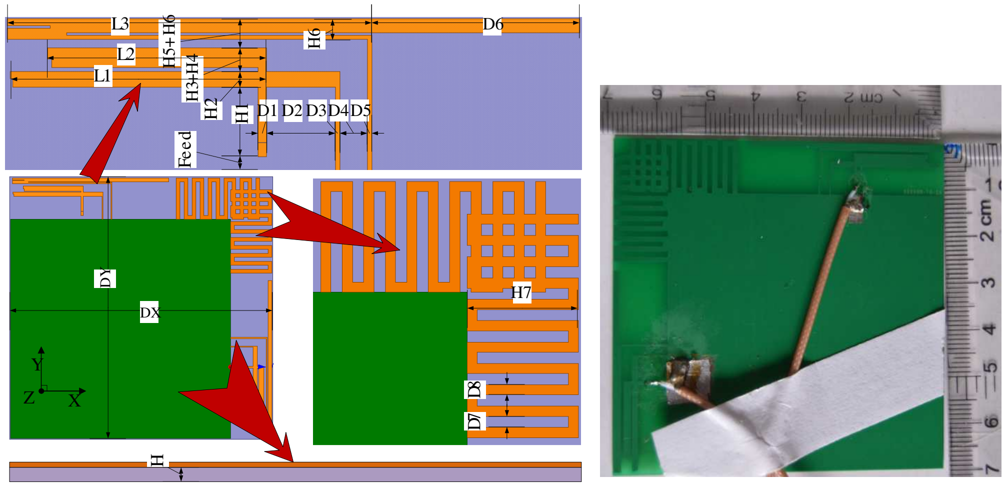
Many printed MIMO antennas have been discussed in literature recently. In [1], a compact planar MIMO antenna system of four elements is proposed for the whole 2.4-GHz WLAN band. Two types of antenna elements printed on different sides of the substrate are used in the structure for better isolation performance. In addition, a series of slits etched in the ground plane is proposed to improve the mutual coupling. In [2], a modified PIFA antenna by adding a proper chip capacitor was designed to enhance the lower band and by adding a shorted strip or forming a coupled section to enhance the upper band. In [3], by adding the two parasitic monopoles, the mutual coupling is greatly improved, meanwhile, the bandwidth increases somewhat. In [4], a penta-band CRLH-based antenna was designed and integrated into a cellular handset. The measured results demonstrated that the proposed CRLH-based antenna had superior performance and smaller size compared to other conventional antenna designs.

In this article, we proposed a modified IFA antenna printed on one top layer of a 0.6 mm thick with the FR4 substrate and the dielectric constant of 4.5. The antenna was designed to cover the low band and upper band of TD-LTE for mobile terminals.

2. ANTENNA DESIGN

The basic antenna element has the shape of English character F, and hence it is called inverted-F antenna. The print IFA is a new different antenna based on the basis of monopole antenna with a short-circuit line, so the transmission line theory of the original model must be modified [5–9]. The print IFA can be similar to a transmission line which is shorted in one end and which is opened in a nother. It can be modeled by the equivalent circuit method.

The geometry and photo of the proposed MIMO antenna for mobile terminals is shown in Fig. 1. The antenna consisted of two elements were placed in the right and left corners of a PCB with a volume of $69\,\text{mm} * 69\,\text{mm} * 0.6\,\text{mm}$.



(a) (b)

Figure 1: (a) MIMO antenna model. (b) Photo of MIMO antenna.

The traditional inverted-F antenna covers only one frequency band and it should be modified to have multiband frequency band-with. In order to get the dual band performance of each MIMO antenna element, a branch with the length of $L2$ was used to get another band. The modified inverted-F antenna with two radiation arm can provide two resonating path, but it is difficult to get a wide upper band (2.6 GHz) of TD-LTE. To deal with this problem, a parasitic element with a length of $L3$ was introduced to increase the upper band-with. The dimensions of the basic antenna element are (in millimiters) shown in Table 1.

Table 1: Comparison between the perfusion coefficient (B) for the different tissues.

$D1$	$D2$	$D3$	$D4$	$D5$	$D6$	$D7$	$H1$	$H2$	$H3$	$H4$
0.6	5	0.3	2	0.3	15	1	5	1.1	0.3	1.4
$H5$	$H6$	$H7$	$L1$	$L2$	$L3$	F	H	DX	DY	
0.6	1.5	1.9	17.7	14.9	26	1	0.6	69	69	

For the design of a compact MIMO antenna, coupling among antenna elements can no longer be neglected because antenna elements are closely spaced in a limited room, and the displacement between antennas will be influenced both in space diversity and in induced pattern diversity. We proposed two methods to reduce the mutual coupling of the MIMO antenna. The firs method is the use of ground elements. The second method is layout of two antenna element with different places.

3. RESULTS AND DISCUSSION

The commercial software HFSS and CST was used for the simulation of the MIMO antenna model. The simulated and measured S-parameters are showed in Fig. 2. As shown in Fig. 2, we can see that both of simulation and measured results are in agreement.

The simulated of 3D farfeild radiation patterns are shown in Fig. 3, antenna 1 with lumport 1 is shown in the up corner of the model, antenna 2 with lumport 2 is shown in the low corner.

The correlation coefficient (ρ) is a measure that describes how much the communication channels are isolated or correlated with each other. This metric considers the radiation pattern of the antenna system, and how much the patterns affect one another when operated simultaneously. The square of the correlation coefficient is known as the envelop correlation coefficient. The envelop correlation

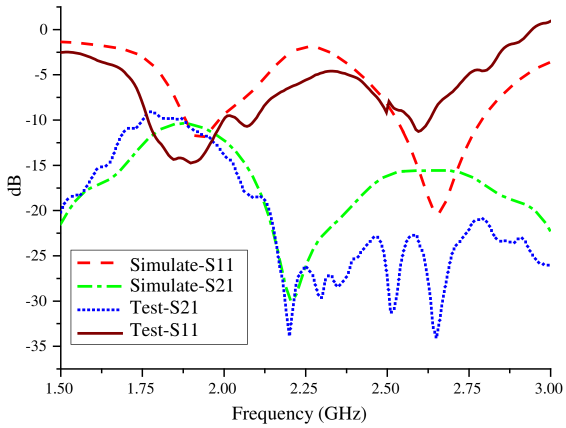


Figure 2: S-parameters.

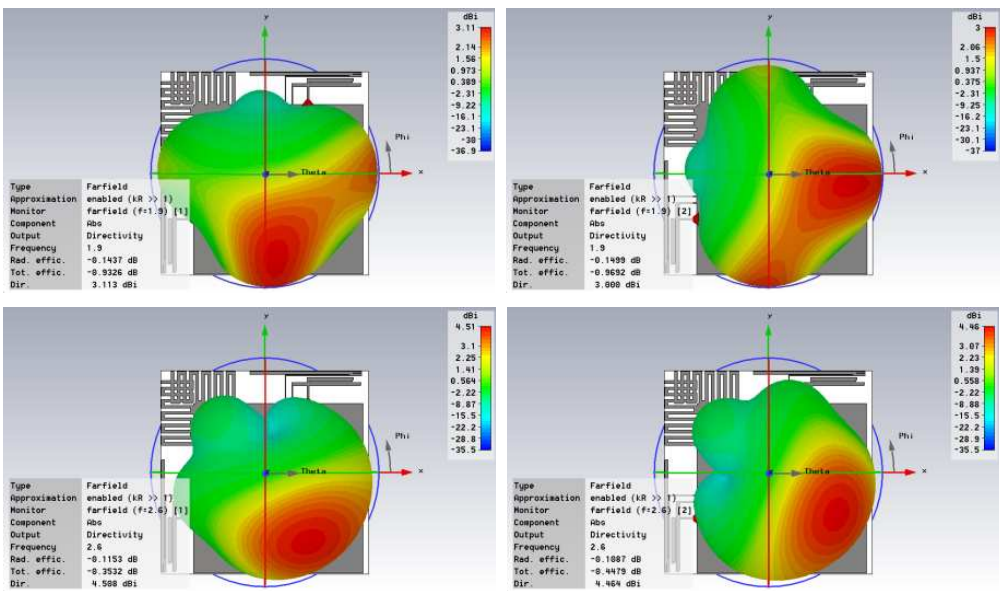


Figure 3: 3D radiation patterns.

coefficient (ρ_e) can be calculated using the following formula [10].

$$\rho_e = \frac{\left| \iint_{4\pi} \left[\vec{F}_1(\theta, \varphi) * \vec{F}_2(\theta, \varphi) \right] d\Omega \right|^2}{\iint_{4\pi} \left| \vec{F}_1(\theta, \varphi) \right|^2 d\Omega \iint_{4\pi} \left| \vec{F}_2(\theta, \varphi) \right|^2 d\Omega}, \tag{1}$$

where $\vec{F}_i(\theta, \varphi)$ is the three-dimensional field radiation pattern of the antenna when the i port is excited, and Ω is the solid angle. The asterisk is the Hermitian product operator. This is a complicated expression that requires three-dimensional radiation-pattern measurements and numerical integration.

The correlation coefficient can be calculated using the S parameters for simple in [11, 12] when a lossless and single-mode antenna is considered. The formula with S parameters only is given by

$$\rho_{eij} = |\rho_{ij}|^2$$

where

$$\rho_{ij} = \frac{S_{ii}^* S_{ij} + S_{ji}^* S_{jj}}{\sqrt{(1 - |S_{ii}|^2 - |S_{ji}|^2)(1 - |S_{jj}|^2 - |S_{ij}|^2)}} \tag{2}$$

As shown in Fig. 4, the radiation-pattern-based ECC of the proposed MIMO antenna has the ECC of below 0.05 in both lower and higher frequency bands. The modified inverted-F antenna with compact size and dual band frequency is suitable to be an antenna element of MIMO antenna for TD-LTE.

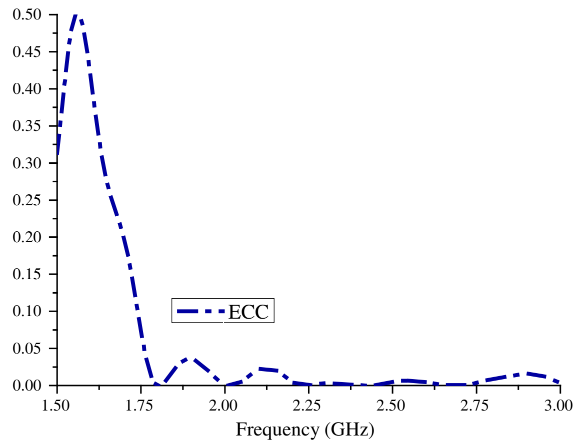


Figure 4: ECC.

4. CONCLUSION

The small printed inverted-F antenna (IFA) for LTE system, near the band-with 1800 MHz and 2.6 GHz, has been studied in this paper. The small antenna can be used in other frequency band wireless communication system such as 3G. It is very convenient and quickly to design this kind of antenna, more over, this kind of antenna designed in the experiment can be easily mass-fabricated with low production cost.

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