A Multi-Band High-Isolation MIMO Antenna for 5G Mobile Phone

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***Abstract*—In this paper, a multi-band multiple input multiple output antenna system with a high isolation degree is designed.The MIMO antenna system comprises of four monopole antenna elements, each of which includes an inverted F-shaped and a ring. The MIMO antenna system operates in Chinese Sub-6GHz 5G communication frequency band, namely 2.515-2.675 GHz, 3.4-3.6 GHz and 4.8-4.9 GHz. The structure of simple and relatively compact is the characteristic of MIMO antenna system. Therefore, a good isolation degree between antenna elements is obtained without adding decoupling structure, and the envelope correlation coefficient between antenna elements in the corresponding frequency band is extremely low. Simulation results demonstrate that the designed MIMO antenna system exhibits better radiation efficiency in the operating frequency band. The design of this paper has a profound impact on 5G mobile antenna.**

***Index Terms*—5G, antenna, multi-band, MIMO.**

I. Introduction

The continuous advances in science and technology have brought the mobile communication technology for fifth-generation (5G) networks into people's daily life. 5G has three characteristics: ultra-high speed, ultra-large connection and ultra-low delay [1]. Multi-antenna technology has been widely applied as the advance of wireless communication technology. MIMO technology is the basic way to improve power efficiency and spectral efficiency by using infinite spatial dimension resources. Therefore, MIMO antenna system design has been widely studied. Previous research has manifested that multi-antenna system conforms to the development of 5G mobile phones as there are more frequency bands for 5G communication, however most studies only cover less frequency bands. For example, single-band and dual-band antennas are realized by using monopole [2]-[4]. Three frequency bands covering 5G communication are generated, but the ground clearance is sacrificed to some extent [5]. On top of that, the space in the mobile phone frame is limited, and the multi-antenna system requires the antenna elements to be small enough and the antennas to be highly isolated from each other. There are challenges in designing a MIMO antenna system that satisfies the public.

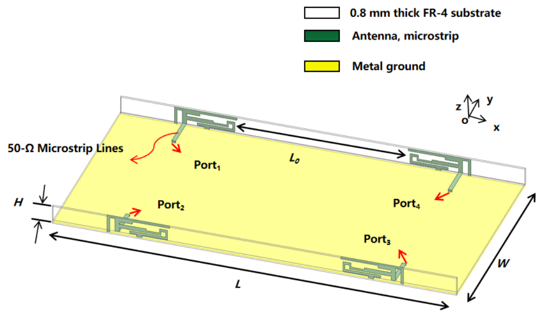

Fig. 1. Overall structure of the suggested antenna.

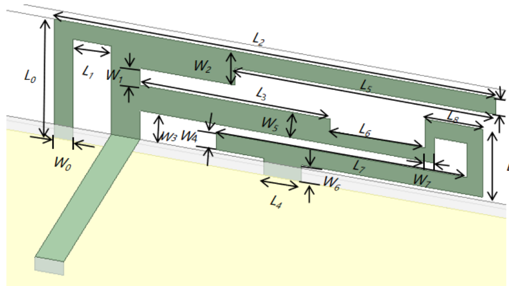

Fig. 2. Specifications of the suggested antenna.

To further support Sub-6GHz bands covering 5G communications in China, we propose a three-band 4-port MIMO antenna which has not gaps on the ground and has high isolation and miniaturization. In addition, the antenna design is very simple.

II. Antenna Configuration and Operating Principles

A. Antenna Configuration

Figure 1 shows the structure and size of the MIMO antenna system. The traditional size of the mobile phone model is 150 × 75 × 7 mm^3. All antenna elements are printed on the FR4 dielectric substrate, which has a thickness of 0.8 mm, dielectric constant of 4.4, and loss tangent of 0.02. The back side is

TABLE I
SPECIFIC DIMENSIONS OF ANTENNAS (UNIT:MM)

Parameter	L_0	L_1	L_2	L_3	L_4	L_5	L_6	L_7
Value	7	2	23.2	10	2	13.7	5	13.2
Parameter	L_8	L_9	L_{10}	W_0	W_1	W_2	W_3	W_4
Value	3	4	65	1	1	2	1.7	1
Parameter	W_5	W_6	W_7	W_8	L	W	H	
Value	1.5	1	0.5	1	150	75	7	

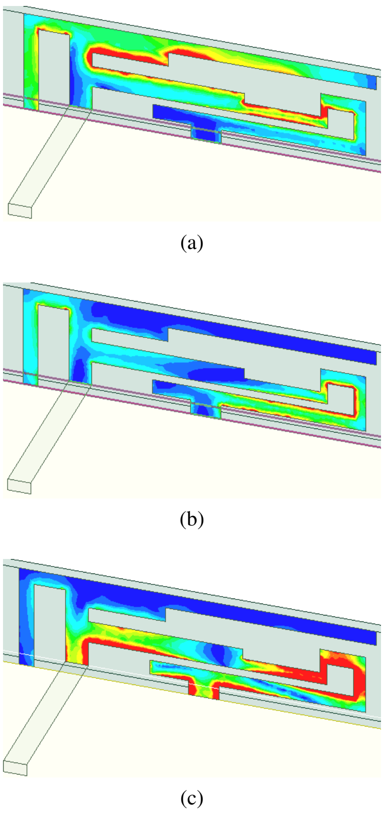

Fig. 3. Antenna element surface current distribution at (a) 2.6 GHz, (b) 3.5 GHz, and (C) 4.9 GHz

printed ground. Figure 2 is the specific size diagram of the antenna element, which is composed of an inverted F-shaped and a ring monopole. The width of the inverted F-shaped oscillator and the width of the ring part are both gradual, and there is a junction at the bottom of the ring connected to the ground.

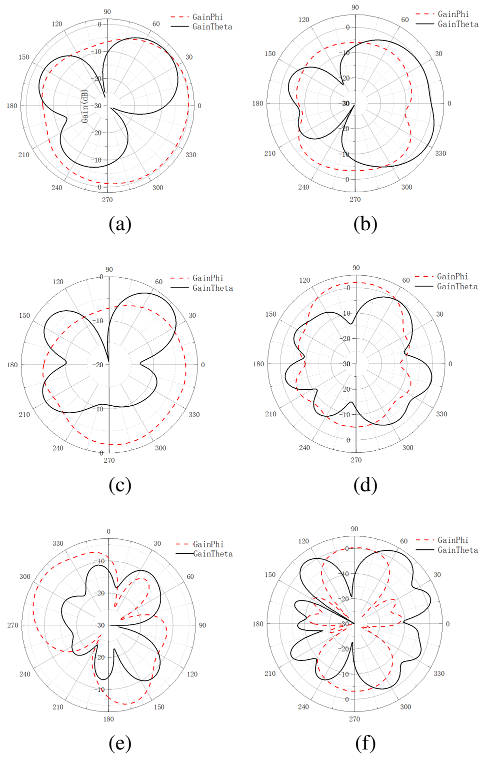

Fig. 4. Simulations of the suggested antennas radiation patterns in 2.6 GHz (a-b.), 3.5 GHz (c-d.), and 4.9 GHz (e-f).

B. Operating Principles

The distribution of current on the surface of an antenna element during resonance is illustrated in Fig. 3. When the antenna is operating at 2.6 GHz, most of the current is dispersed in the inverted F-shaped portion, that is, the low frequency band of the inverted F-shaped antenna excitation. The antenna uses 3.5 GHz and 4.9 GHz for operation, and the current is mainly distributed in the ring part, that is to say, the ring part is used to excite the middle and high frequency bands. The ring bending part extends the current path to stabilize the resonance in the middle frequency band, and the ring gradual part can ensure the bandwidth of the 3.5 GHz band is sufficient. In addition, the bottom of the ring part is provided with a shorting stub, which can lead a part of the current to the ground, making sure the antennas in the medium and upper frequency bands have adequate impedance matching.

III. Simulation Results and Discussions

The suggested MIMO antenna system is simulated and optimized by HFSS software, and verified in CST. Due to the centrosymmetric structure of the system, we only analyze the results for some elements. Figure 4 depicts the simulated radiation patterns of designed antenna at the corresponding frequency band points respectively. The simulated element antenna reflection coefficients in the MIMO antenna system are depicted in Fig. 5. It is evident that the S-parameter curves of all ports are highly consistent, and the -6 dB impedance

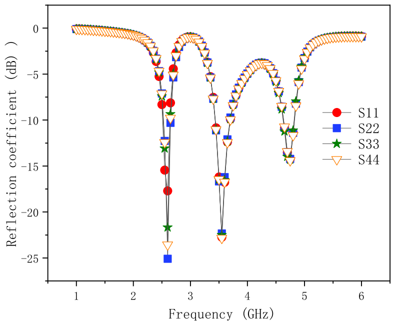

Fig. 5. Simulation of the suggested antenna's coefficient of reflection.

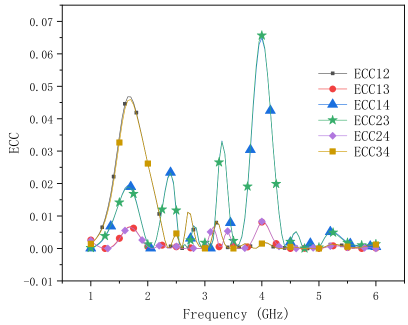

Fig. 7. Simulated ECCs between the recommended antenna's two elements.

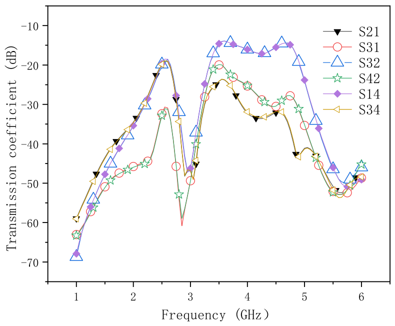

Fig. 6. Simulated mutual connections between two elements of the recommended antenna.

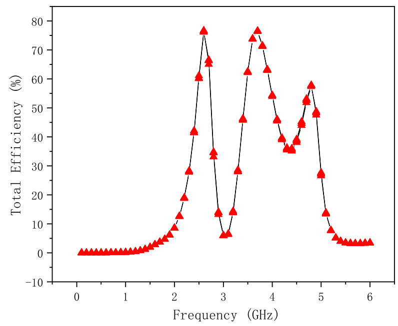

Fig. 8. Simulation of the recommended antenna's radiation efficiency.

bandwidth of each antenna element completely covers the expected frequency bands of 2.4, 3.5, and 4.9 GHz. Figure 6 is the transmission coefficient curve of the MIMO system element antenna, reflecting the degree of mutual influence between any two ports in the MIMO system. The results demonstrate that any two ports may be isolated from each other by more than 14 dB, and that ports 2 and 4 can be isolated by more than 20 dB. The isolation between ports 2 and 3 and the isolation between ports 3 and 4 are higher than 15 dB. The calculated envelope correlation coefficient (ECC) between any two antenna elements is shown in Fig. 7, and the ECC in the expected frequency band is all lower than 0.07, which is within the standard range. Figure 8 demonstrates the radiation efficiency diagram of the MIMO antenna system. Simulation results demonstrate that the MIMO antenna system's overall efficiency is 77% within the low- and mid-frequency range, and 66% within the high frequency range, respectively.

IV. Conclusion

This paper designs a multiband, relatively compact, miniaturized 4-port 5G mobile phone MIMO antenna system. The simulation results demonstrate that the Chinese 5G bands of 2.515-2.675 GHz, 3.4-3.6 GHz, and 4.8-4.9 GHz can be covered by an impedance bandwidth of -6 dB. The total efficiency of the MIMO antenna system is over 70% across the frequency range, the antenna elements are highly isolated, and the corresponding ECC is less than 0.07.

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