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Design of Low Profile MIMO Antennas for Mobile Handset Using Characteristic Mode Theory

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Abstract – **Designing highly integrated and efficient MIMO antennas for mobile handset is challenging, especially for low frequency bands below 1 GHz. In this work, by analyzing and manipulating the characteristic modes of a mobile handset, we propose a low profile dual-band MIMO antenna with high integration ability. Both antennas cover a bandwidth of 100 MHz at the center frequency of 0.9 GHz. The isolation between the antennas is over 10 dB, and the envelope correlation is below 0.1, which ensures high efficiency of the antenna system and good MIMO performance.**

Index Terms — **MIMO antenna, Characteristic mode theory, Mobile antenna, Compact antenna.**

I. INTRODUCTION

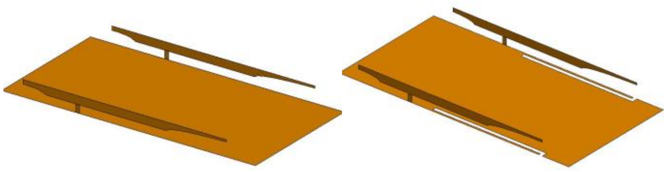
High integration of modern mobile handset has made the device thinner and smaller, hence increasing the complexity of the antenna design, particularly for low frequency bands. What makes the situation worse is that multiple antennas are required in Long Term Evolution (LTE) for higher data rate, making the volume for each antenna even smaller. In perspective of multiple-input-multiple-output (MIMO) communication, sharing the same mobile chassis to radiate leads to strong mutual coupling and high correlation between multiple antennas, resulting in low efficiency and poor MIMO performance [1].

Recently, theory of characteristic mode (TCM) has shown its great potential in designing low correlated MIMO antenna systems. In [2], a three-port mobile antenna system has been developed at 2.5 GHz by exciting orthogonal modes of the chassis. An isolation of over 15 dB was achieved. At this frequency band, the MIMO antennas were further made pattern reconfigurable by loading parasitic element and hopping between modes [3]. At frequency bands below 1 GHz, TCM has been utilized to increase the bandwidth of the single antenna through hybrid feeding [4]. It was also employed for MIMO antenna design at 760 MHz. However, the attained frequency bandwidth is quite limited [5]. Particularly, [6] presented a method of designing orthogonal MIMO antennas by manipulating the characteristic modes of the chassis. Later, the bandwidth of the antennas is successfully enlarged [7]. The drawback of the design in [7] is that ground clearance is required for the main antenna, and part of the volume is taken on one side of the chassis.

In this paper, a highly integrated dual band MIMO antenna system is proposed by analyzing the modes of the chassis using TCM. The bandwidth of both antennas is around 100 MHz at low frequency band. The isolation is over 15 dB and the envelope correlation is below 0.1. Furthermore, it is easy to integrate with mobile handset and does not take any extra space.

II. CHARACTERISTIC MODE STUDY

The TCM analysis begins with a T-strip loaded mobile chassis, as shown in Fig.1 (a). Different from the rotationally loaded T-strip in [7], where the two strips work as one antenna, the T strips in this work are symmetrically loaded, and are potentially used as two antennas. The eigenvalues of the T-strip loaded chassis is shown in Fig. 2. It is observed that there are three modes within the frequency bands, among which λ_1 and λ_2 resonate at 0.95 GHz, and λ_3 approaches zero at a higher frequency. By examining the characteristic currents and characteristic fields of each mode, it is found that λ_1 and λ_2 correspond to fundamental dipole mode and transverse dipole mode along the length and width of the chassis, respectively, and λ_3 is the resonance of the slot between the chassis and the T-strip. In order to increase the bandwidth of the first two modes, the resonant frequency of λ_3 needs to be moved down. Hence, slots are etched in the ground plane to increase the length of the slot formed by the T-strips, as presented in Fig. 1(b). The eigenvalues of the mobile chassis with slot is compared with that without slot in Fig. 2. λ_1 and λ_2 almost keeps unchanged, whereas the resonant frequency of λ_3 decreases.



(a) (b)

Fig. 1 Symetrically loaded T-strip mobile chassis (a) without slot (b) with slot.

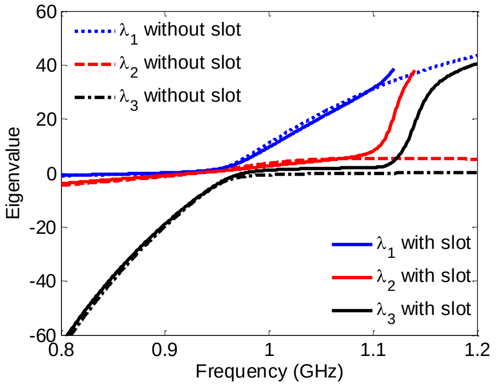


Fig. 2 Eigenvalues of the T-strip loaded chassis with/without slot.

III. Antenna Simulations

According to the TCM analysis in Section II, the MIMO antenna system is designed, with its geometries shown in Fig. 3. To make the handset thinner, the two metal strips are folded inside the phone, which only slightly changes its performance. Two ports are used instead of the shorting pin to excite the antennas. To match the port, a two element *L* matching network consisting of a 5.2 nH parallel inductor and a 5 pF series capacitor was used. The width of the slot is 1 mm.

Each of the two ports excites a hybrid mode composed of the fundamental and transverse dipole modes of the chassis, as illustrated in TCM analysis. The two hybrid modes represent two dipoles along two diagonals of the chassis, as noted in Fig. 3, and they are quasi-orthogonal to each other. The contribution of fundamental and transverse mode to each antenna will be further analyzed in the full paper.

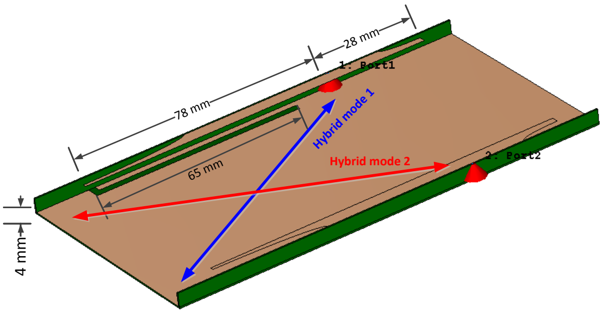


Fig. 3. Geometries of the proposed antenna and illustration of the hybrid modes.

The S parameters of the MIMO antenna are presented in Fig. 4. Due to symmetry of the antennas, the S parameters are identical for both antennas. It covers 855-955 MHz at low bands and 1675-1810 MHz at high bands, respectively. Due to the resonance of the slot, the bandwidth at the low band is enlarged. The radiation patterns of the two antennas at 0.9 GHz is shown in Fig. 5. The correlation between the two ports is below 0.1 over the operating frequency.

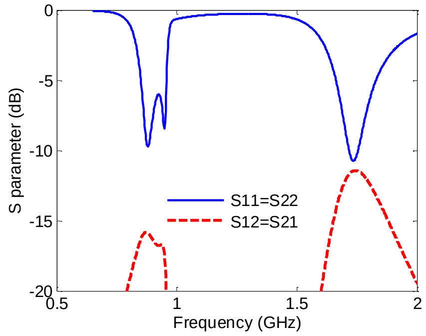
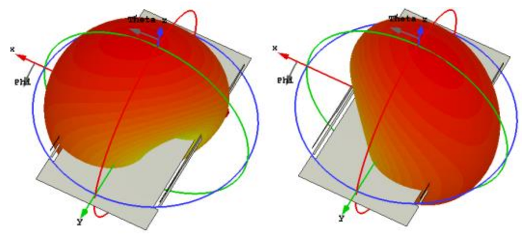


Fig. 4. S parameters of the proposed dual band MIMO antenna.



(a) (b)

Fig. 5 Radiation patterns of the MIMO antenna at 0.9 GHz: (a) port 1 is excited (b) port 2 is excited.

IV. Conclusion

A dual band MIMO antenna with high integration ability is designed based on TCM. By exciting quasi-orthogonal hybrid modes, the isolation of the antennas is over 10 dB, and the correlation is below 0.1. Slots are etched to increase the bandwidth of the antennas to 100 MHz at the low frequency bands. More analysis on TCM will be provided in the full paper.

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