An Ultra-low-profile MIMO Antenna for 5G Smart-phones

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***Abstract* - A low-profile wideband antenna is presented for the MIMO application of mobile devices. The antenna is formed by placing the inverted-F antennas (IFAs) on an artificial magnetic conductor (AMC). Besides the local resonant mode at the frequency of in-phase reflection, a surface wave mode on the AMC is excited to broaden the bandwidth. By designing the IFAs and their placement on the AMC, an efficiency radiation is formed in the presence of surface wave. As an example, a MIMO antenna with 8 elements is designed and fabricated. The total volume of the antenna is 140mm × 70mm × 0.97mm. The bandwidth is from 3.3GHz to 3.8GHz with measured efficiency larger than 50%. The antenna can be integrated into the back-cover of smart phones and the antenna efficiency is not much affected by the working platform.**

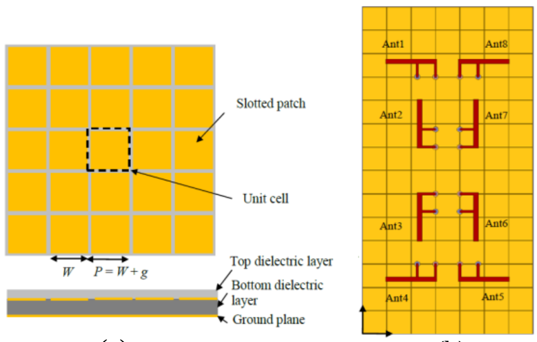
***Index Terms* — AMC, low-profile antenna, MIMO, smart-phones.**

1. Introduction

Recently, many MIMO antenna designs have been proposed for 5G mobile devices. In [1], a new printed MIMO system with 8 IFA elements is presented. The couplings and envelope correlation coefficients (ECCs) are well controlled. In [2], a frequency reconfigurable antenna is proposed for mobile devices. Frequency reconfigurability is realized through a cluster of coupled elements that excited with frequency dependent weights and phase. These antennas show excellent MIMO performance, but may take up large space and the performance may be lowered when integrated into real device. One possible solution is to design low-profile antennas on the back-cover of smart phones. In [3], the in-phase property of the high-impedance surface (HIS) is exploited to design low-profile antenna for mobile device. In [4], a reflection phase of 45°~ 135°is discriminated as impedance match frequency band of wire antenna. The overall height of the antenna is around 0.04λ. In this paper, the AMC-based low-profile antenna is further lowered to 0.01λ. To broaden the bandwidth, the TM_0 surface wave mode on the AMC surface is excited. The IFAs is used as a surface wave launcher, by which the surface wave is directed to the ground edge and scattered to generate an efficient radiation.

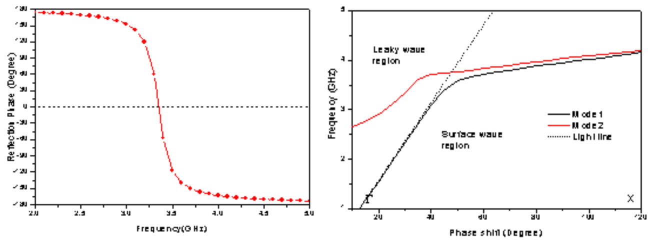
2. Antenna Design

The geometry of the AMC-based MIMO antenna is illustrated in Fig. 1, which is formed by placing IFAs onto an AMC surface. The emphasis of this paper is on the wideband antenna design, so only the common AMC structure is used, but the method can be generalize to AMC geometries. Since



(a) (b)

Fig. 1. (a) Geometry of the AMC and (b) the proposed low-profile MIMO antenna.



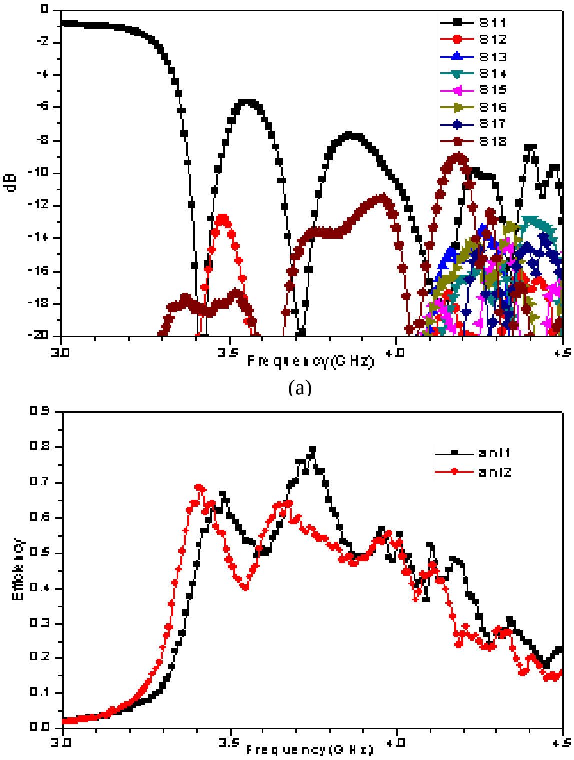
(a) (b)

Fig. 2. (a) Reflection phase for normal incident and (b) Dispersion diagram of the AMC.

the total profile of antenna is strictly limited, we are forced to choose a thin dielectric substrate with high dielectric constant. The thickness of the bottom dielectric layer is selected as: h_1 = 0.8mm and dielectric constant: ε_1 = 10.2. The thickness of the top dielectric layer is: h_2 = 0.1mm and the dielectric constant: ε_2 = 4.2. So the total thickness of the antenna will be 0.9mm. To explain the working mechanism of the antenna, a mode analysis is performed to the AMC. At first, the reflection phase for normal incident is calculated, which are plotted in Fig. 2 (a). From the data, the in-phase reflection occurs at 3.4GHz and the bandwidth is from 3.3GHz to 3.5GHz by the ±90° criteria. At 3.4GHz, the transverse electric field is maximized while the magnetic field is minimized. So the AMC exhibits a high surface impedance, which can prevent the propagation of surface waves. The induced field will be scattered into free-space instead of bounded to the AMC surface. So an efficiency radiation is formed at the frequency of in-phase reflection. But the associated bandwidth is limited, another working mode is needed to broaden the bandwidth. From Fig. 2(b), when the frequency is higher than 3.6GHz, the TM_0 mode is more and more bounded to the AMC surface.

(a) (b) (c)

Fig. 3. Photo of antenna prototype, (a) Planar IFA on AMC, (b) Measured thickness and (c) Integration with smart-phone.



(a)

(b)

Fig. 4. (a) Measured S-parameters and (b) measured efficiency.

Similarly, when the frequency is higher than 3.8GHz, the TE_1 mode will also enter surface wave region. The surface wave will propagate on the AMC surface and scattered when hitting the ground edge. The radiation efficiency of surface wave is usually low because it travels a long distance in lossy medium. The radiation pattern will degenerate because it may be scattered to different directions. In the low-profile MIMO antennas, the feeding structure is near to the AMC, the power is more easily coupled into the surface wave mode. And multiple excitation structures will be placed on a large and irregular AMC ground, the surface waves that excited at different locations will propagate all over the AMC and cause large mutual coupling and ECC. To mitigate the negative effects of surface wave, the IFA is used as the feeding structure instead of wire antennas. The IFA can launch a relative directional surface wave compared with wire antenna, and retain a relative compact size compared with some surface wave beamforming network [5]. In Fig. 1(b), the IFAs are so place that the surface wave is directed from the feeding structure to the ground edge, where it is scattered into free-space. Since the surface wave is scattered before long-distance propagation on the AMC, antenna efficiency is improved. Because the surface wave is mainly scattered at one edge, a nearly broadside and conical radiation pattern is also formed.

Next, the proposed MIMO antenna will be fabricated and measured. The photos of the antenna prototype are shown in Fig. 3. The AMC and IFAs will be fabricated separately on two dielectric layers, which are then stick together by an adhesive layer, so the total thickness is a little larger than 0.9mm. From Fig. 3(b), the measured thickness is around 0.97mm. In Fig. 3(c), the antenna is integrated into a smart-phone. The antenna board is covered with a sold mask and tailored to the shape of the back-cover of the smart-phone. The back-cover antenna does not take up inner space of the device and is totally isolated from the working platform, which makes it different from previous 5G MIMO antennas for mobile device.

The S-parameters of the MIMO antenna are measured, the measured data are plotted in Fig. 4 (a). From the data, two working modes are excited at 3.4GHz and 3.7GHz. The first working mode occurs at the in-phase reflection frequency, the impedance bandwidth is around 100MHz if -6dB criteria applied. By exciting the surface wave mode, a broadband from 3.3GHz to 3.8GHz is realized. The bandwidth is around 500MHz, corresponding to a relative bandwidth of 14%. The antenna efficiency is measured and the data are plotted in Fig. 4(b). Within the working band, the measured efficiency is larger than 50%. When the frequency is beyond 4.0GHz, higher order of the surface wave modes will be excited. The reflect coefficient is still less than -6dB, but the antenna efficiency decrease rapidly, as shown in Fig. 4(b).

3. Conclusion

A low-profile MIMO antenna based on the AMC is proposed for 5G smart-phones. The total thickness of the antenna is around 0.97mm. The antenna can works from 3.3GHz-3.8GHz with efficiency larger than 50%. The antenna can be integrated into the back-cover of smart-phones and the performance will not be affected by the working platform.

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