Multiplexing Efficiency of High Order MIMO in Mobile Terminal for 5G communication at 15GHz

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***Abstract* – The multiplexing efficiency of high order MIMO in mobile terminal at 15GHz for 5G communication is studied in this paper. The multiplexing efficiency of two MIMO topologies are compared is calculated with a narrow angular spread Gaussian distributed incoming wave model in order to illustrate the mm wave channel characterize.**

***Index Terms* — MIMO, Multiplexing Efficiency, mobile terminal, 5G**

1. Introduction

Due to the shortage of spectrum resources below 6GHz, the cm and mm wave band (10GHz to 200GHz) becomes a promising candidate for the next generation mobile communication (5G) as massive amount of bandwidth can be used [1]. However, the propagation environment will be dramatically changed in such a high frequency comparing to current cellular bands below 6GHz, it is critical for us to study the suitability and performance in the mm wave band for current wireless communication technologies.

Currently, multiple-input and multiple-output (MIMO) technology has been widely implemented in mobile communication systems. MIMO technology can increase the channel capacity by exploiting the multipath propagation but without consuming any extra bandwidth and power, which makes it still very attractive even in cm or mm wave band for the future 5G communication.

However, the performance of MIMO antennas in mobile terminals is highly depends on the propagation environment. Traditionally, the 3D uniform angular spread (AS) model is adapted to evaluate MIMO performance of mobile terminals in cellular bands below 6GHz, which is due to the fact that a rich scattering environment with large angle of arrive (AoA) can be obtained at this frequency band in practical. However, in the mm wave band, depending on the mobile environments, the number of multi path and the angular spread tend to be relatively smaller [2], the 3D uniform angular spread model may not provide a reasonable assumption when we evaluate our terminal antenna in the mm wave band.

In this paper, we compare MIMO performance of two 4x4 MIMO antenna arrays in mobile terminals at 15GHz. MIMO performance is evaluated by the metric "multiplexing efficiency (MUX)" [3]-[4], which is defined:

$$MUX = \sqrt[M]{\left(\prod_{i=1}^{M} MEG_i\right) * \det(R)} \quad (1)$$

Where R denotes the antenna correlation matrix, Rij is the complex correlation coefficient for *ith* and *jth* antenna element, and $MEGi$ is the mean effective gain of ith antenna, which is define in (2)

$$MEG = \int_0^{2\pi}\int_0^{\pi}\{\frac{XPR}{1+XPR} G_\theta(\theta,\phi)P_\theta(\theta,\phi) + \frac{1}{1+XPR} G_\phi(\theta,\phi)P_\phi(\theta,\phi)\} sin\theta d\theta d\phi \quad (2)$$

Where XPR stands for the cross polarization ratio and XPR = 1 is assumed in this study. Moreover, based on some channel measurement results [2], the power angular spread is defined as Gaussian distribution on both vertical and horizontal plane for both polarizations, and it can be expressed as in (3)

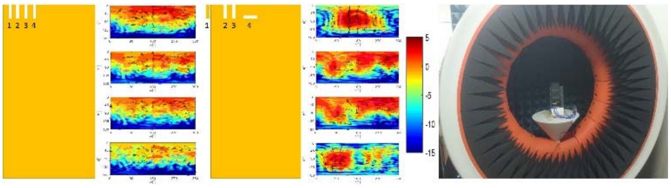
$$P_\phi(\theta,\phi) = P_\theta(\theta,\phi) \propto exp[-\left(\frac{(\theta-\theta_0)^2}{2\sigma_\theta{}^2} + \frac{(\phi-\phi_0)^2}{2\sigma_\phi{}^2}\right)] \quad (3)$$

Where the incident direction is denoted by (θ_0, ϕ_0), and the angular spread constant σ_θ and σ_ϕ are both set to be 30° for the vertical and horizontal plane, to illustrate a narrow angular spread in mm wave band.

The calculation is based on measured radiation patterns of two MIMO antenna mockups at 15GHz, both include four elements. All measurements are carried out in SATIMO system in Microwave Vision Group Lab in Paris, France.

2. Antenna Design

Two MIMO antenna arrays are studied in this paper, their topologies and radiation patterns are shown in Fig. 1(a) and (b). The first configuration is a linear MIMO array which is composed by four identical notch elements with a half wavelength separation distance at 15GHz. The second array is a hybrid MIMO arrays with one edge patch element, two notch elements and one slot element. Their radiation patterns and polarizations are complementary to each other in the hybrid MIMO array, which can highly exploit the degree of spatial multiplexing. Both MIMO arrays are placed on the top of the phone chassis, and the free space measurement setup in SATIMO chamber is shown in Fig. 1(c). The MUX with 3D uniform angular spread model of the linear and the hybrid MIMO arrays are -1.6dB and -0.8dB, respectively. Both arrays can achieve a high MIMO performance in this situation.



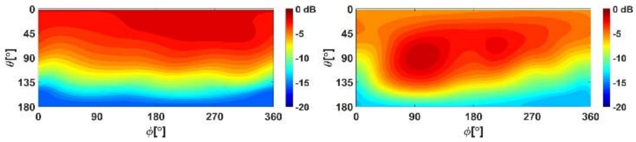
(a) (b) (c)

Fig. 1. (a) The antenna topology and measured radiation patterns of the linear MIMO array, (b) the antenna topology and measured radiation patterns of hybrid MIMO array and (c) the measurement setup in SATIMO chamber.

3. Results and Discussion

(1) MEG

The geometric mean MEG of four elements in both antenna mockup are presented in Fig. 2. The value is presented against the incident direction (θ_0, ϕ_0). With a small angular spread of incoming waves, the linear MIMO array shows a higher value of MEG in overall since their radiation patterns are overlap with each other. On the other hand, the hybrid array gives less "blind area" since their radiation patterns are complementary to each other.



(a) (b)

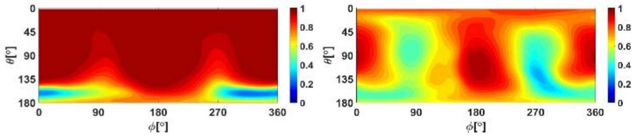
Fig. 2. The geometric mean MEG of (a) the linear MIMO array and (b) the hybrid MIMO array

(2) Correlation

In order to evaluate the overall correlation coefficient between all four ports by a single parameter, equivalent envelope correlation coefficient (EECC) [5] is defined in (4):

$$EECC = 1 - \det(\mathrm{R}) \quad (4)$$

The EECC of the two MIMO arrays against the incident directions are presented in Fig. 3. The linear MIMO array shows much higher correlation than the hybrid array due to their similar radiation patterns and polarizations. For the hybrid array, the high EECC mainly appears on two sides of the phone ($\varphi = 180^\circ$ and $\varphi = 0^\circ$), where the cross pole level is increased at this angles.

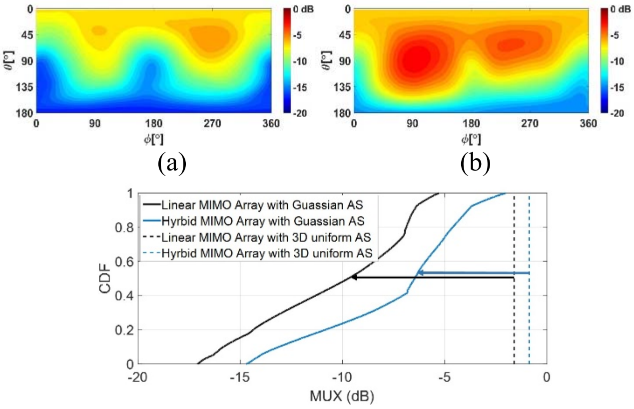


(a) (b)

Fig. 3. The EECC of (a) the linear MIMO array and (b) the hybrid MIMO array

(3) MUX

Finally, the MUX of the linear MIMO array and hybrid MIMO array against incident angles are shown in Fig. 4(a) and (b), and their cumulative distribution function (CDF) is also presented in Fig.4 (c). Due to the high correlation, the linear MIMO array shows much lower MUX. The hybrid array clearly outperform than the linear array, especially in the area that can be covered by the main beam of all four ports, e.g. the front and back planes of the phone (around $\varphi = 90^\circ$ or $\varphi = 270^\circ$). Comparing to 3D uniform model, the degradation of MUX is also smaller for the hybrid array than the linear array, which states that the hybrid array is more robust to the changing of propagation environment comparing to the linear MIMO array.



(a) (b) (c)

Fig. 4. The MUX of (a) linear MIMO array and (b) the hybrid MIMO array, (c) the statics of MUX in different cases

4. Conclusion

In this paper, we discussed and compared MIMO performance of two 4x4 MIMO arrays in mobile terminals at 15GHz for the 5G communication. Due to the more directive radiation patterns of terminal antennas and smaller angular spread of incoming waves in cm and mm wave bands, MIMO performance of mobile terminals will be more sensitive the propagation environment, and thus it is import to evaluate their MIMO performance in a proper channel model. From the results, we can see that even though both MIMO arrays can achieve high MUX in 3D uniform propagation model, the hybrid MIMO array with complementary radiation patterns and orthogonal polarizations shows better MUX and more robust to the changing of propagation environment than the linear MIMO array when the angular spread of the incoming waves become narrower. The real channel should be in between narrow Gaussian and 3D uniform in different environments, where hybrid array always show better performance.

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