The Determination Method of Optimum Radiation Pattern to Enhance MIMO Channel Capacity

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Abstract

This paper presents optimum radiation pattern to enhance channel capacity of mobile terminal. We use two handset antenna models to estimate channel capacity in the presence of human body. The optimum pattern determined by envelope correlation enhances channel capacity, which is demonstrated using phase controlled built-in antenna with phantom model.
Keywords : Channel Capacity MIMO Phantom Radiation Pattern

1. Introduction

In recent years a lot of mobile devices adopt MIMO (Multiple-Input Multiple-Output) systems. It is important for MIMO systems to enhance channel capacity in order to provide high speed mobile communication. The method of MIMO channel capacity enhancement by phase control has been already reported [1], where the optimum radiation pattern is given by adjusting the phase difference for antenna arrays without including the effect of human body. This paper investigates the method to determine the optimum radiation pattern of mobile handset considering the effect of a human body.

2. Optimization of Radiation Pattern

We use the antenna model for mobile handset as shown in Fig. 1 and the detail geometry of the antenna elements is shown in Fig. 2. The antenna is composed of four IFAs (Inverted F-shaped Antennas) and put in the top of the mobile handset. It assumes 2×2 MIMO (Multiple-Input Multiple-Output) systems. The pairs of IFA are combined through an analog phase shifter to obtain the adaptive pattern control. The frequency is 2 GHz and two pairs of IFAs are arrayed in orthogonal to decrease the correlation between two antenna ports [2]. We change the phase difference δ every 30 degrees and calculate channel capacity (C) to obtain the optimum radiation pattern. The channel capacity is calculated by equation (1) [3]

$$C = [\sum_{j=1}^{N_t} \log(\lambda_j \gamma_0 / N_t + 1)] \quad (1)$$

where N_t is number of transmitting antenna, λ_j is eigen value of $H^H H$ (H:channel matrix), λ_0 is Signal-to-Noise Ratio (SNR). Nakagami-Rice propagation model is assumed in the above equation, where SNR is 20 dB and Rician K-factor is 3 dB. The incoming wave is confined xy-plane and we calculate the envelope correlation in this plane. We change the angle of incoming wave (ϕ=0~360 deg.) and calculate channel capacity for every incident angle. Then we evaluate the average of these channel capacity and determine the optimum phase difference.

3. Real Usage Model Analysis

For more accurate evaluation of real usage environment, we use two types of model (Talk Position model, Viewer model). Before the evaluation of human body, the characteristic of mobile handset in free space is examined to find the phase difference to minimize the correlation. The reflection coefficients of each IFAs are shown in Fig. 3 and radiation patterns of each array in Fig. 4.

In talk position model, users talk on the phone with holding the handset in their hand and bringing it close to their ears. It has head and hand part of human body as shown in Fig. 5. The head is sphere with radius of 100 mm with relative permittivity of 43.37 and conductivity of 1.204 S/m. The hand is composed of combination of blocks with relative permittivity of 54 and conductivity of 1.45 S/m. The effect of human head and hand is dominant in talk position, then we neglect the effect of arm and body to simplify the simulation model. In viewer model, the users hold the handset with looking at the display in front of their body. We consider upper half of the body include one arm as shown in Fig. 6. The channel capacity for each model is shown in Fig.7. The result shows that the optimum phase difference for each model is almost the same, where the channel capacity is given by averaging it for every incoming wave angle. The optimum phase difference is 180° for the talk position and 150° for the viewer model, however the difference in channel capacity by two phase difference is very small. Then we use the phase difference of 180°. In viewer model the radiation patterns of δ =180° are shown in Fig. 9 and the channel capacities as a function of incoming wave direction in xy-plane are shown in Fig. 10, where the average channel capacity is 9.8 bit/s/Hz at δ =0° and 12.8 bit/s/Hz at δ =180°. The enhancement ratio of channel capacity is 30.7 %.

In the next step, we consider another handset antenna model, where the antennas are installed at the bottom of the chassis. Recently, the position of an antenna is changed from top to bottom part to reduce SAR (Specific Absorption Rate) in talk position. Instead of far from the brain region, the antenna is surrounded by a hand and its radiation pattern is seriously changed. The model in Fig. 1 (a) is turned upside down as shown in Fig. 1 (b). With this model we calculate channel capacity and decide the phase difference to obtain the optimum radiation pattern. The channel capacity for each model is shown in Fig. 8. The channel capacity of bottom side antenna is reduced in viewer and talk position model because of the effect of hand. However, the optimum phase difference is 180° for both talk and viewer models. In viewer model the radiation patterns of δ =180° are shown in Fig. 11 and the channel capacities as a function of incoming wave direction in xy-plane are shown in Fig. 12, where the average channel capacity is 7.8 bit/s/Hz at δ =0° and 11.0 bit/s/Hz at δ =180°. The enhancement ratio of channel capacity is 40.3 %.

4. Conclusion

This paper discussed the determination method of optimum radiation pattern. All calculation result indicates the optimum pattern is given by considering phase difference. And the optimum phase difference is not depended on the effect of a human body.

References

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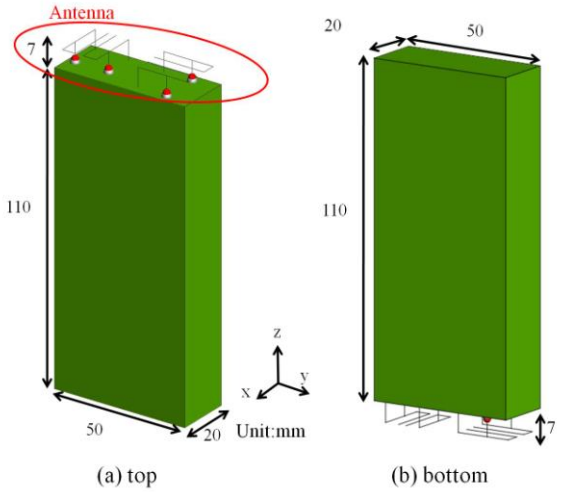


Fig. 1 Mobile terminal geometry

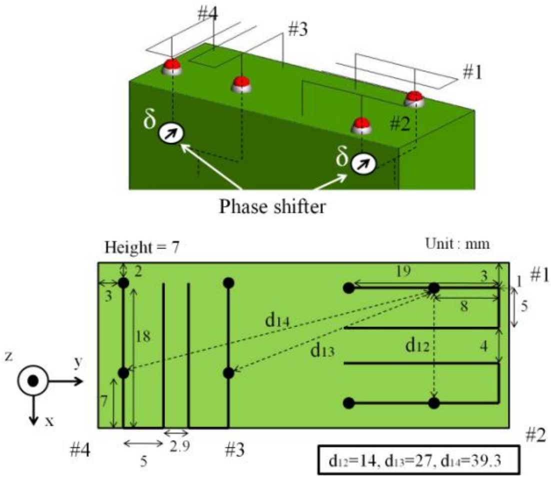


Fig. 2 Antenna geometry

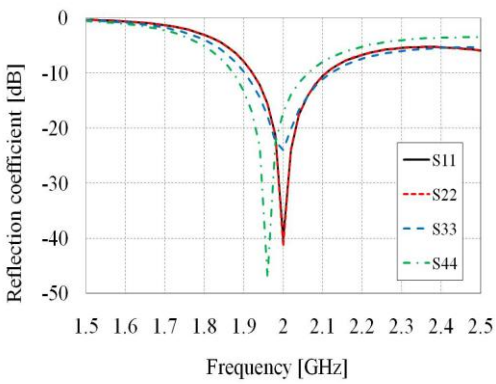


Fig. 3 S-parameters

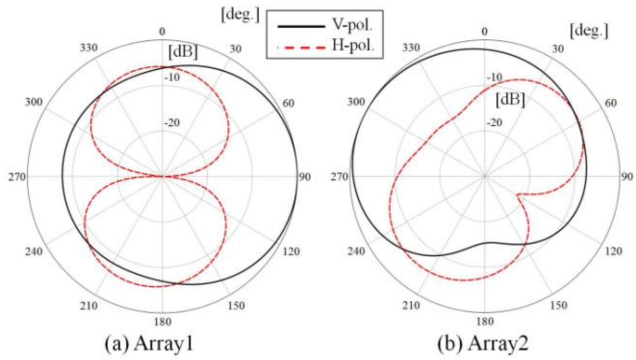


Fig. 4 Radiation pattern

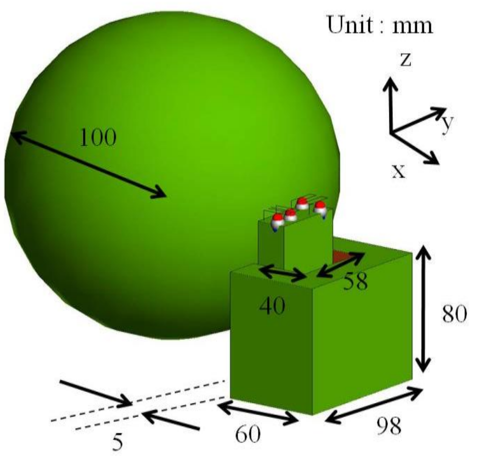


Fig. 5 Talk Position model

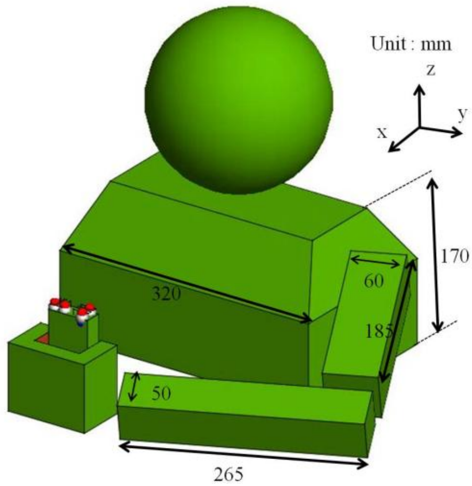


Fig. 6 Viewer model

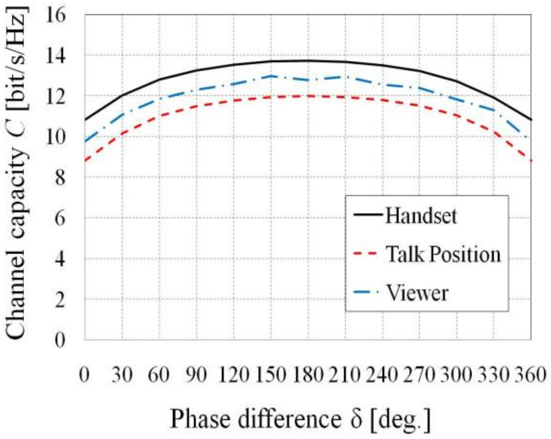


Fig. 7 Channel capacity of top antenna

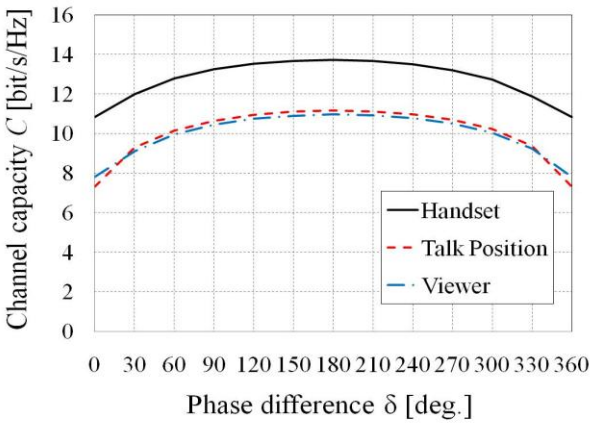
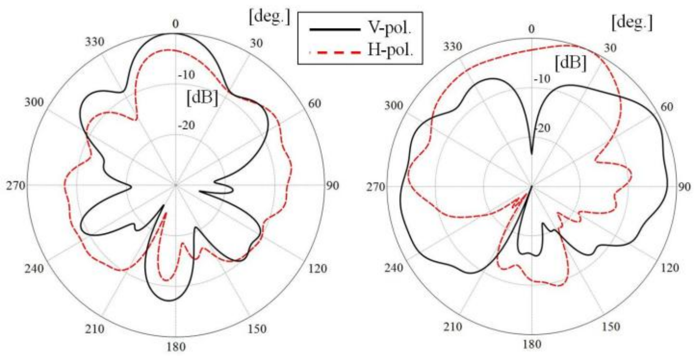


Fig. 8 Channel capacity of bottom antenna



(a) Array1 (b) Array2

Fig. 9 Radiation Pattern
Top antenna viewer model, δ =180 deg., xy-plane

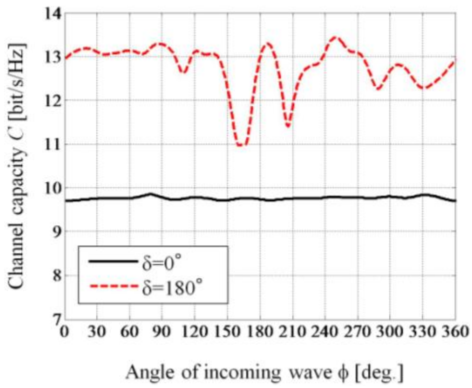
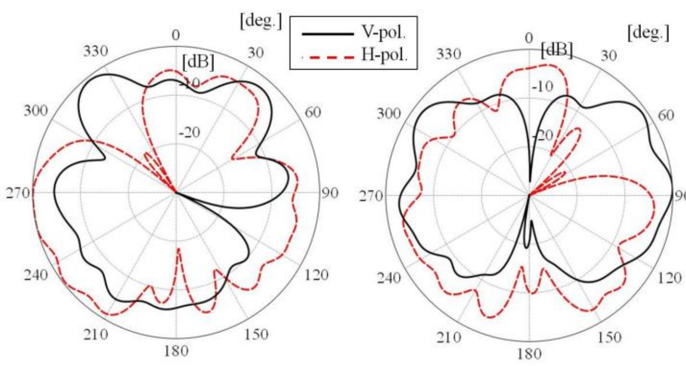


Fig.10 Channel Capacity
Top antenna viewer model, δ =180 deg.



(a) Array1 (b) Array2

Fig. 11 Radiation Pattern
Bottom antenna viewer model, δ =180 deg., xy-plane

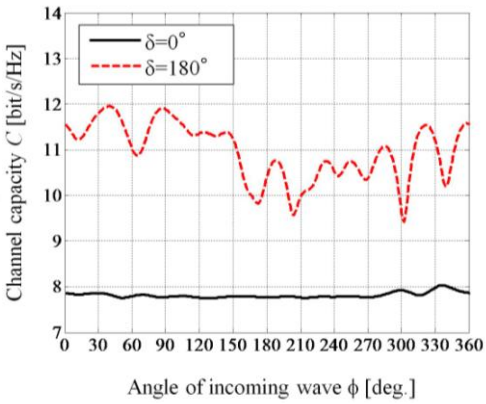


Fig.12 Channel Capacity
Bottom antenna viewer model, δ =180 deg.