Capacity Analysis of Antenna Arrays with Various Transmitting Angles

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Abstract- This paper focuses on the research of channel capacity of Multiple-Input Multiple-Output (MIMO) system with different transmitting angles in straight tunnels. The channel capacities of MIMO Long Term Evolution (MIMO-LTE) system using spatial and polar antenna arrays by different transmitting angles are computed. Numerical results show that, The channel capacity for transmitting angle at 15 degrees is largest compared to the other angles in the tunnels. Moreover, the channel capacity of Polar Array (PA) is better than that of Spatial Array (SA) in the straight tunnels. Besides, the channel capacity for the tunnels with traffic is larger than that without traffic.

MIMO technology has attracted huge attention in wireless communications, due to its ability of offering significant increase in data throughput and link range without additional bandwidth or transmit power in the presence of multi-path scattering. In this paper, channel capacities of MIMO-LTE system [1], [2] by using spatial and polar antenna arrays at different transmitting angles are computed. The most suitable transmitting angle is investigated. The channel capacities for spatial array (SA) and polar array (PA) are compared in the straight tunnels with and without traffic.

After normalizing process, equation can be rewritten as follow:

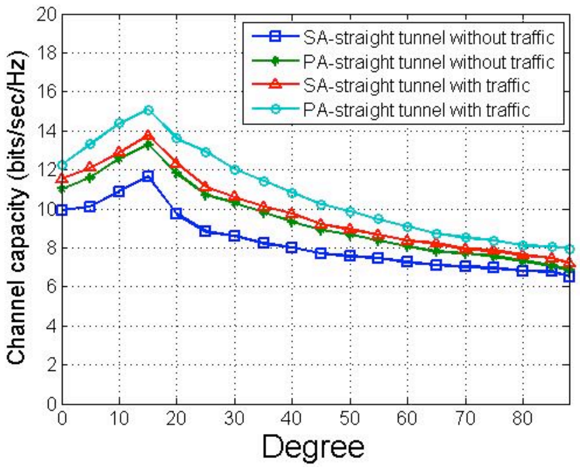
$$\boldsymbol{C}_{\boldsymbol{SE}}^{\boldsymbol{LTE}} = \frac{1}{\boldsymbol{BW}} \sum_{\boldsymbol{f}=1}^{\boldsymbol{N_f}} \boldsymbol{B} \log(\det(\boldsymbol{I} + \boldsymbol{SNR}_r \times \hat{\boldsymbol{R}}_{\boldsymbol{H},\boldsymbol{f}})) \tag{1}$$

Where $SNR_r = \frac{SNR_t}{N_t} \times H_n{}^2$ denotes the ratio of average receiving signal power to noise power on each receiving antenna and $\hat{R}_{H,f}$ is the normalized eigenmatrix at the fth frequency component.

By using these images and received fields, the channel frequency response can be obtained as following:

$$H(f) = \sum_{p=1}^{N_p} a_p(f) e^{j\theta_p(f)} \tag{2}$$

where p is the path index, N_p is the number of paths, f is the frequency of sinusoidal wave, $\theta_p(f)$ is the pth phase shift and $a_p(f)$ is the pth receiving magnitude. Note that the channel frequency response of LTE systems can be calculated by equation (2) in the frequency range of LTE for desired signal.



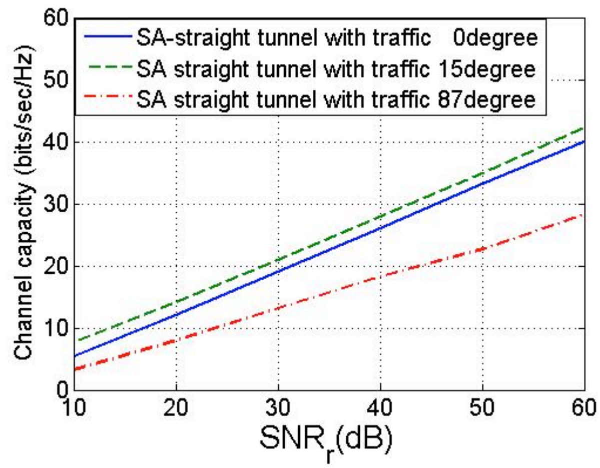


Fig 1. The average capacities of MIMO-SA and MIMO-PA system Fig 2. The average capacities of MIMO-SA system

The average capacities at SNRr=20dB for different transmit angles of Spatial Array Multiple-Input Multiple-Output (MIMO-SA) and Polar Array Multiple-Input Multiple-Output (MIMO-PA) in the straight tunnel are shown in Figure 1. It is clear the channel capacity for the transmit angle of 15 degrees is the largest. The average channel capacity at transmitting angle of 15 degrees without traffic for MIMO-PA and MIMO-SA is 13.26 (bits/sec/Hz) and 11.66 (bits/sec/Hz), respectively. The average channel capacity with traffic for MIMO-PA and MIMO-SA is 15.05 (bits/sec/Hz) and 13.76 (bits/sec/Hz), respectively. It is seen that the capacity for MIMO-SA is smaller than that for MIMO-PA. In other words, when the MIMO-SA system breaks a multipath channel into several individual spatial channels to enhance the capacity, the individual spatial channels are affected by each other. As a result, the correlation of MIMO-SA is stronger compared to MIMO-SA. Numerical results show that changing the polarization can improve the channel capacity effectively. It is also clear that the capacity for the tunnel with traffic is larger than that without traffic, no matter what MIMO-SA or MIMO-PA is employed.

The channel capacities of MIMO-SA at transmitting angles of 0, 15 and 87 degrees for different SNRr in the straight tunnel with traffic are plotted in Fig. 2. It is seen that the channel capacity is almost linearly proportional to single to noise ratio. The average channel capacity of MIMO-SA at SNRr=30dB for transmit angles of 0, 15 and 87 degrees is 19.01 (bits/sec/Hz), 20.91 (bits/sec/Hz) and 13.21 (bits/sec/Hz), respectively. The channel capacities for MIMO-PA is larger than those for MIMO-SA when the SNRr is the same.

Knox [3] presents a full-duplex design using a single circularly polarized antenna. Since we do not need to allocate different antennas for receiving and transmitting, and will be the subject of a future study.

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REFERENCES

1. Jae-Young Chung , Taesik Yang . Juhyung Lee ”Low correlation MIMO antenna for LTE 700MHz band” *IEEE International Conference on Acoustics, Speech, and Signal Processing*, pp. 2202-2204.
2. W.F. Young ”A Channel Propagation Model for the 700MHz Band” *IEEE Wireless Personal Communication* ,May. 2010 , pp.1-6.
3. M. Knox, “Single antenna full duplex communications using a common carrier,” *in 13th Annual Wireless and Microwave Technology Conference*, Apr. 2012.