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A Simplified 3D Fading Channels Adopted in MIMO Beamforming Schemes

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I. Abstract

A simplified 3D (three dimensions) fading channel model deployed in MIMO (multi-input multi-output) beamforming system is explored in this article. Both AoA (angle of arrival) and AoD (angle of departure) which impact the overall system performance is examined in the report. There are numerical results are offered for validating the accuracy the theoretical derived formulas. Furthermore, plots work out from combination with different number of transmitter and receiver for comparison is studied. The increment in AoA parameters definitely generates the impact of the system performance when the consideration of simplified 3D channel.

II. Introduction

Accordingly, it is known that the infrastructure is assigned with 5 layers for the 5G (5th generation) wireless systems. Physical and Medium Access Control layers are definitely impacting the system performance of a 5G cellular system. Extensive AoD (angle of departure) and AoA (angle of arrival), path loss, and multipath time delay spread measurements were conducted for steerable beam antennas of differing gains and beam widths for a wide variety of transmitter and receiver locations. The paper also provides measurements and models that may be used to design future 5G MMW cellular networks and gives insight into antenna beam steering algorithms for these systems. According to the paper in 2007, the capacity performance has been investigated for a multiple antennas system which was proposed to switch among different MIMO transmission schemes include statistical beamforming, double space-time transmit diversity, and spatial multiplexing over spatially correlated channels. According to the paper in 2006, the authors claimed that exact BER (bit error rate) analyzed for different modulation schemes in a correlated Rayleigh MIMO channel were presented. The linear scaling of throughput achieved in MIMO system for wireless networks was challenged. According to the paper in 2014, An extension of the ITU2D channel model to 3D is proposed in which is by adding a distance dependent elevation spread based on observations from ray tracing. Through system-level simulations we observe that the behavior of 3D MIMO is greatly impacted by the modeling of the 3D channel. For an MIMO system with a 3D-BF receiver combining with MRC (maximal ratio combining) operating over correlated fading channel is examined, in both different transmitter and receiver antennas environments.

III. MIMO beamforming system with simplified 3D channel

A weighted sum of channels with the K elements is assigned in the element. The channel port is given by

$$\left[\bar{H}_n\right]_{s,t} = \sum_{antenna \in port\ s} \omega_{antenna}\left[H_n\right]_{antenna.t}$$

Where the sum presented above is performed over all antenna elements in port s. Accordingly, if the real 3D channel is considered, then each antenna port adopts which is rewritten as

$$h_{u,s,n}(t;\tau) = \sum_{m=1}^{M}\begin{bmatrix} {}^{F}Rx,u,V(\varphi n,m) \\ {}^{F}Rx,u,H(\varphi n,m)\end{bmatrix}\begin{bmatrix}\alpha_{n,m}^{VV} & \alpha_{n,m}^{VH} \\ \alpha_{n,m}^{HV} & \alpha_{n,m}^{HH}\end{bmatrix}\begin{bmatrix} {}^{F}Tx,u,V(\phi n,m) \\ {}^{F}Tx,u,H(\phi n,m)\end{bmatrix}$$
$$\times\exp(j2\pi\lambda_0^{-1}(\bar{\varphi}n,m\cdot{}^{\bar{r}}Rx,u))\exp(j2\pi\lambda_0^{-1}(\bar{\phi}n,m\cdot{}^{\bar{r}}Tx,s))$$
$$\times\exp(j2\pi\upsilon_{n,m}t)\delta(\tau-\tau_{n,m})$$

Normally, the radio MIMO channel is a $N_T \times N_R$ matrix and which is able to be rewritten as

$$H(\mathrm{t},\ \tau) = \int \vec{g}_r(\Psi)^T h(\mathrm{t},\ \tau,\ \Omega,\ \Psi)\vec{\mathrm{g}}_T(\Omega)$$
$$\times\vec{\mathrm{a}}_R(\Psi)(\vec{\mathrm{a}}_T(\Omega))^T d\Omega d\Psi$$

For each spatial correlated channel experienced fading environment can be expressed as

$$\mathbf{Y}_R = \sqrt{E_s/N_T}\,\mathbf{H}\mathbf{X}_T + \mathbf{N}$$

IV. 3D-BF channel capacity system

In this section channel capacity of a MIMO system with 3D-BF transmission, generally, the channel capacity is given as

$$C_{pdf}^{3D-BF} = \mathbb{E}\left[\Xi(S,\ y)\right]$$

An alternative way the CF(characteristic function) can be determined as

$$CF(\phi) = E\left[\exp\left(\phi\cdot\Xi(S,y)/\log_2 e\right)\right]$$
$$= E\left[\log_2\left|\boldsymbol{I}_{\mathrm{t}} + \boldsymbol{Q}_{\mathrm{t}}\right|\right]$$

The joint pdf of AoA and AoD (arrival of departure) can be rewritten as

$$p_{\theta_{n,m},\phi_{n,m}}(\theta_{n,m},\phi_{n,m}) = \left|J\right|^{-1} p_{\mathrm{r},\phi_{n,m}}\left(\frac{D\sin(\theta_{n,m})}{\sin(\phi_{n,m}-\theta_{n,m})},\phi_{n,m}\right)$$

Consequently, the channel capacity of MIMO system, $C_{\mathrm{N}ak}^{3D-BF}$, can be evaluated as

$$C_{Nak}^{3D-BF} = \log_2 e\cdot 8(dBi)\cdot\sum_{i=0}^{N_R-1}\sum_{k=1}^{m_i}\Delta_{N_R}\left(i,k,m_u,\sigma_u,l_q\right)$$
$$\times\frac{1}{\sigma_i^{m_i}\left(m_i-1\right)!}\cdot\Omega^{-m_i}\cdot\Gamma\left(m_i\right)\cdot\frac{m_i}{m_i+1}\cdot\psi\left(m_i+1,m_i+2;\frac{1}{\Omega\sigma_i}\right)$$

V. Numerical result

The validation of the derived theoretical formulas is illustrated in this section, first the Indoor factor is always set as a value $K = 3.6$. For simplicity, however, without loss the generality, the correlation coefficients are generated by the Gaussian correlation model of an equally spaced linear array with an arbitrary correlation coefficient is adopted. It is of interest to note that the correlation matrix followed by the linear array has a Toeplitz form constructed by correlation elements, ρ_{ij}, $i, j = 0,\cdots,N_R-1$. It is easy to understand that the performance is becoming much better when the fading parameter increase. Finally, the phenomena of AoA parameter impacts the MIMO beamforming system is illustrated in Fig. 2. The curves are corresponding to different $N_T \times N_R$ values. It is valuable to see the correlation coefficient that generally relates to the outcome of d/λ, and which changes the size of AoA. Hence, the channel capacity definitely becomes degradation when the correlation coefficient is promoted.

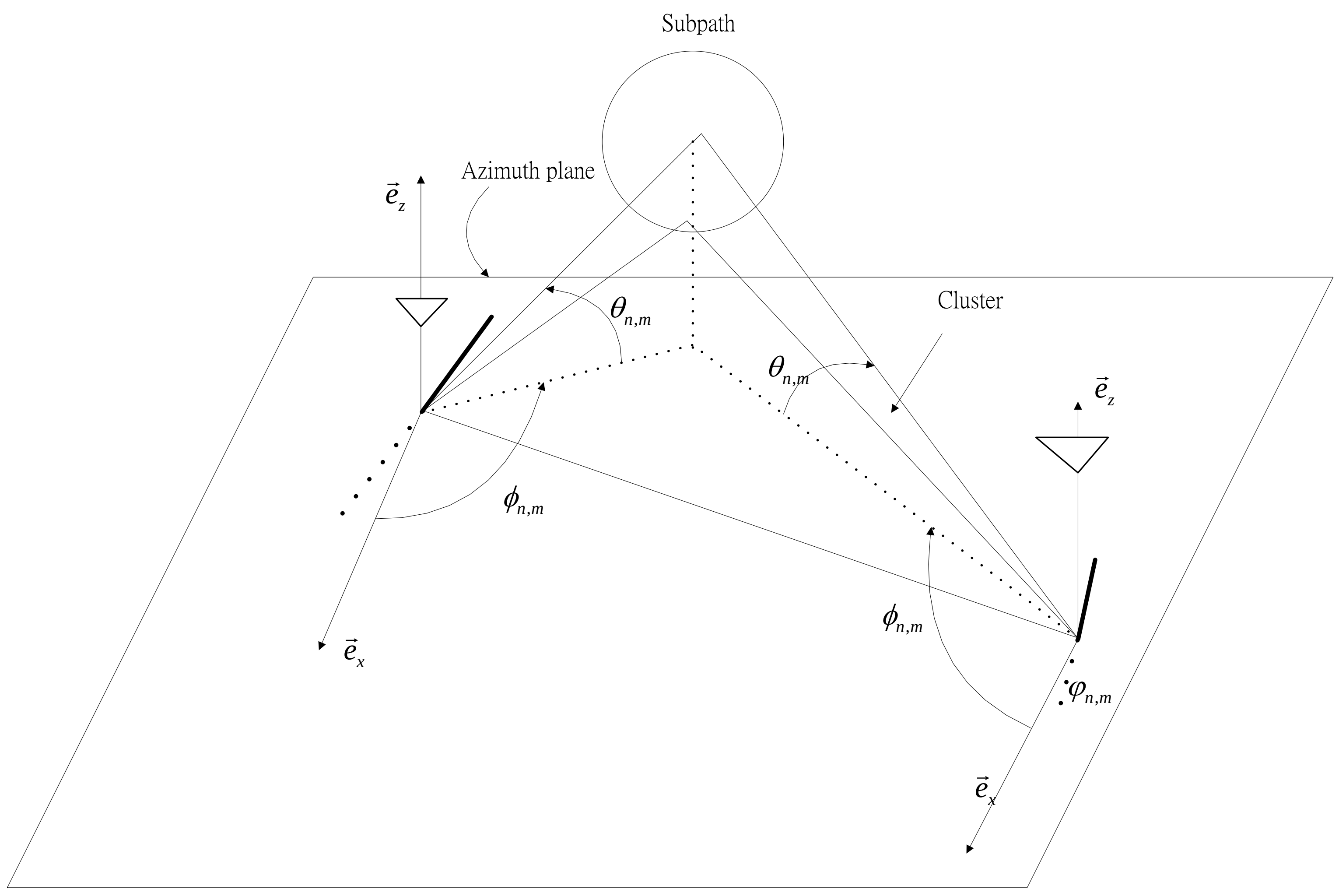

Fig. 1. A simple deployment of simplified 3D channel model.

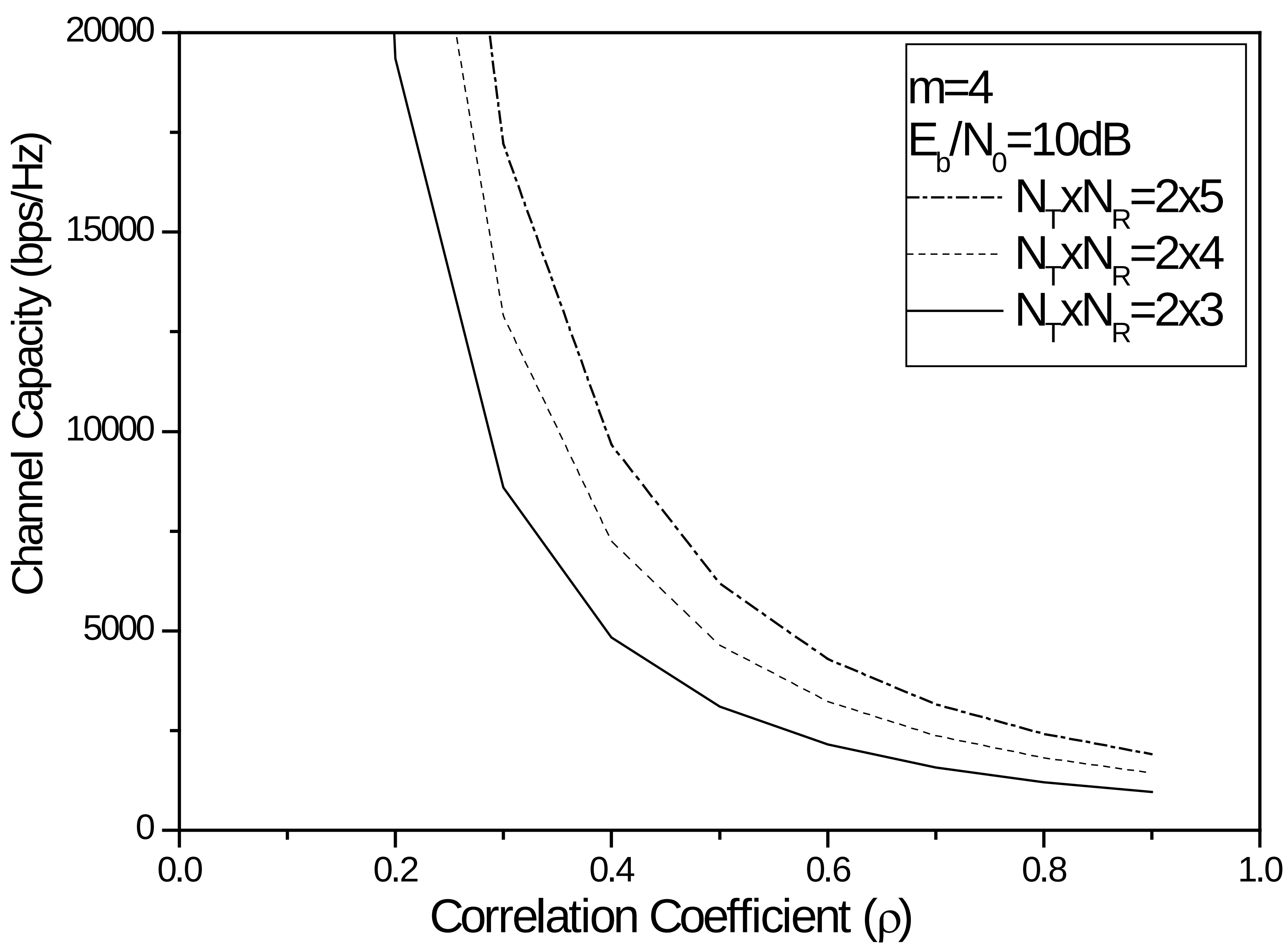

Fig. 2 Channel capacity for MIMO system over correlated-Nakagami-*m* fading with $m = 4$, $E_b/N_0 = 10$ *d*B.

VI. Conclusion

In the report both AoA and AoD for the MIMO (multi-input multi-output) 3D-BF system over the spatial correlated-fading channel is explored. The channel correlation is alternative to present the AoA for numerical analysis The numerical results are gained from different scenarios with distinct number of antennas at transmission and receipt ends. Specifically discussing and saying that the results are always outperformance for the situations which the larger number in receiver antennas when the spatially correlated channel exists in it. Moreover, it is worthy to note that the performance of a MIMO beamforming scheme will be mostly dominated by fading parameter still when the correlated-Nakagami-*m* environment (considering the AoA and AoD parameters) is established as the channel model for MIMO system.