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Performance of Multi –user MIMO system in the presence of Polarization diversity

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ABSTRACT
Employing Dual Polarized antenna plays a vital role for the future generation MIMO systems due to its advantages such as space effectiveness and robustness. In this paper, we provide Outage probability of Multi-user Dual Polarized antenna in an uplink environment. Specifically, we provide the simulation results of Outage Probability for different varying parameters such as an increase in a number of the user, noise variance, and Cross Polarization Discrimination. This parameter is investigated through Monte Carlo simulation.
Keywords **–** Multiple-Input Multiple-Output, Cross Polar Discrimination.

I. INTRODUCTION

MIMO system has the potential of increasing the spectral efficiency of a system through a method known as spatial multiplexing [1], and the ability to improve the link reliability through a method known as transmit diversity [2]. These multiplexing and diversity gains achieved by a MIMO system are a strong function of the channel characteristics, which in turn depend on the scattering environment and on the array configuration deployed at the transmitter and the receiver [3]. In MIMO systems correlation takes place between the channels because of lack of antenna spacing and the scattering properties of the transmission environment. Because of this, the system performance degrades. In order to have an uncorrelated channel between the transmitter and receiver large antenna spacing's are required both at the base-station and the mobile unit. Employing of multiple antennas may not be the best solution due to the space limitation. Employing of polarization diversity is the best solution.

Polarization diversity refers to the signaling strategy whereby, information signals are transmitted and received simultaneously on orthogonally polarized waves. In this two spatially separated unipolarized antennas are replaced by Dual Polarized antennas. The employment of polarization diversity results in cost and space effective of the system. There are two effects on the polarization difference in MIMO systems on the channel. The first one is Cross Polar Discrimination (XPD). The power loss in a communication system is due to the polarization difference between the transmitting antenna and receiving antennas and also a communication system with a transmitting antenna and receiving antennas having horizontal and vertical polarization or vertical and horizontal polarization experience a power loss because of orthogonally polarized antennas. This phenomenon is known as XPD [4]. The second is cross-correlation coefficient. It is a measure of correlation between signals appearing at the two antennas with same or distinct polarizations. Hence, XPD and correlation coefficient plays an important role in MIMO systems using antennas with polarization difference. By employing polarization diversity, the performance of a system can be increased with transmitting and receiving several uncorrelated signals. Though there is a vast work on modeling and analyzing of Dual Polarized antennas in the recent years. But, the work related to utilization of polarization diversity with multi-user uplink scenario is limited [5],[6]. So, there is a need for modern communication system designs to use the benefits of polarization diversity in Multi-user uplink systems. It can be applied to the MIMO communication system with lack of space such as GSM, WIFI, LTE, WIMAX etc [7].

In this paper, we present the simulation results of Outage probability for Multi-user Dual polarized MIMO system in an uplink scenario.

Notations: Throughout the paper, we took bold lower case letters as vectors and bold upper case letters as a matrix. $(.)^H$ and $\mathbf{E}[.]$ denotes conjugate transpose and expectation, respectively.

II. SYSTEM MODEL

A Multi-user MIMO system with Dual polarized antennas is considered for an uplink scenario which is characterized by a Rayleigh fading, in which M Dual Polarized receive antennas at mobile unit transmits the messages to one Dual

Polarized antenna at Base station as presented in Figure 1. The data received from the m^{th} mobile unit is multiplied by a combining vector $\mathbf{y}_m$ which can be expressed as

$$\begin{aligned} w_m &= \mathbf{y}_m \boldsymbol{\xi}_m \\ &= \mathbf{y}_m{}^H \mathbf{Z}_m \mathbf{s}_m + \mathbf{y}_m{}^H \sum_{d=1,d\neq m}^{M} \mathbf{Z}_d \mathbf{s}_d + \\ &\quad + \mathbf{y}_m{}^H \mathbf{n}_m \end{aligned} \quad (1)$$

where

1. $\mathbf{s} = [s_0 \quad s_1]^T$ is the transmit signal vector.
2. $\boldsymbol{\xi} = [\xi_0 \quad \xi_1]^T$ is the received signal vector.
3. $\mathbf{n}$ is the 2x1 temporally i.i.d. zero-mean complex Gaussian noise vector satisfying $\mathbf{E}\{\mathbf{nn^H}\} = \boldsymbol{\Sigma_m^2 I_2}$.
4. $\mathbf{Z}$ is the 2x2 channel matrix.
5. $\boldsymbol{y} = [y_0 \quad y_1]^T$ is the combining vector.

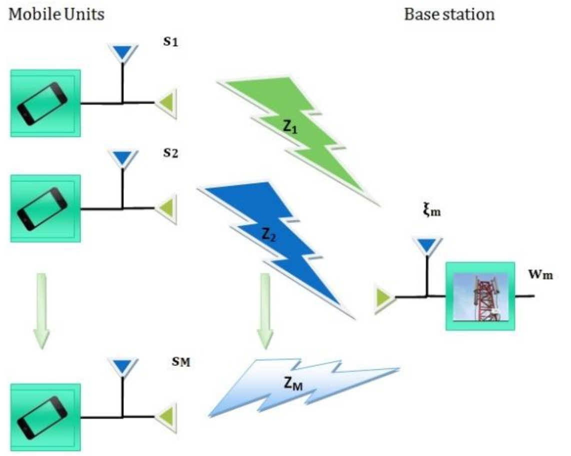

Figure 1 General Block Diagram of multi-user Dual Polarized uplink system

III. OUTAGE PROBABILITY FOR DUAL POLARIZED ANTENNAS

From equation (1) the Signal-to-Interference- Plus-Noise Ratio $\left(\frac{P}{IN}\right)_m$ for a certain threshold η for m^{th} user can be expressed as

$$\left(\frac{P}{IN}\right)_m (\eta) = \frac{|\mathbf{y}_m{}^H \mathbf{Z}_m \mathbf{s}_m|^2}{\left|\mathbf{y}_m{}^H \sum_{d=1,d\neq m}^{M} \mathbf{Z}_d \mathbf{s}_d\right|^2 + \|\mathbf{y}_m\|^2 \Sigma_m^2}$$

For Dual Polarized antenna system the channel matrix can be expressed as

$$\mathbf{Z} = \begin{bmatrix} Z_{0,0} & Z_{0,1} \\ Z_{1,0} & Z_{1,1} \end{bmatrix}$$

The components $Z_{1,1}$ and $Z_{0,0}$ of the channel matrix **Z,** are co-polarized components and the components $Z_{0,1}$ and $Z_{1,0}$ are cross-polarized components. In case of Rayleigh fading, the components of channel matrix $\mathbf{Z}$ are circular complex Gaussian with zero mean and variance Σ_m^2 . We consider the model provided by Bolcskei *et al*. [8] for modeling and Analyzing the Dual Polarized channel. Aforementioned above XPD and Cross correlation coefficients are the important factors. For DP system XPD is given as [8] $\mathrm{XPD} = \frac{1}{\alpha}$

Where α lie in between 0 and 1 which represents antenna ability to separate orthogonally polarized waves. Based on experimental results in [9], the transmit correlation coefficient β and receive correlation coefficient γ for DP antennas are expressed as

$$\beta = \frac{\mathbf{E}\{z_{0,0}\, z_{0,1}{}^*\}}{\sqrt{\alpha}} = \frac{\mathbf{E}\{\, z_{1,0} z_{1,1}{}^*\}}{\sqrt{\alpha}}$$

$$\gamma = \frac{\mathbf{E}\{z_{0,0}\, z_{1,0}{}^*\}}{\sqrt{\alpha}} = \frac{\mathbf{E}\{\, z_{0,1} z_{1,1}{}^*\}}{\sqrt{\alpha}}$$

The outage probability is found based on the simulation setup made based on SINR equation in (2).

IV. RESULTS

In this section, we did Monte Carlo simulations for an uplink scenario with Dual Polarized antennas in a multi-user environment by averaging the channel over 10000 trials.

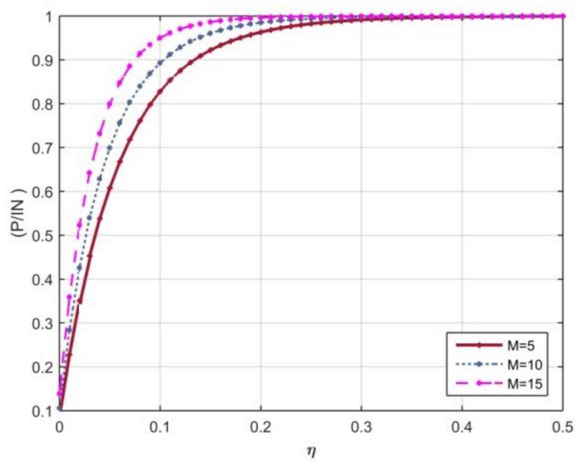

Figure 2 Comparison of Outage probability for a number of users (M).

In Figure 2, we studied the effect of increase in the number of user on Outage Probability with Dual Polarized antennas by setting the parameters $\Sigma_m^2 = 10$ β=0.6, α=0.5,and γ=0.2. It is observed that the Outage probability gets deteriorates with a rise in the number of users.

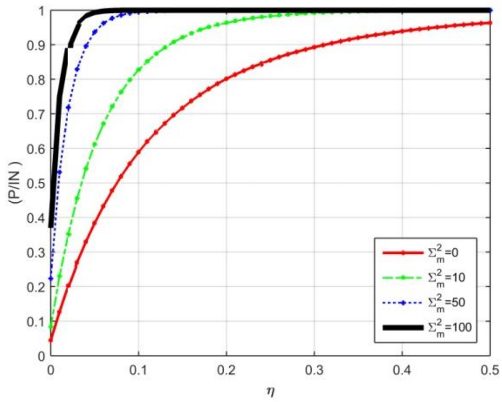

Figure 3 Comparison of Outage probability with different noise variances.

In Figure 3, Performance of Dual Polarized antenna is compared based on noise variance in terms of Outage Probability. It is realized that Outage Probability deteriorates with a rise in noise variance.

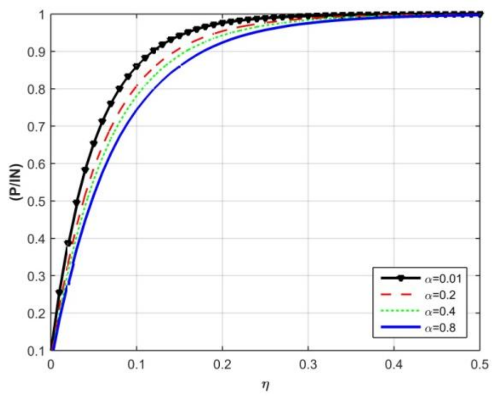

Figure 4 Comparison of Outage probability with different XPD coefficient(α).

In Figure 4, we show the effect of XPD on Dual Polarized antennas. We found that the Outage Probability is better at high α value.

V. CONCLUSION

In this paper, the performance metric of Dual Polarized antenna is examined in terms of Outage probability in multi-user MIMO system in an uplink system for Rayleigh fading. We consider the presence of multiple co-channel inference and additive white Gaussian noise with multiple Dual Polarized antennas at the receiver. Our Simulation results show that Outage probability degrades with an increase in a number of users and noise variance.

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