Performance of Spatial Multiplexing in the Presence of Polarization Diversity

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**Abstract**-In practice large antenna spacings are needed to achieve high capacity gains in multiple-input multipleoutput (MIMO) wireless systems. The use of dual-polarized antennas is a promising cost effective alternative where two spatially separated antennas can be replaced by a single antenna element employing orthogonal polarizations. This paper investigates the performance of spatial multiplexing in MIMO wireless systems with dual-polarized antennas. We compute estimates of the symbol error rate as a function of cross-polarization discrimination (XPD) and spatial fading correlations. Using these estimates, we show that dual-polarized antennas can significantly improve the performance of spatial multiplexing systems. It is demonstrated that improvements in terms of symbol error rate of up to an order of magnitude are possible. We furthermore fmd that in general for a given SNR there is an optimum XPD for which the symbol error rate is minimum. Finally, we present simulation results and we show that our estimates closely match the numerical results.

# 1.INTRODUCTION AND OUTLINE

The use of multiple antennas at both ends of a wireless link drastically increases capacity through a technique call spatial multiplexing. This capacity gain strongly depends on transmit and receive antenna spacing. Unfortunately, large antenna spacing increases both size and cost of base station and renders the use of multiple antennas. The use of dual polarized antennas is a promising cost effective alternative where two spatially separated antennas can be replaced by a single antenna element employing orthogonal polarization.

MIMO system employs more than one antenna on the transmitting and receiving ends. In order to achieve high capacity gains, there is need for large antenna spacing of several wavelengths.

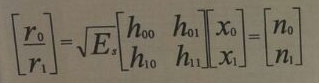
Although our techniques are generally applicable, for the sake of simplicity, we consider a link with one dual-polarized transmit and one dual polarized receive antenna. Our contribution are as follows:

* We introduce a channel model for dual polarized single input single output link
* We propose a method for computing estimates of the uncoded symbol error rate of spatial multiplexing
* We identify the propagation conditions, we show that improvement in terms of symbol error rate
* We demonstrate that our symbol error estimates closely match the simulation results.

We consider a system with one dual-polarized transmit and one dual-polarized receive antenna. The input-output relation is given by

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Where x=[x0 x1]’ is the 2x1 transmit signal vector whose elements are taken from a finite(complex) constellation chosen that the average energy of the constellation elements is 1, r=[r0 r1]’ is the 2x1 receive signal vector, n is a complex valued Gaussian noise



In practice, the following polarizations are generally considered: horizontal, vertical, and +45-45degrees slanted polarization. The signals x0 and x1 are transmitted on the two different polarizations, and r0 and r1 are the signals received on corresponding polarization. We emphasize that although we are dealing with one physical transmit and one physical receive antenna, the underlying channel is a 2-input 2-output channel also we assume that the channel is purely Rayleigh.

The correlation between the elements of the matrix H and the variances of the elements depend on the propagation conditions and the choice of polarizations.

# symbol error rate

## Impact of Polarization Diversity

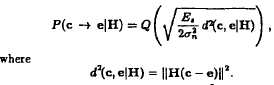
Scattering in the multi antenna channel is rich enough independent parallel spatial data pipes are created within the same bandwidth, which ideally yields a linear capacity increase. Virtual multiple antennas are created by employing different polarizations and the MIMO channel matrix is replaced by the polarization matrix. In the limiting case alpha=0 (i.e. perfect XPD) every realization of H yields orthogonal columns and hence high multiplexing gain can be expected.

## Error probability

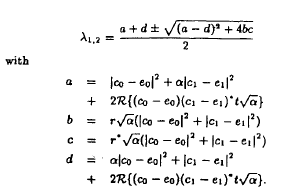
## The channel in transmitter is unknown and in the receiver is known and the maximum likelihood (ML) at receiver is

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The probability that the receiver decides erroneously in favour of the vector is given by



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# 2.simulation results

In this section, simulation results demonstrating the performance of spatial multiplexing in the presence of polarization diversity and spatial fading correlation.

The Simulation serves to demonstrate an accurate estimate of the symbol error rate for high SNR.

The following are the simulation results for various alpha, r and t values.

For

Alpha=0.4

r=0.3

t=0.5



# 3.conclusion

We found that in the presence of high spatial correlation dual polarized antennas can yield a significantly improved multiplexing gain. The symbol error rate which we have computed was found to be very accurate in the high SNR regime. In the presence of transmit correlation the use of polarization diversity can yield significant improvements in terms of symbol error rate. In addition we found that for high spatial fading correlation for a given SNR in general there is an optimal value of alpha for which the symbol error rate is minimum.

4. REFERENCES

1.J. J. A. Lempikiinen and J. K. Laiho-Steffens, “The performance of polarization diversity schemes at a base s- tation in small/micro cells at 1800 MHz,” IEEE Trans. Veh. Tech., vol. 47, pp. 1087 - 1092, Aug. 1999.

2.H. Bolcskei and A. J. Paulraj, “Performance of spacetime codes in the presence of spatial fading correlation,” in Asilomar Conf. on Signals, Systems, and Computers, (Pacific Grove, CA), Oct. 2000.

3Helmut Bolcsket, Rohit U. Nabar, V.Erceg, D.Gesbert, Arogyaswami J. Paulraj,”Performance of Spatial Multiplexing in the Presence of Polarization Diversity” IEEE, 2001

MATLAB CODING:

clc;

clear all;

close all;

%randn('state',0); % Fixed ramdom seed

%1. initialisation

M=4; % M channels

N=10000; % N set of channels

H\_Symbol\_corr=zeros(N,M);

alpha=0.4; %correlation matrix coefficient

r=0.3;

t=0.5;

%2. generate a QPSK modulation

aa=(1+i)/sqrt(2);

bb=(-1+i)/sqrt(2);

cc=(-1-i)/sqrt(2);

dd=(1-i)/sqrt(2);

Two\_QPSK\_Combine = [aa aa;aa bb;aa cc;aa dd;...

bb aa;bb bb;bb cc;bb dd;

cc aa;cc bb;cc cc;cc dd;

dd aa;dd bb;dd cc;dd dd]';

%3. Rayleigh fading x+iy channel => a = sqrt(x^2+y^2) rayleigh channel

H\_Symbol=(randn(N,M)+1i\*randn(N,M))/sqrt(2);

R = [1 sqrt(alpha)\*(t) sqrt(alpha)\*(r) 0;

sqrt(alpha)\*t alpha 0 sqrt(alpha)\*(r);

sqrt(alpha)\*r 0 alpha sqrt(alpha)\*(t);

0 sqrt(alpha)\*r sqrt(alpha)\*t 1];

[U,D]=eig(R);

Tx\_Form = sqrt(D) \* U';

H\_Symbol\_Corr = H\_Symbol\*Tx\_Form;

SNR = (0:2:20);

length(SNR)

for mm=1:11

symbol=(sign(randn(2,N))+1i\*sign(randn(2,N)))/sqrt(2);

noise\_amp = (10^(-SNR(mm)/20))\*sqrt(2);

noise=noise\_amp\*(sign(randn(2,N))+1j\*sign(randn(2,N)))/sqrt(2);

for k=1:N

H\_matrix = reshape(H\_Symbol\_Corr(k,:)',2,2).';

sym\_pair = [symbol(1,k) symbol(2,k)].';

noise\_pair = [noise(1,k) noise(2,k)].';

r\_signal\_pair = H\_matrix \* sym\_pair + noise\_pair;

% detect minimum distance

R\_1 = r\_signal\_pair \* ones(1,16);

E\_1 = R\_1 - H\_matrix \* Two\_QPSK\_Combine;

dist\_1 = sum(E\_1.\*conj(E\_1));

[Y\_1,i\_1] = min(dist\_1);

detect\_sym(1,k)= sign(abs(Two\_QPSK\_Combine(1,i\_1)-symbol(1,k)));

detect\_sym(2,k)= sign(abs(Two\_QPSK\_Combine(2,i\_1)-symbol(2,k)));

end

detect\_sym\_pair(k) =sum(sum(detect\_sym));

Avg\_SER(mm)=sum(detect\_sym\_pair)/(2\*N);

end %mm

%4. plot

semilogy (SNR,Avg\_SER, 'bs-');

xlabel('snr');

ylabel('symbol error rate');

title('symbol error rate variation with snr');

grid on;

OUTPUT:

