International Journal of Computer and Electrical Engineering, Vol. 2, No. 4, August, 2010
1793-8163

Switching in MIMO-Frequency Selective Channels

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***Abstract*—Multiple transmit and receive antenna systems have recently become of interest because it provides enormous capacity without any extra cost and power. Two practical techniques for space-time modulation are transmit diversity and spatial multiplexing. In this paper we propose switching condition for multiplexing or diversity suitable in frequency selective channels, by assuming finite length MMSE-DFE is using at the receiver for equalization. The decision is sent to transmitter via low feedback rate channel to switch between the diversity and multiplexing. Spatial multiplexing and space-time block code with two transmit two receive antennas on a typical urban COST-203 MIMO channel is taken as a case study for simulation.**

***Index Terms*—MIMO, MMSE-DFE, Frequency selective channels, Alamouti code, Diversity.**

I. Introduction

In MIMO communication system uses multiple antennas at the transmitter and receiver to achieve various advantages. traditionally, antenna arrays have been used at the transmitter and the receiver to achieve array gain, which increases the output SNR of the system. In the mid-1990s, adaptive antennas and smart antennas were introduced to describe antenna arrays that are made adaptive in a manner that it changes its transmission and reception characteristics when the radio environment changes. Array antennas have been implemented in GSM networks, fixed broadband wireless access networks, and third generation (3G) CDMA networks. More recently, a way of using multiple antennas has been discovered to achieve diversity and multiplexing gain by exploiting the once negative effect of multipath. Under suitable conditions, i.e. a scatter rich environment, the channel paths between the different transmit and receive antennas can be treated as independent channels due to the multipath effects caused by the scatterers. Initial works in this research area, suggests that MIMO effectively takes advantage of the random and multipath delay spread to increase the data rate of the system. The exploitation of this additional spatial degree of freedom can increase the throughput and improve the performance of the system. In summary, the main advantages of MIMO system can be categorized as diversity gain and spatial multiplexing gain [1]-[5].

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Recently switching between the diversity and multiplexing is very interesting. This schemes improves the system performance. In this system at receiver decides the channel is suitable for diversity or multiplexing and decision is sent to the transmitter via low feedback rate channel. In this paper we compare diversity and multiplexed transmission from the point of view of instantaneous channel knowledge, with a fixed rate, in a frequency selective channel. The diversity or multiplexing performance is mainly depends on the mean square value (MSE) [6]-[8].

II. System Model

Our aim is to calculate a MIMO equalizer so that we can negate the cross-channel interference (CCI) inherent in MIMO systems, and also the ISI present in wideband transmission systems. We must first define a model to represent the transmission system y=Hx+v where x is a length MK vector representing the input to the MIMO system and M is the number of transmitters and K is the length of the input signal. Further, H is the frequency selective MIMO matrix of dimensions (N(K-L+1)× MK), where N is the number of receivers and L is the impulse response length of the MIMO channel, v is a length (N (K-L+1)) vector represent the noise and y is a length (N (K-L+1)) vector representing its output. We have used a time-domain representation of MIMO cross-channel transfer and the ISI. As such the output vector, y are given as follows; $y=\left[y_1^H,.....,y_p^H\right]^H$ where $y_k=\left[y_1(0).....,y_1(K-L+1)\right]^H$ and $y_k(n)$ is the received signal at receiver k at time n. The input vector x and AWGN vector v are defined similarly. Finally we have the MIMO channel convolution matrix

$$H=\begin{pmatrix} H_{11} & H_{21}..... & H_{M1} \\ H_{12} & H_{22}..... & H_{M2} \\ \vdots & \vdots & \vdots \\ H_{1P} & H_{2P} & H_{MN} \end{pmatrix} \quad (1)$$

Where

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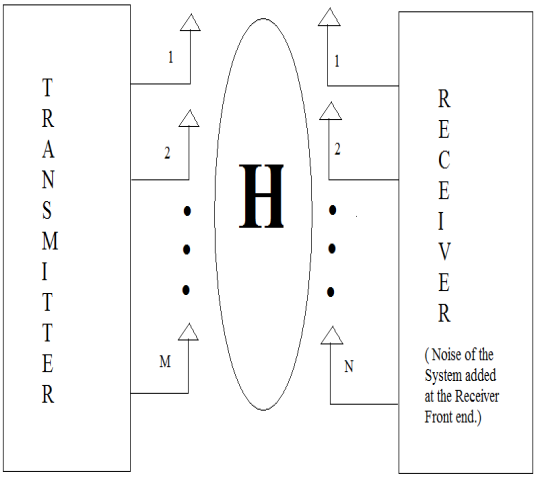

Figure 1. MIMO System

$$H = \begin{pmatrix} h_{mn} \cdots & 0 & 0 \\ 0 & h_{mn} \cdots\cdots & 0 \\ \vdots & \vdots & \vdots \\ 0 & 0 & h_{mn} \end{pmatrix} \quad (2)$$

Where $h_{mn} = \left[h_{mn}(0) \cdots\cdots h_{mn}(L-1) \right]$.

A. Channel Model

Let us assume that the jth received signal is a superposition of L paths. The resulting channel impulse response can then be described using the Gaussian distributed widesense stationary (WSS) model is given by

$$h_{ij}(t,\tau) = \frac{1}{\sqrt{L}} \sum_{p=1}^{L} e^{(2\pi f_{dp} t + \theta_L)} h_{RF}\left(\tau - \tau_p\right) \quad (3)$$

Where f_{dp} is the Doppler spread of the path p due to the receiver motion, θ_p is the angular spread of the signal path p. It is a random variable with uniform distribution in the interval $\left[0, 2\pi\right]$. τ_p is the delay spread of the path p which is a random variable with probability density function proportional to the mean power delay spectrum of the propagation environment. h_{RF} is the impulse response of the receiver filter. Four propagation environments are widely used for simulating receiver performance: typical urban (TU), bad urban (BU), hilly terrain (HT) and rural area (RA), each of one have specific parameter values. Hilly terrain is suitable for many channels of practical interest in mobile wireless communications, which is our interested channel. As an example, an HT channel for a mobile users having a speed of 95 km/h is presented Fig. 2.

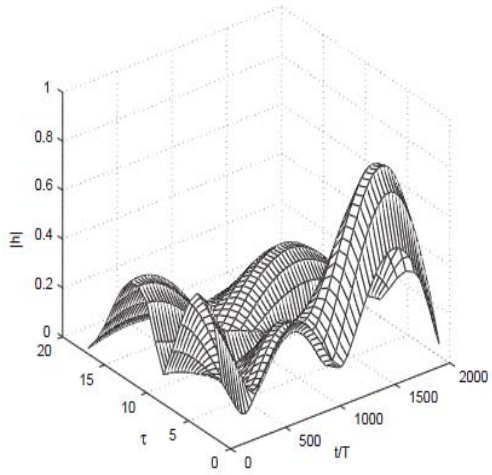

Figure 2. Typical HT Channel

III. MIMO Performance Analysis

A. Performance of the Diversity in the Frequency Selective Channels

We assume matrix channel is frequency selective channel, the orthogonality at the receiver does not hold any more, and thus ML Decoding cannot realized simply processing. Therefore, we add MIMO MMSE-DFE to combat the temporal ISI, i.e, to maintain orthogonality at the receiver. We equalize the channel free from ISI. So the orthogonality after the equalizer between the symbols still holds. This equalizer performance is depends on the mean square value at the decision point device. Probability error for MIMO MMSE-DFE channels is given by

$$\bar{P}D \le \exp\left(\frac{1}{E\left[\|Y(K)\|^2\right]}\right) E\left[\left(-\frac{1}{J_{STBC}}\right)\right] \quad (4)$$

Where $J_{STBC}(n) = tr(D^{-2})$ [9]-[11].

B. Performance of the Spatial Multiplexing in the Frequency Selective Channels

The Cholesky decomposition of the matrix $H^H R_v^{-1} H + R_s^{-1}$ is $H^H R_v^{-1} H + R_y^{-1} = (D'U')^H D'U'$ (5)

Where U', D' are upper, diagnol matrices respectively.

MSE of the detection is given by $J_{SM} = E[\|e(n)\|^2] = E[\|y(n) - y(n)'\|^2]$, MSE is n terms trace is given by

$$MSE = tr\left(E\left[\left(y(n) - y(n)'\right)\left(y(n) - y(n)'\right)^H \right] \right) \quad (6)$$

Where $J_{SM}(n) = tr(D^{-2})$, $y(n)'$ is MIMO-DFE detected signal. Evaluating exact expression for ber is very difficult.

This method gives an upper-bound approximation ,an efficient asymptotic measure of system performance over frequency-selective channels. An upper bound was derived in for a SISO system with coherent detection. The exponent of the bound given in [12] and [13] is identical to MSE divided by the variance of the input signal and, therefore, the BER upperbound in our spatial multiplexing system is given by

$$\bar{P}SM \le \exp\left(\frac{1}{E[\|Y(K)\|}2\right)E\left[\left(-\frac{1}{J_{SM}}\right)\right] \quad (7)$$

C. Channel Characterization

The analysis in the previous sections shows that the performance of each transmission scheme depends on the MIMO channel H. MSE value of spatial multiplexing, diversity varies depends on the channel matrix. Which is better we can determine using the MSE values of the spatial multiplexing, diversity. By pulgging equation (4) and (7) switching criterion for frequency selective channels is based on MSE is given, J_D less than or equal to J_{STBC} switch to diversity otherwise switch to multiplexing as shown in Fig. 3. Expressing in terms of condition (K) is given by

$$T=\frac{tr(D^{-2})}{tr(D'^{-2})} \quad (8)$$

In terms of T, if T less than are equal to one switch to diversity otherwise switch to spatial multiplexing.

IV. Simulations

In this section, we evaluate performance of the system using the condition (T) based switching. In all simulations presented here, we implement the MIMO-DFE algorithm outlined in [8]-[11] and compare the performance of the system, as measured by its symbol error rate (SER) when transmitting BPSK constellation points through (2,2) Rayleigh fading channels (COST-207).

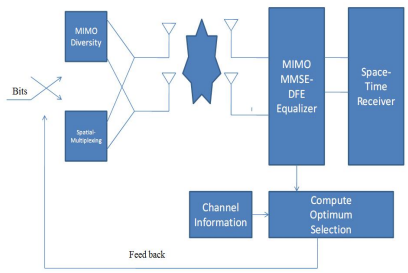

Figure 3. Switching between the Diversity and Multiplexing in Frequency Selective channel.

In decision directed mode, we have taken decisions by comparing original transmitted sequence. We have taken decisions as follows: magnitude of the equalized signal less than zero case, If phase of equalized signal is less than 180° degrees, it is considered as a transmitted symbol is zero, otherwise it is consider as a one. Magnitude of the equalized signal greater than case: magnitude of the equalized signal greater than zero case, If phase of equalized signal is less than 180° degrees, it is considered as a transmitted symbol is one, otherwise it is consider as a zero. Basically, number of filter taps depends on the RMS dealy spread and sampling time. Based on this, we considered feed forward filter length 10 and feed back filter length 6 for given COST-207 frequency selective channel.

Let M = 2, N = 2 and R = 4b/s/Hz. The encoder switches between the Alamouti MIMO diversity scheme, spatial multiplexing with BPSK modulation constellation. In the multipath propagation receiver side due to the constructive addition of phase amplitudes which is greater than the 4 volts as shown in Fig. 4 for single frequency selective channel. Perfect channel knowledge and zero-delay feedback is assumed.

In Fig. 5 we plot the probability of bit error, estimated over 2000 Monte Carlo simulations, obtained using condition(T) switching. At SNR=12dB spatial multiplexing, diversity curves are overlapping, so at lower SNR spatial multiplexing is performing well, at higher SNR diversity is performing is well. By using our criterion we have got diversity gain at higher SNRs 3dB, lower SNRs marginal gain in frequency selective channels as shown in Fig. 5. At lower SNRs we are not getting diversity gain because our criterion approximated at the higher SNRs.

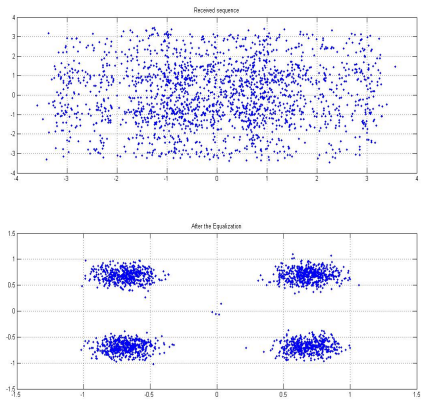

Figure 4. Scattering Diagrams at SNR=18dB

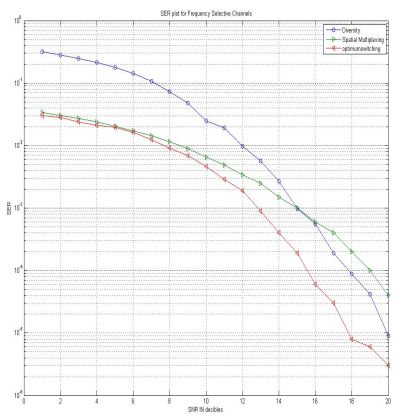

Figure 5. BER Plot for Switching In frequency Selective Channels.

V. Conclusions

A new switching creterion for frequency selective MIMO channels has been derived. The proposed switching creterion

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for ferquency selective channels have got diversity gain at higher SNRs and marginal gain at lower SNRs.

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