

Mitigation of the ill conditioning effect of the spatially multiplexed channel in the MIMO OFDM detector

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Abstract— In this article we discuss the effect of ill conditioning on the performance of a spatially multiplexed. It is shown that the ill conditioned in spatially multiplexed channels worsen the performance of detectors. The two detectors considered in this paper are zero forcing (ZF) and minimum mean square error (MMSE) detector. The performance is measured by the symbol error rate (SER).

Index Terms—Multiple Input Multiple Output (MIMO), Orthogonal frequency division multiplexing (OFDM), Zero Forcing (ZF) , Minimum Mean Square Error (MMSE)

1. INTRODUCTION

Orthogonal frequency division multiplexing is used to eliminate the effect intersymbol interference for transmission over frequency selective fading channels [1]. OFDM is a technique used to broadcast media like e.g European terrestrial digital television (DVB-T) and digital audio broadcasting (DAB) .Pilots are used to measure the channel state information for the receiver. The demand for high data rates makes the development of MIMO systems important. MIMO systems can provide high data rates in point to point links in a network but also increase the overall system customership or users [2] .The combination of MIMO and OFDM creates a system with high bit rates that is resistant to intersymbol interference and can be used for multimedia services.

We are going to look at the performance of ZF and MMSE in MIMO with OFDM modulation. MIMO system is created spatial multiplexing. V-BLAST detector will later be used but it uses zero forcing detection. V-BLAST with successive interference cancellation (SIC) in a spatially multiplexed channel without ill conditioning produces the better SER results than ZF and MMSE receivers .Either one of the improved detectors can be used in first iteration of V-Blast detector .It should be noted that V-BLAST with SIC completely crushes in ill conditioned environment if the correlation factor is close to one. We demonstrate the effect of ill conditioning on the linear detectors and investigate the improvements .Ill conditioning can be brought by fading correlation and rice component and it makes decoding difficult. [3]

II. SYSTEM MODEL

In this paper a MIMO OFDM system is considered. The number of transmitters and receivers is variable. The MIMO OFDM model consists of N_{tx} transmitters and N_{rx} receivers. In the transmitter the serial data is converted to N_{tx} parallel blocks. Each block has got N subcarriers and P pilot symbols are inserted in the N_{tx} parallel streams therefore there are $N-PN_{tx}$ data streams per antenna. The transmitter and receiver are assumed to be time and frequency synchronized. The OFDM signal is obtained by using IDFT and is detected at the receiver using DFT. OFDM signal $x_{n,m}$ ($n \in [0, N-1]$, m denotes block index) suffers from inter symbol interference (ISI) on transmission .Guard interval is introduced to remove ISI between adjacent symbols. Cyclic prefix is added to the guard interval to reduce complexity of the receiver. The cyclic prefix converts the linear convolution of the signal and the channel to circular convolution [4].The cyclic prefix of length N_{cp} and the CP is the last part of a block that is added to the signal. The channel is quasi-static it remains constant during the transmission of one block. The CP should be larger than channel impulse response (CIR) of length L taps .We adopt the bandlimited filter model with restrict energy response enclosure within the first L /taps with tap gains described by vectors $H(i) = [h_1(i), \dots, h_{(L-1)}(i)]$ where $i = 0, 1, 2, \dots$ denotes the serial index of block. The k^{th} path response of the wide sense stationary uncorrelated scattering is modeled as [5]

$$g(t, i) = \sum_{k=0}^{K-1} a_k(i) \delta(t - \tau_k)$$

According to the formula

$$H(i) = \sum a(i)$$

where a_k is the path gain, τ_k is the path delay,

$a_k(i) = a_0(i), \dots, a_{k-1}(i)$ the path gains are zero mean Gaussian variables. The parameters are estimated by using pilot symbols transmitted with the ofdm symbol. Least squares channel estimation is used to estimate the channel parameters. At the receiver the CP is removed and the signal is passed through the DFT .The received signal from the i^{th} block is

$$Y(i) = Y_0, \dots, Y_{N-1}(i) = XD(i)H(i) + W(i)$$

where $n \in [0, N - 1]$

$W =$ is the CFR vector

and $W(i) = (W_0(i), \dots, W_{N-1}(i))^T$ this DFT transformed noise

III DETECTORS

In a linear receiver like ZF the symbol estimate X^* is given by the transformation of received signal Y

$$X^* = H^+ Y$$

where H^+ is the Moore–Penrose pseudoinverse [6] of H . The inverse exists even when H is rank deficient. The MMSE receiver the transmitted symbol is estimated by

$$X^* = H^H (H H^H + \delta^2 I)^{-1} Y$$

where δ^2 is not equal to zero but when it approaches zero the MMSE performance asymptotically approaches ZF detector. I is an identity matrix. In the new proposed biased MMSE detector the variance is varied to a maximum value of the noise variance. A small conditioning number close to one shows the matrix is well conditioned and a large value shows ill conditioning. Single value decomposition (SVD) is used to find the eigenvalues of the channel matrix in MIMO system. The minimum eigenvalue is scaled down to approach zero. The new matrix is calculated using the new eigenvalues matrix in reverse SVD

IV RESULTS

In a MIMO channel without ill conditioning the performance of ZF and MMSE detector is similar this is shown by figure 1 below

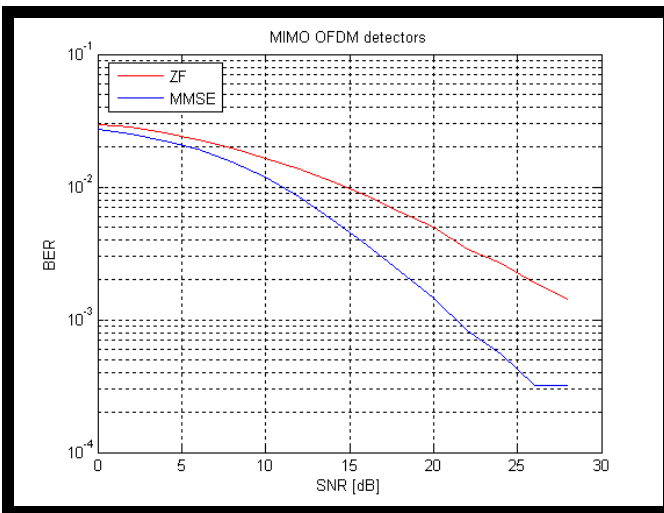


Figure 1: Performance of ZF and MMSE receivers

At low signal to noise ratio (SNR less than 5dB) the two receivers perform the almost the same with MMSE offering lower symbol error rate (SER). Both detectors are tested for six transmitters and six receivers with QPSK modulation. In the case of MIMO channel with ill conditioning the performance of the two detectors degrades as shown by figure 2.

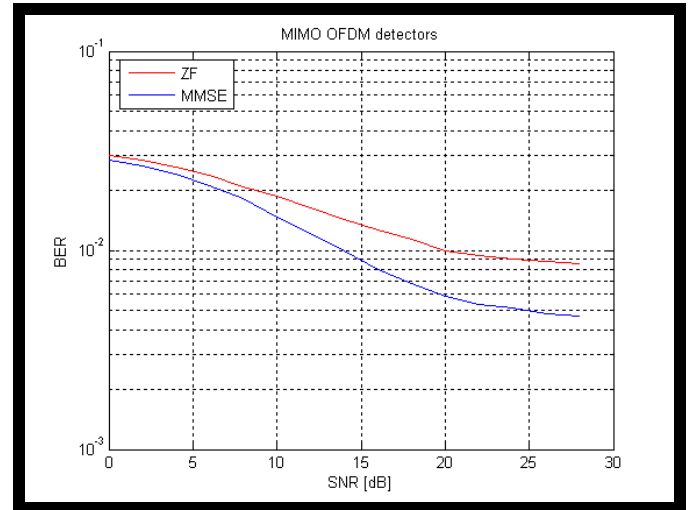


Figure 2: Performance of a MIMO system in ill conditioned channel

The MIMO system used in figure 2 has six transmitters and receivers. It is shown that the performance of both receivers is degraded by ill conditioning in the MIMO channel matrix.

In future work the effect of ill conditioning on a system with different number of transmitters and receivers will be investigated. The effect of varying the noise variance (δ^2) in the MMSE detector will be explored. An improvement to the linear detector can be applied to V-BLAST as V-BLAST uses zero forcing to create an ordering matrix for detection.

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