Minimum Mean Square Error-Ordered Successive Interference Cancellation (MMSE-OSIC) in UWB-MIMO Systems

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***ABSTRACT*: Developing of low complex and high performance detection algorithms are challenging. In this paper, we introduce the ordered successive interference cancellation (OSIC) scheme with MMSE in UWB-MIMO system. Especially we use MMSE, OSIC, RAKE combination to evaluate the performance of UWB-MIMO system in multipath environment. We compare the performance result based on the number of multipath and number of antennas.**

Keywords: MMSE, ZF, MIMO, UWB, OSIC.

I. INTRODUCTION

Ultra-wideband (UWB) radio technology has attracted enormous interests for applications requiring high data rates over short ranges especially in health care and commercial usage. Now days MIMO is mostly considering in all communication systems. In the last few years it got lots of attention due to their capabilities to improve channel capacity and reliability.

The capacity achieved in UWB-MIMO and the bit error rate is highly dependent on the detection algorithms. By adding detection technique with interference cancellation techniques give distinguish performance. In this paper we verified the algorithm MMSE-OSIC-RAKE to improve the performance of UWB-MIMO system. Previously the OSIC with zero forcing (ZF) performance was analyzed for different UWB-MIMO systems [1]. The error rate expression of an OSIC receiver on a log-normal multipath fading channel is theoretically derived in a closed form solution [2]. The minimum mean square error detector for MIMO systems on flat Rayleigh channels was considered in [3], [4]. Our work focuses on the error performance of MMSE with OSIC for UWB-MIMO in a log-normal fading channel. We compare MMSE with OSIC and without OSIC for different multipath environment in UWB-MIMO system.

This paper is organized as follows: Section II shortly introduce MMSE detection scheme. System model is discussed in section III. In section IV brief explanation of OSIC algorithm is given. Simulation results and discussion are part of the section V. Finally the conclusion part is come in section VI.

II. MMSE

To mitigate the noise enhancement, the MMSE is one of the solution, where noise is taking during constructing the filtering matrix [5]. The formula for the MMSE is given below.

$$W_{MMSE} = \arg_G \min(E\left[\left\|Gr - X\right\|^2\right]) \qquad (1)$$

Furthermore equation (1) is simplified to the below version.

$$W_{MMSE} = (H^H H + \sigma_n^2 I_{n_T})^{-1} H^H \qquad (2)$$

σ_n^2 is the noise variance, and H^H is the Hermitian transpose of matrix H.

III. SYSTEM MODEL

The error performance of UWB-MIMO over indoor wireless channels was analyzed [2]. Let M_T denote the number transmit antennas and M_R number of receive antennas ($M_R \geq M_T$). The input data is converted from serial to parallel independent streams. These M_T streams are used to modulate UWB pulses. After that all the waveforms are divided in to M_T transmit antenna for transmission. The received signal is corrupted by AWGN among independent M_R receiver antennas. For avoidance of inter symbol interference the pulse repetition interval should be far bigger than the channel delay spread. RAKE receiver is the best choice for the time being to combine the MMSE paths information of the same symbol to prepare it statistically for detections.

The mathematical model is quite clear and easy to understand. The signal vector over M_T transmit antenna is given as $b = [b_1, b_2, ..., b_{M_T}]^T$, and b_n represent the transmitted symbol from the n-th antenna. By assuming perfect time and synchronization the system equation is given below which clear more parameters and equations.

$$Y(l) = \sqrt{E_s} H(l) b + n(l) \quad ... \quad (3) \qquad l = 0, ..., L-1$$

Where $Y(l) = [y_1(l),\, y_2(l), ... y_{M_R}(l)]^T$ the received signal vector for the l-th path, E_s is the energy/symbol. $H(l)$ is the channel matrix and should be defined in terms of transmit and receive antennas. $H(l) = [h_1(l), h_2(l), ... h_{M_T}(l)]$. The noise terms across all M_R received antennas is given in equation $n(l) = [n_1(l),\, n_2(l), ... n_{M_R}(l)]^T$ .We also consider the generalize RAKE receiver which consists of matched filter defined in the system equation.

IV. OSIC WITH MMSE

Here OSIC is applied to the MMSE-RAKE architecture for multipath channels. The OSIC process should be performed for each path before the RAKE combining. The output of the received signal vector and filter matrix for the $l-th$ path is $z(l) = G_{MMSE}(l) Y(l)$.

Fig. 1 shows how the OSIC algorithm works together with MMSE for the lth path in UWB-MIMO system.

Input :

$H_1(l) = H(l),\ G_{MMSE,1}(l) = G_{MMSE}(l)$

$Y_1(l) = Y(l),$

for $i = 1, 2, \ldots, M_T$

$G_{MMSE,i}(l) = H_i(l)^{\dagger}$

$k_i(l) = \arg\min_{j} \left(\|g_i^j(l)\|^2 \right)$

$z_{k_i(l)}(l) = g_i^{k_i(l)}(l) Y_i(l)$

$\hat{z}_{k_i}(l) = Quan[z_{k_i(l)}(l)]$

$Y_{i+1}(l) = Y_i(l) - h_{k_i(l)}(l)\, \hat{z}_{k_i(l)}(l)$

$H_{i+1}(l) = H_i^{\bar{k}_i(l)}(l)$

end

Fig.1. MMSE-OSIC Algorithm

$g_i^j(l)$ is the row j of $G_{MMSE,i}(l)$, $H_{i+1}(l) = H_i^{\bar{k}_i(l)}$ do nulling operation of the column $k_i(l)$, and $Quan[z_{k_i}(l)]$ is the quantization operation. By doing some mathematical operation and modification the decision variable (DV) and average error probability is given in the following two equations [1], [2].

$$DV = \sum Y_n(l)\beta_n^2(l) \ and \ \beta_n(l) = \frac{1}{\sqrt{[(H(l)^H H(l))^{-1}]_{nn}}}$$

$$P^n_{b,MMSE-OSIC} = \int_0^{\infty} P_r^n(t) f_{\gamma_n^{'}}(t)dt \qquad (4)$$

Where $f_{\gamma_n^{'}}(t) = (0.5^{\omega} / \Gamma(\omega)) t^{\omega-1} e^{-t/2}$, $\Gamma(\omega)$ is gamma distribution function, $\omega = 0.5 D^n_{MMSE-OSIC}$. The variable $\gamma_n^{'} = \sum_{i=0}^{L(M_R - M_T + n)} |q_i^{(n)}|^2$ is chi-square distributed random variable with degree of freedom $D^n_{MMSE-OSIC} = L(M_R - M_T + 1)$. $BER_{MMSE-OSIC} = 1/_{M_T} \sum_{n=1}^{N_T} P^n_{b,MMSE-OSIC}$ is the average bit error rate for the all data streams.

V. Simulation Results

During simulation we consider different parameters. PAM is the modulation technique exploited during simulation. SNR/bit in decibel is defined as $\eta_b = \frac{E_b}{N_o} + 10\log_{10}(L(M_R - M_T + 1))$, $\upsilon(l) = e^{\Phi(l)}$ is the lognormal fading amplitude and $\Phi(l)$ is the Gaussian random variable with mean $\mu_{\Phi(l)}$ and variance σ_{Φ}^2 . Standard deviation of $20\log_{10}\upsilon(l) = \Phi(l)(20\log_{10}e)$ is assumed to be 5dB. $\mu_{\Phi(l)} = -\sigma_{\phi}^2 - \rho L/2$ is the required condition to satisfy the average power of path l $E[\upsilon(l)^2] = e^{-\rho l}$, where $\sigma_{\Phi} = 5/(20\log_{10}e)$. The power decay factor $\rho = 0$ (all paths keep equal average power) and the receiver keep knowledge of the channel fading coefficient of L paths are our considerations.

Fig. 2 shows the performance analysis of MMSE and MMSE-OSIC with the parameters $(M_R, M_T, L) =$ (2, 2, 2) and (4, 4, 4). The graph is obtained for BER vs SNR/bit. The MMSE-OSIC-RAKE shows superior performance over MMSE-RAKE. The reason of this improvement is the power gain due to the diversity order for every increasing cancellation step. Performance is also increases by increasing the number of paths combined but it results the receiver complexity too.

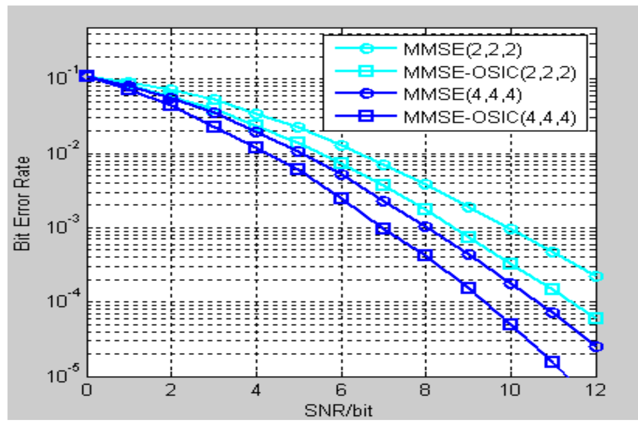

Fig.2 MMSE vs MMSE-OSIC

VI. Conclusion

In this paper MMSE-OSIC for UWB-MIMO system in multipath environment is presented. It improved the performance as well as diversity order. MMSE-OSIC performance is better than MMSE. The big challenge for this algorithm is its complexity. Due to increase in multipath the complexity rise may occur. The reduction in complexity for this algorithm for multipath will make it more powerful algorithm.

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