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Semi blind Channel Estimation Technique with Pulse Shaping for MIMO- OFDM Systems

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ABSTRACT- In this paper, a very efficient semi-blind approach is developed with pulse shaped Multiple-Input-Multiple-Output Orthogonal-Frequency-Division-Multiplexing (MIMO-OFDM) systems. In digital communication systems, pulse shaping filters and matched filters are used. When the signal's bandwidth becomes larger than the channel bandwidth, the channel starts to introduce distortion to the signal. This distortion is usually seen as inter symbol interference. To control the Inter Symbol Interference (ISI) the pulse shaping filters are used. The pulse shaping filter is realized in the up-sampling domain by a square root raised-cosine filter. By utilizing the knowledge of pulse shaping filters a time domain semi-blind estimation method is developed for the MIMO channel.

KEYWORDS- Most Significant Taps (MSTs), multiple-input-multiple- output (MIMO), multiple-input-multiple-output orthogonal frequency division multiplexing (MIMO-OFDM).

I. INTRODUCTION

Mobile wireless communication is coming to a new era with higher data rate, integrated multimedia services and wide internet accessibility. Due to the distinct advantages of both multiple-input multiple-output (MIMO) and orthogonal frequency division multiplexing (OFDM), MIMO-OFDM technologies has been considered as a strong future wireless communication systems[7]. MIMO-OFDM channel estimation techniques can be categorized into the following three classes: 1) training-based methods; 2) blind methods and 3) semi-blind methods. First, training-based methods, such as the least-square (LS) and the minimum mean square error (MMSE) methods, employ known training signals to render an accurate channel estimation. Blind MIMO-OFDM channel estimation algorithms**.** which exploit the second-order stationary statistics or other properties, and have a better spectral efficiency. Combining the advantages of both the training-based and the blind algorithms, a semi-blind MIMO channel estimation technique has been extended to MIMO-OFDM systems.

A wireless channel often be modeled as a sparse channel, in which the delay spread could be large, but the number of significant (nonzero) paths is normally very small. Based on the sparsity assumption of the equivalent discrete-time channel, where only a few taps in the long tapped delay line are considered most significant, the sparse structure of the channel, where only a few taps in the long tapped delay line are considered most significant, the sparse structure of the channel has been employed to improve channel estimation for OFDM and code-division multiple access (CDMA) systems. All the sparse channel estimation methods utilize a training sequence and comply with the following two steps: 1) Detect the positions of the most significant taps (MSTs), which are also referred to as nonzero taps, and 2) obtain an estimate of effective channels by exploiting the position of the MSTs.

It is well known that the pulse-shaping filter as well as the matched filter are very commonly used in digital communication systems. These methods have actually been developed for the estimation of the composite channel including the pulse-shaping and matched filters. By utilizing the information of both filters, some improved channel estimation algorithms have been obtained for OFDM systems and CDMA systems.

In existing approach they used a new semi-blind channel estimation algorithm that can eliminate the effect of pulse-shaping, and thus give a better channel estimation performance.

II. RELATED WORKS

In [1] the obtained correlation matrix of the received signal is expressed in terms of the most significant taps (MSTs) of the sparse channel to obtain an efficient channel. In [2] the positions of the MSTs of the sparse channel and the most significant lags of the correlation functions is used with a pilot-assisted LS estimation to detect the MSTs in a semi-blind algorithm. This MST detection algorithm can be extended for the estimation of MIMO-OFDM channels. In [4] a semi-blind channel estimation method is proposed for pulse-shaped MIMO-OFDM systems. This estimation method is developed for the multi-path channel. To reduce the computational complexity of the time-domain algorithm, a frequency-domain algorithm is derived.

III. DATA MODEL

Consider a MIMO-OFDM system with N_T transmit and N_R receive antennas. The frequency-selective channel can be considered as a combination of L_C multi-paths, namely,

$$H_c\ (t) = \sum_{l=0}^{Lc-1} \Gamma_l\ \delta(t - t_l)$$

Where t_l is the delay of the l-th path and Γ_l is an $N_R \times N_T$ attenuation matrix. Assuming the transmit pulse-shaping filter g_t (t) and the receive matched filter g_r (t), the composite channel can be represented by an $N_R \times N_T$ matrix H(t), with its (i_R,i_T)-th element as

$$\boldsymbol{h}_{i_R,i_T}(t) = \boldsymbol{h}_{i_R,i_T,c}(t) * g_t(t) * g_r(t) \quad (1)$$

Where $\boldsymbol{h}_{i_R,i_T,c}(t)$ is the (i_R,i_T)-th element of H_c(t). Most of the existing channel estimation literatures focus on the entire discrete channel, i.e. the sampled version of the continuous-time channel response. Thus, the channel can be regarded as an array of L-tap FIR filters characterized by a number of $N_R \times N_T$ matrices H(n) (n=0,1,…,L-1) with $\boldsymbol{h}_{i_R,i_T,c}(n)$ being its (i_R,i_T)-th element. The time domain signal received at the i_R-th antenna can be written as:

$$\boldsymbol{h}_{i_R,i_T}(n) = \sum_{i_T=1}^{N_T} \boldsymbol{h}_{i_R,i_T}(\mathrm{n}) \circledast x_{i_T} + v(n) \quad (2)$$

Where x_{i_T} (n) is the transmit time-domain signal at the i_T -th antenna and the noise v_{iR} (n) ϵ $¢^{N_R \times 1}$ is a spatio-temporally uncorrelated noise with zero mean and variance δ_V^2.

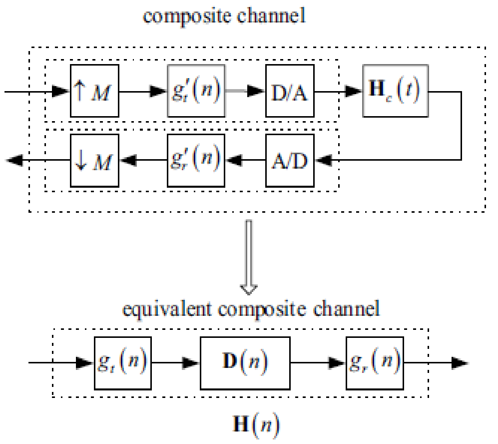

Fig. 1. Discrete-time channel model with pulse shaping

In this model, an up sampling is usually implemented by inserting M-1 zeros between the consecutive input samples prior to pulse shaping. The transmit filter g_t (t) and the receive filter g_r(t) in (1) are then replaced by two root raised-cosine FIR filters g_t'(n) and g_r'(n), whose sampling period is T/M. A discrete-time model equivalent to the composite MIMO-OFDM channel can be formulated as an $N_R \times N_T$ matrix H(n), whose (i_R,i_T)-th element is given by

$$\boldsymbol{h}_{i_R,i_T,c}(n) = d_{i_R,i_T}(n) * g_t(n) * g_r(n) \quad (3)$$

Where $g_t(n)=g_t'(Mn)$, $g_r(n)=g_r'(Mn)$ and $d_{iR,iT}(n)$ is the (i_R,i_T)-th element of the equivalent multi-path channel matrix D(n). The combination of the digital-to-analog (D/A) converter, the multipath channel H_C (t), and the analog-to-digital (A/D) converter can be represented by an equivalent discrete-time "multipath" channel H_e(n).

In general, the channel path may not arrive at the exact sampling time, but it can be considered an equivalent path that occurs at the sampling instant synchronized to H_e(T/M), because the waveform of the D/A converter can normally be assumed as p(t)=1, 0≤ t <

(T/M). Thus, in the case of L_d paths, the discrete-time channel $H_e(n)$ can be represented by,

$$He(n) = \sum_{i=0}^{L_d-1} D(i)\,\delta(n - l_{ui}) \quad \text{i)}\ \delta(n - l_{ui}) \tag{4}$$

Where D(i) and l_{ui} are the channel matrix and the delay with respect to the *i*th path. Now, the composite discrete-time channel H(n) can be regarded as a down sampled version of the convolution of the transmit pulse-shaping filter $g_t(n)$, the discrete-time multipath channel H_e (n), and the received matched filter $g_r(n)$. The delay l_{ui} can be determined prior to channel estimation. In advanced wireless networks, the times of arrival (TOAs) are often estimated at the start of communication and are periodically updated. Based on the knowledge of TOAs, i.e., l_{ui}, i=0,1,…, L_d -1, we develop a sparse semi-blind algorithm for the estimation of the up-sampling duration based effective channel matrix, i.e., D(i), i=0,1,…, L_d -1.

In contrast to the semi-blind estimation, of the up-sampling duration-based effective channel vector, i.e.,

$$d \triangleq vec(\bar{D})$$

Where

$$\bar{D} \triangleq \left[d_1, \ldots, d_{N_R}\right] \tag{5}$$

$$d_{i_R} \triangleq \left[d_{i_{R,1}}^T, \ldots, d_{i_R N_T}^T\right]^T$$

$$d_{i_R,i_T} = \left[\, d_{i_R,i_T}(0), \ldots, \quad d_{i_R,i_T}(L_d - 1)\right]^T \quad {}_{d}\text{-1)} \tag{6}$$

The new optimization scheme over the up-sampling duration-based effective channel vector as

$$\min_{\top}\mathbf{d}\,\Delta = \|Y_{\downarrow}pilot - \dashv\ \vdash A_{\downarrow}D\ d\dashv \|_{\downarrow}(F\ )^{\uparrow}2 + \alpha\|B \tag{7}$$

Where B_D is a blind constraint matrix, and the matrix $A_D = I_{N_R} \otimes A_D$, A_D is obtained by LS estimation for up-sampling duration-based channels.

V. BLIND CONSTRAINT ON SPARSE CHANNEL IN UPSAMPLING DOMAIN

The channel in the up-sampling domain, including the pulse-shaping and matched filters, be denoted by $H_u(n)$, whose (i_R, i_T)-th element is given by

$$\boldsymbol{h}_{u,i_{R,}i_T}(n) = g(n) * \boldsymbol{h}_{e,i_{R,}i_T}(n) \ {}_{*}\boldsymbol{h}_{e,i_{R,}i_T}(n) \tag{8}$$

Where $\boldsymbol{h}_{e,i_{R,}i_T}$ is the (i_R, i_T)- th element of $H_e(n)$, and g(n)= $g_t(n) * g_r(n)$.

VI. CORRELATION MATRIX AS A FUNCTION OF CHANNEL MATRIX IN UPSAMPLING DOMAIN

In the absence of noise, the correlation matrix of the received signal in the up-sampling domain $y_u(n)$, $R_u(l) \triangleq E\{y_u(n)y_u^H(n-l)\}$ can be expressed in terms of channel matrices $H_u(l)$ as

$$R_u(l) = \begin{cases} \dfrac{1}{M}\displaystyle\sum_{i=l}^{L_u-1} H_u(i)H_u^H(i-l),\ l = 0,1,\ldots,L_u - 1 \\ 0,\ l > L_u - 1 \end{cases}$$

Where L_u is the length of $H_u(l)$.

$H_u(l)$ If an ideal pulse-shaping scheme is used, we have g(n)=δ(n), and

$$R_u(l) = R_e(l)$$

$$= \begin{cases} \dfrac{1}{M}\displaystyle\sum_{i=l}^{L_u-1} H_e(i)H_e^H(i-l), & l = 0,1,\ldots,L_u - 1 \\ 0,\ l > L_u - 1. \end{cases}$$

Where 1/M is a fixed coefficient. The effect of g(n) on $R_u(l)$ is the same for all antenna links.

VII. SIMULATION RESULTS

A MIMO-OFDM system with 2 transmit and 4 receive antennas are considered. A 3-tap MIMO-FIR filter is assumed, in which each tap corresponds to a 2×4 random matrix whose elements are i.i.d. complex Gaussian variables with zero mean and unit variance.

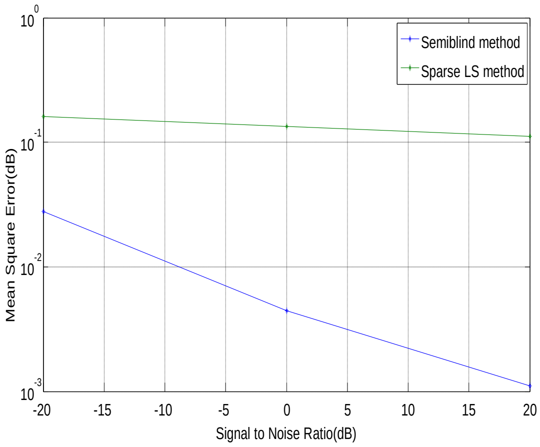

Fig. 2 Signal to Noise Ratio Vs. Mean Square Error

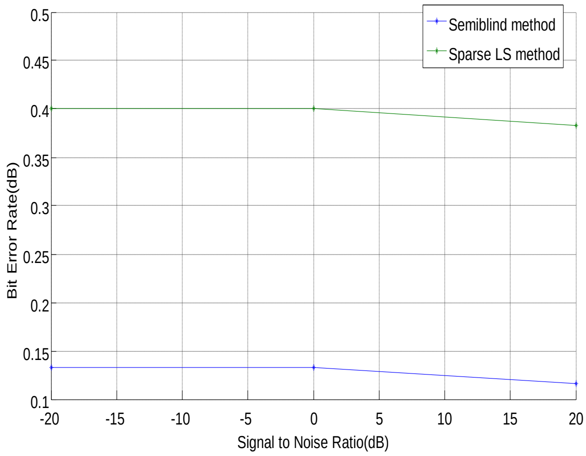

Fig. 3 Signal to Noise Ratio Vs. Bit Error Rate

The performance of the channels are simulated using MATLAB tool.

Channel A: In this simulation, the estimation of channel for pulse-shaped MIMO-OFDM systems has an exponentially decaying profile. A square root raised-cosine filter with an order 16, an oversampling rate of 4, and a roll-off factor of 0.15 is used for the pulse shaping and matched filters. Here the semi-blind algorithm with pulse shaping and the sparse LS algorithm with pulse shaping for an up-sampling duration based channel is simulated. The simulation involves 30 subcarriers. The Fig 2: shows the channel estimation result of the sparse LS algorithm and the sparse semi-blind algorithm. It shows that the sparse semi-blind algorithm with pulse shaping significantly outperforms the sparse LS algorithm with pulse shaping. Fig 3: shows the channel estimation result of the sparse LS algorithm and the sparse semi-blind algorithm. It shows that the bit error rate of semi-blind algorithm is significantly low when compared to the sparse LS method.

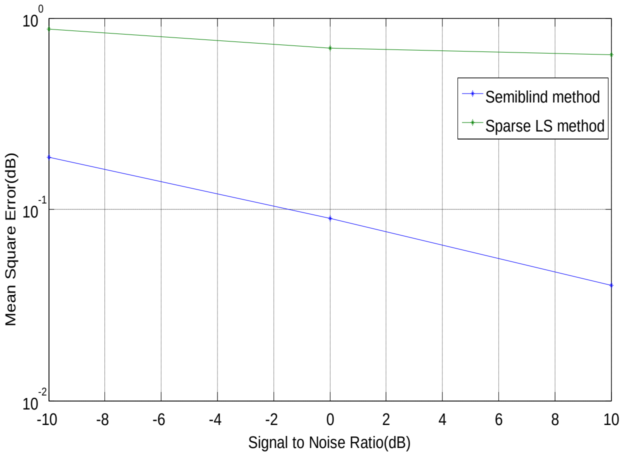

Fig. 4 Signal to Noise Ratio Vs. Mean Square Error

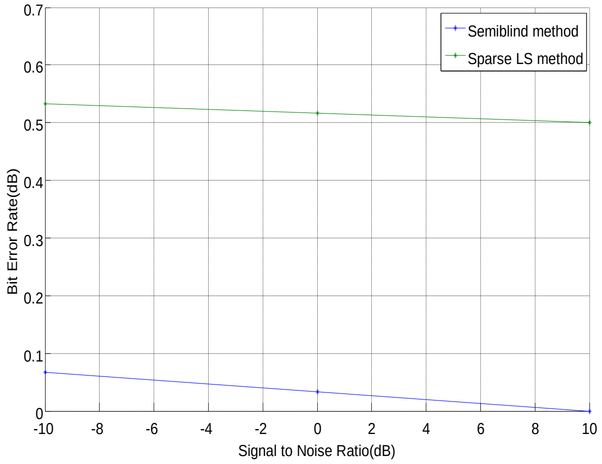

Fig. 5 Signal to Noise Ratio Vs. Bit Error Rate

Channel B: In this simulation, the estimation of channel for pulse-shaped MIMO-OFDM systems has an exponentially decaying profile. A square root raised-cosine filter with an order 16, an oversampling rate of 4, and a roll-off factor of 0.15 is used for the pulse shaping and matched filters. Here the semi-blind algorithm with pulse shaping and the sparse LS algorithm with pulse shaping for an up-sampling duration based channel is simulated. The simulation involves 30 subcarriers. The Fig 4: shows the channel estimation result of the sparse LS algorithm and the sparse semi-blind algorithm. It shows that the sparse semi-blind algorithm with pulse shaping significantly outperforms the sparse LS algorithm with pulse shaping. Fig 5: shows the channel estimation result of the sparse LS algorithm and the sparse semi-blind algorithm. It shows that the bit error rate of semi-blind algorithm is significantly low when compared to the sparse LS method.

VIII. CONCLUSION

The semi-blind channel estimation of pulse-shaped MIMO-OFDM systems exploits the pulse-shaping filter available in the transmitter and the receiver, a time-domain semi-blind solution was developed to obtain an efficient channel.

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