Pilot Aided Channel Estimation for MIMO-OFDM Systems

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Abstract: An efficient channel estimation technique is described in this paper for Multiple Input Multiple Output Orthogonal Frequency Division Multiplexing (MIMO-OFDM) communications over frequency selective channel. Space Time Block Code (STBC) is used to estimate the channel in the frequency domain. The channel estimation technique uses pilot sequence inserted at the beginning of each transmitted OFDM block. Theory and methods are presented in details. The performances of the proposed algorithm are evaluated using software Matlab. Simulation results for different number of transmit and receive antennas are given.

1. Introduction

Future wireless mobile systems will aim to support high quality of services and high data rates by employing techniques that can enhance channel capacity. Space-time block code (STBC) has emerged as one of the major techniques for improving channel capacity as shown in [1]. Over the recent years, the combination of Multiple Input Multiple Output (MIMO) with Orthogonal Frequency Division Multiplexing (OFDM) has gained significant interest and is considered as one of the most promising techniques for present and future wireless communication systems such as WiMax or 3G [2, 3].

Knowledge of channel state information at the receiver is needed to decode space-time codes. Therefore, estimation of the channel is required in order to recover the data as channel parameters are usually not known at the receiver. Pilot sequences known at the receiver is one of the techniques used in wireless communications to estimate the initial channel parameters. For STBC systems, orthogonal pilots are employed at the transmitter and used at the receiver to estimate the channel such as in [4-6].

In this paper, a new channel estimation technique for MIMO-OFDM is proposed. Simple equations are derived. The algorithm can work for any modulation and any number of subcarrier. Moreover, this new scheme is able to work for any number of transmit and receive antenna and achieves good performances as it has only a 4dB loss compared to the ideal case.

The paper is organized in the following way. First, a description of the system is given and STBC-OFDM is introduced. Then, the channel estimation technique is presented and equations of the new estimation technique are derived. Next, simulation results are shown for different numbers of transmit and receive antennas using 16-QAM modulation. Finally, conclusions are given.

2. System description

In this section, the proposed system is first presented and MIMO-OFDM equations for the ideal case (with no channel estimation) are briefly summarised. The space-time coded OFDM system for two transmit and one receive antenna is shown in Fig.1 for simplicity. However, the method can be readily extended to any number of transmit and receive antennas, the results of which will be presented in section 4. As it can be seen from the figure, pilots are first added to the data and then modulated and encoded on the space time encoder. The output of the encoder is then split into two ways, one for each antenna as described for the simple case of MIMO space-time coding in [7]. From [7] applied for the OFDM system, we can have the following vectors for antennas 1 and 2:

$$X_1 = [s_1 \;\; -s_2^* \;\; s_3 \;\; -s_4^*, ..., s_{N-1} \;\; -s_N^*] \quad \textbf{(1)}$$

$$X_2 = [s_2 \;\; s_1^* \;\; s_4 \;\; s_3^*, ..., s_N \;\; s_{N-1}^*] \quad \textbf{(2)}$$

Where X_1 and X_2 are the vectors of the output for pathways 1 and 2 respectively of the space time encoder; s_1, s_2 are the pilot symbols and s_3, s_4,..., s_N are the signal symbols; N is representing the total symbol number which is equal to the double of the number(k) of subcarriers.

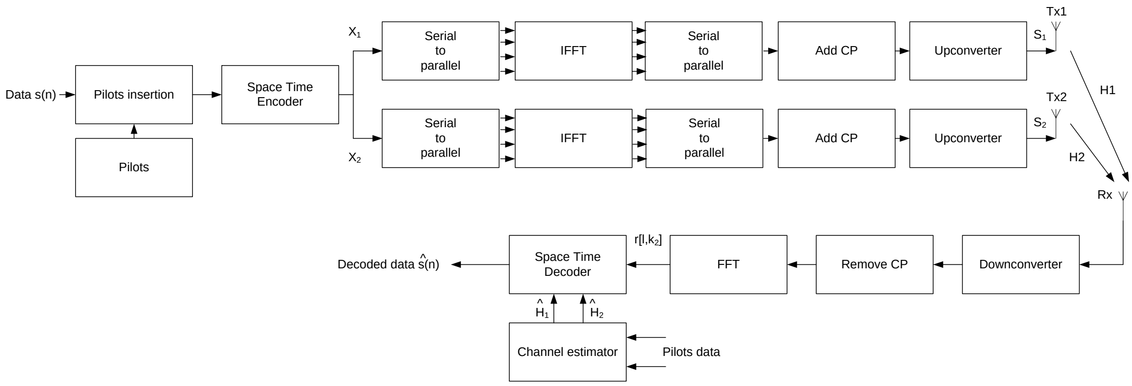

Fig. 1: A block diagram of a two transmit and one receive antennas MIMO-OFDM system

The encoded data are then passed through a serial to parallel block where data are regrouped according to the subcarrier and time as shown in Table 1 for antenna 1.

Table I: The encoded data according to time and subcarrier

Subcarrier / Time	1	2	k
t	s_1	s_3	s_{N-1}
t+T	$-s_2^*$	$-s_4^*$	$-s_N^*$

A cyclic prefix assumed longer than the largest delay spread is added to the signal of each antenna and then the signal is transmitted through the frequency selective channels H1 and H2 from antennas 1 and 2 respectively to the receiver.

During transmission, noise is also added to the transmitted signals and by assuming H[n,k]=H[n+1,k], the received signal can be expressed as:

$$r[n,k] = H_1[n,k]S_1[n,k] + H_2[n,k]S_2[n,k] + W[n,k] \quad \textbf{(3)}$$

Where r[n,k], S[n,k] and W[n,k] are the received symbols, transmitted symbols and the Gaussian noise sample respectively and n refers to the n-th OFDM block and k to the k-th subcarrier. In addition, S_1 and S_2 are the signals transmitted from antennas 1 and 2 respectively and are given by:

$$S_1 = [s_1 \;\; s_3, \ldots, s_{N-1} \;\; -s_2^* \, -s_4^*, \ldots, -s_N^*] \quad \textbf{(4)}$$

$$S_2 = [s_2 \;\; s_4 \;, \ldots, s_N \;\; s_1^* \;\; s_3^*, \ldots, s_{N-1}^*]$$

Finally, the received signal is decoded according to [7] and with the OFDM, the results are given by:

$$\begin{aligned} \tilde{S}_i[n,k] &= H_1^*[n,k]r[n,k] + H_2[n,k]r^*[n,k+1] \\ \tilde{S}_{i+1}[n,k] &= H_2^*[n,k]r[n,k] - H_1[n,k]r^*[n,k+1] \end{aligned} \quad \textbf{(5)}$$

With i=1, 3, 5,..., N-1, representing the symbol number and $\tilde{S}$ is the decoded signal.

3. Proposed channel estimation method

In pilot aided channel estimation, pilots are first transmitted in order to estimate the channel. Here, as the system is based on OFDM, pilots are sent at the beginning of each OFDM block in order to decode the data in that block. Once the channel is estimated, equation (5) is used to decode the transmitted symbol by replacing H_1 and

H_2 by the estimated ones. Thus, the two received symbols and the first symbol of each block of each antenna are used to estimated H_1 and H_2.

The estimated equation for H_1 and H_2 can be expressed as:

$$\hat{H}_1[n,k] = \frac{r[n,k]S_1^*[n,k] - r[n,k+1]S_2[n,k]}{\left|S_1[n,k]\right\|^2 + \left|S_2[n,k]\right\|^2} \quad \textbf{(6)}$$

$$\hat{H}_2[n,k] = \frac{r[n,k]S_2^*[n,k] + r[n,k+1]S_1[n,k]}{\left|S_1[n,k]\right\|^2 + \left|S_2[n,k]\right\|^2} \quad \textbf{(7)}$$

Therefore, as mentioned above, by replacing H_1 and H_2 in (5) by $\hat{H}_1$ and $\hat{H}_2$ in (6) and (7), it can be deduced:

$$\begin{aligned} \tilde{S}_{i+2}[n,k] &= \hat{H}_1^*[n,k]r[n,k+2] + \hat{H}_2[n,k]r^*[n,k+3] \\ \tilde{S}_{i+3}[n,k] &= \hat{H}_2^*[n,k]r[n,k+2] - \hat{H}_1[n,k]r^*[n,k+3] \end{aligned} \quad \textbf{(8)}$$

Where, i=1, 3, 5...N-4. This method is very simple and therefore is cost and computation effective.

4. Simulation results

In the following, simulation results for the proposed method are provided for two and four transmit antennas and different number of receive antennas. Simulations were realized using 16-QAM modulation and under frequency selective channel. Additive White Gaussian noise was also used for this simulation. The two figures show a loss of 4 dB between the ideal MIMO-OFDM scheme where channel is assumed known at the receiver and our proposed channel estimation method. For both cases, 140 subcarriers per OFDM block were employed in a 256 FFT. Moreover, simulations were done using an OFDM sample period of 224μs at 8GHz frequency.

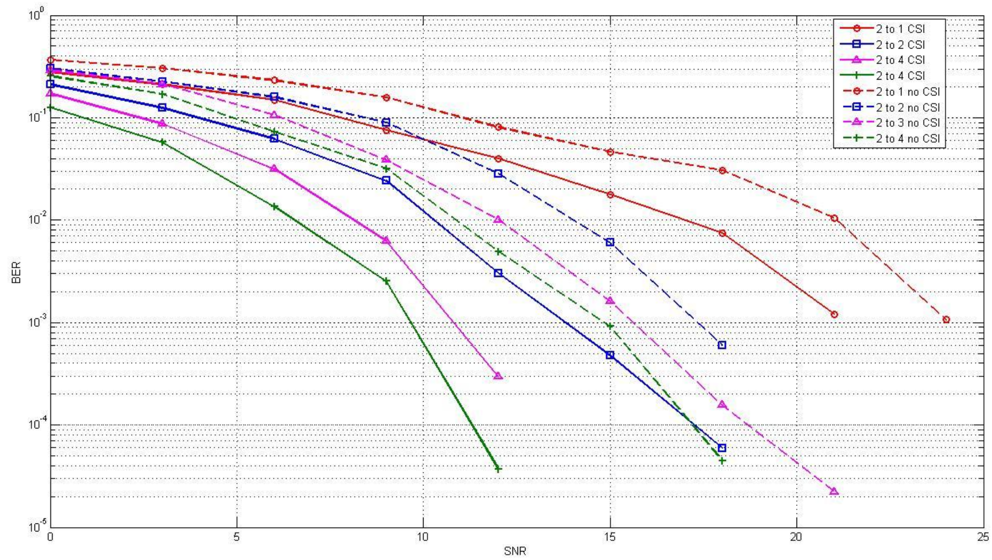

Fig. 2: Results for two transmit antennas and different numbers of receive antenna

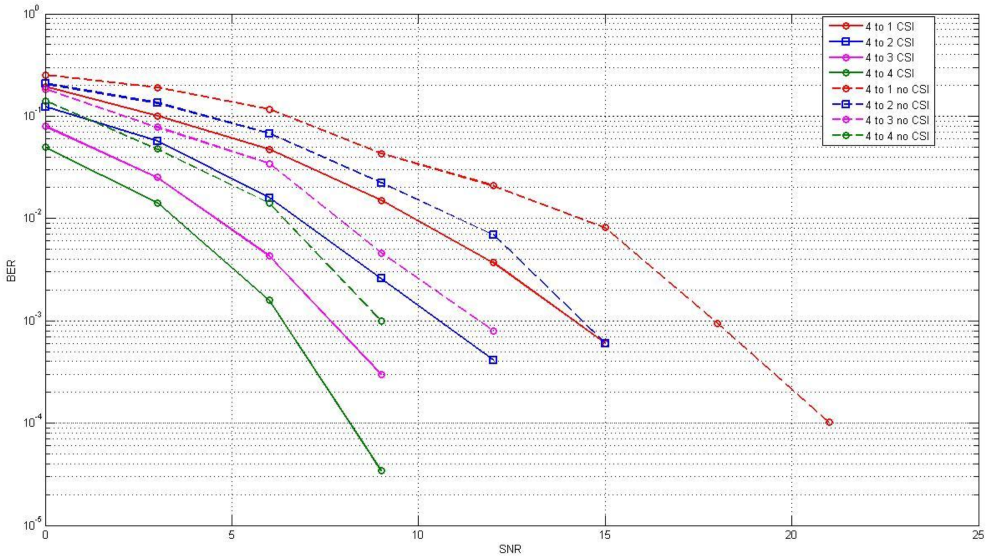

Fig. 3: Results for four transmit antennas and different numbers of receive antenna

5. Conclusions

In this paper, a new pilot aided channel estimation algorithm has been proposed. A derivation of the channel estimation has been conducted. Results for different numbers of transmit and receive antennas have been presented, showing that our scheme has a 4dB loss compared to the ideal case where the channel is assumed known at the receiver. The method can be used for any number of subcarrier; any kind of modulation and any number of transmit and receive antennas. The simplicity of our method is very attractive as it is cost and computation effective. Therefore, future work will be conducted on the further improvement of the estimation method for use in different applications using MIMO-OFDM such as WiMax or DVB-T.

References

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