The Management of Pilot Symbols in MIMO- OFDM Systems by Adding a Feedback Branch

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Abstract— **Channel estimation techniques for Multi Input Multi Output Orthogonal Frequency Division Multiplex (MIMO-OFDM) systems based on a pilot arrangement are investigated. Training based Channel estimation with a block type pilot arrangement is studied through an algorithm for determination of efficient number of pilot symbols in an OFDM symbol by adding a feedback branch and employment of the Maximal Ratio Receiver Combining (MRRC) technique as a MIMO scheme. Channel estimation at pilot frequencies is based on the Least Square (LS) method while channel interpolation is performed by a linear interpolation. Finally, the influence of the new algorithm through three different Stanford University Interim (SUI) channel models are simulated and studied. It will be shown dramatic amount of assigned bandwidth for channel estimation can be saved for data transmission by proposed technique. Moreover, a comparison between this system and a simple OFDM system without any MIMO technique is presented. Also, the Bit Error Rate (BER) performances of both systems are indicated and compared with each other at the end.**

Keywords- Channel Estimation; Cyclic Prefix (CP); Delay Spread; MIMO-OFDM.

I. INTRODUCTION

Today, Orthogonal Frequency Division Multiplex (OFDM) is known and adopted as the most popular transmission technique in manufacturing of wireless communication systems, especially in cellular systems such as Wimax [1], LTE and DVB. On the other hand, several parameters of these communication systems can be improved by Multi Input Multi Output (MIMO) schemes, by increasing the numbers of transmitter and receiver antennas. The rises of system reliability, bit rate, and the growth of coverage areas, are some samples of these improvements. Therefore, by combination of OFDM and MIMO systems in a unique system, it could be possible to gather the advantages of both mentioned systems such as efficient utilization of frequency spectrum, lower amount of inter-symbol interference (ISI), increased reliability, higher data rates and etc [2].

It is undoubted that one of the crucial steps in the recovery of data at the receiver side is Channel estimation. It could be not a very sententious idea that, the true and complete reconstruction of transmitted information is looked impossible without a suitable channel estimation technique. Hitherto, several techniques are presented as a proper channel estimation technique in MIMO-OFDM systems, which are grouped as blind and semi blind [3-5] or training based [6-12] schemes. The aim of this paper is pilot based channel estimation strategies. As it is clear, in every MIMO- OFDM system, the pilot space either in time or frequency domains is a function of some known channel parameters, like delay and Doppler spread. Several techniques have been proposed for introducing a sufficient and suitable estimation of Channel Frequency Response (CFR), with the optimal numbers of pilot symbols in each OFDM symbol.

In [6], a sparse channel estimation is referred to the estimation of the time domain channel impulse response by considering the fact that the channel has a very few nonzero taps. In this paper, a practical suboptimal solution is proposed that is a modified orthogonal matching pursuit (OMP) which exploits the sparseness structure of the MIMO channel. An iterative technique of channel estimation is proposed in [7]. In this scheme, first the pilot symbol aided (PSA) technique is used for the interpolation of the channel. At the second stage, the information bits are sent back to the channel estimator which utilizes the EM algorithm, by using of the turbo iterative decoding and a feedback path. A channel estimation scheme based on the estimation of time of arrivals (TOAs) is presented in [8]. In this paper, the TOAs are first determined by the use of a variant of probabilistic data association (PDA) and employing the minimum description length principle. After that, the PDA is augmented by group decision feedbacks to refine the TOA estimates.

Although it is doubtless that channel estimation is one of the critical and needful stages of an efficient data recovery, the costs of the assigned spectrum for pilot symbols, are sometimes so high and disallowed. In [9], an optimal pilot design for the placement of pilot symbols with the consideration of frequency offset is proposed. However, it is also demonstrated that the constant envelope (CE) condition is adequate, it is not necessary for the arrangement of pilots. In addition, the pilot symbols with multiple envelops can also achieve the optimal performance in terms of the minimization of mean square error (MSE), provided that an additional constraint on the pilot placement is satisfied simultaneously.

In [10], it is explained that the locations of the pilot

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subcarriers can't be equally spaced, because the practical system utilizes the virtual subcarriers. Therefore, it seems so hard to obtain the minimum mean square error (MMSE) of the maximum likelihood (ML) estimation. At the end, this paper presents some methods which can apply to practical MIMO-OFDM systems, the obtained locations and the power of pilot symbols. A robust MSE training signal design for the estimation of MIMO- OFDM channel model with frequency offset and phase noise is developed in [11], especially for the moderate to high amounts of signal to noise ratio (SNR).

In most of these presented estimation techniques, it is considered that there is not a real-time management strategy for the determination of the number of pilot symbols. This problem was questioned in [12] for an OFDM system, and a new scheme for the updating on the numbers of pilot symbols in each OFDM symbol by adding a feedback branch to an simple OFDM system was presented on that paper. Here the authors want to assess this new method on a MIMO-OFDM system which uses the MRRC strategy as an MIMO scheme, and compare the results of this system with the prior OFDM system.

In this paper, first a model of a MIMO-OFDM system which uses the MRRC scheme is presented in the next section. Afterwards the new scheme which was presented in [12] is explained in section III, and some new conditions of the new system are defined for the use of this technique. Then the simulation conditions are explained and simulation results are presented in the next section. SUI [13] channels models are thought as the channel models at the simulation in this paper. At the end, section IV is assigned for conclusion and the argument about the results of the simulations.

II. System Model

The main purpose of the FDM technique is the conversion of a serial data stream with an arbitrary length of LN symbols at a time interval of T seconds into N parallel data sub-streams which each sub-stream has a length of L symbols, and the period of T seconds. By this method, it could be possible to reduce the amounts of ISI in wireless communication systems. On the other hand, the efficiency of these systems can be improved by adding the concept of Orthogonality to the FDM technique. On the other words, by adding Inverse Discrete Fourier Transform (IDFT) and DFT blocks to these systems and without any increase in their bandwidth, they can send higher amounts of information with higher data rates. This new scheme is known as OFDM. The IDFT is defined as:

$$x_m(n) = IDFT\{X_m(k)\} = \sum_{k=0}^{N-1} X_k(k) e^{j2\pi nk/N} \qquad 0 \le n \le N-1 \qquad (1)$$

Moreover, the use of multiple antennas which is known as MIMO techniques, either in transmitter or in receiver sides creates independent channels in space. Receive diversity, transmit diversity, beam forming, and spatial multiplexing are some examples of MIMO techniques. A model of an arbitrary MIMO-OFDM system which uses the $1\times N_R$ MRRC scheme as a MIMO technique is shown in figure 1. In this paper, the number receiving antennas are equal to $N_R=2$. On the other words, the structure of the transmitter in this system is like the structure of a simple OFDM transmitter. The working model of the proposed system, is explained in continue.

In transmitter, first the serial streams of data bits with durations of T seconds are separated into N parallel sub-streams; each one has a period of T seconds, by the serial to parallel convertor (S/P) block. After that, the IFFT of the paralleled sub-streams are calculated by the Inverse Fast Fourier Transform (IFFT) block. Then the acts of CP insertion and summation of time domain sub-streams are done simultaneously, by using of a parallel to serial block convertor (P/S). The CP insertion has two advantages for these kinds of systems. The first and the more important benefit of this work is the use of IFFT and FFT in practice. Adding cyclic prefix to the transmitted signal creates a signal which appears to be periodic in the receiver side. On the other hand, if the length of CP is longer than the impulse response of the channel, the ISI between OFDM symbols can be eliminated completely. At the end the resultant signal is transmitted through the fixed wireless channel by the transmitting antenna.

A set of six SUI channel models are considered to be the channel models of the proposed fixed wireless communication system. The multipath fading of these channels is modeled as a tapped delay line with three non-uniform delay taps. These channel types represent three terrain types and a large variety of Doppler and delay spreads with two kinds of Omni-directional and directional antennas.

In this paper it is assumed that the channel conditions are approximately constant in a period of several OFDM symbols. In other words, it is considered that the channel parameters are like some random variables, in which each one has a uniform distribution with an arbitrary mean and a very small variance.

The structure of the receiver is a little more complicated in comparison with a simple OFDM system which was used in [12]. It is considered that the receiver uses the 1×2 MRRC receive diversity technique to recover the transmitted information which is known as the most prevalent form of spatial diversity that is this system has two receiving antennas. On the other words, a combination of the information from both received branches is used to determine the amount of the transmitted data. At the first stage, the receiver catches two different copies of the transmitting data with its receiving antennas, which are arrived from two different paths between the transmitter and the receiver. Then by using the Fast Fourier Transform (FFT) after the simultaneous acts of CP deletion and S/P conversion in each branch, the baseband form of these signals can be written as:

$$R_1 = H_1 S + N_1 \qquad (2)$$

$$R_2 = H_2 S + N_2 \qquad (3)$$

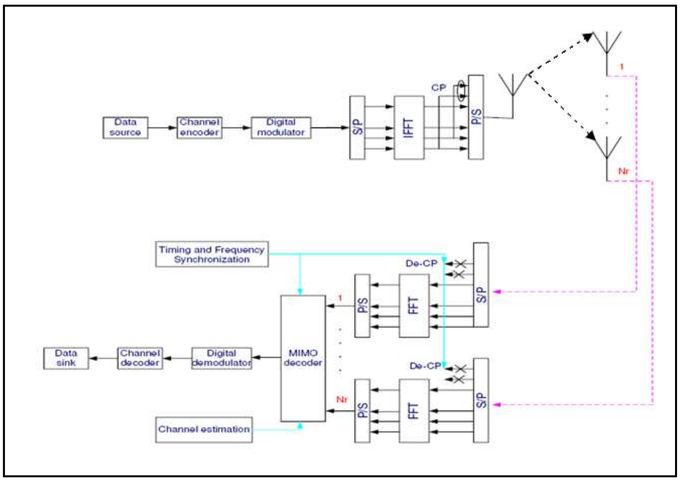

Figure 1. A block digram for a MIMO-OFDM transceiver which uses the resceive diversity scheme (SIMO-OFDM)

Where N_i and H_i represent complex noise with interference, and the complex coefficient of the ith branch of the channel. With the assumption that N_1 and N_2 are Gaussian distributed, and the using of the maximum likelihood decision rule at the receiver, it could be possible to determine that the ith symbol is sent if and only if:

$$d^2(R_1, H_1S_i) + d^2(R_2, H_2S_i) \leq d^2(R_1, H_1S_k) + d^2(R_2, H_2S_k) \quad ; \forall\, i \neq k \tag{4}$$

Where is the Euclidean distance between x and y. The MRRC scheme for two branches calculates this equation:

$$\tilde{S} = {H_1}^* R_1 + {H_2}^* R_2 \tag{5}$$

In conclusion, by using (5) and the expansion of (4), the decision rule equation for PSK signals which are employed in this paper for data modulation scheme, can be simplified as:

$$d^2(\tilde{S}, S_i) \leq d^2(\tilde{S}, S_k) \qquad ; \forall\, i \neq k \tag{6}$$

The last key point of the proposed systems could be mentioned by a question. As it can be seen, the MMRC technique requires knowing about the coefficients of the channel. Therefore, how the receiver can be aware of the channel response? Therefore the need of using an appropriate channel estimation scheme seems inescapable. The training based channel estimation technique with the block type arrangement is considered to be the chosen channel estimation technique in this paper. The proper distance between the pilot symbols is obtained by the equation:

$$N_P^f = 1/\Delta f.\sigma_\tau \tag{7}$$

Where, Δf and σ_τ are the bandwidth of a subcarrier, and delay spread respectively. In this paper the method which was considered to be use in [12] is used for the estimation of delay spread. In this technique, first the power delay profile (PDP) is estimated from the channel frequency correlation (CFC) which is calculated by the estimated symbols at the receiver. At the end, the root mean square (RMS) value of delay spread can be calculated by this equation:

$$\sigma_\tau = \sqrt{\overline{\tau^2} - \bar{\tau}^2} \tag{8}$$

Where the amounts of $\bar{\tau}$ and $\overline{\overline{\tau^2}}$ can be obtained by:

$$\bar{\tau} = \frac{\sum_k P(\tau_k)\tau_k}{\sum_k P(\tau_k)} \tag{9}$$

And

$$\overline{\tau^2} = \frac{\sum_k P(\tau_k){\tau_k}^2}{\sum_k P(\tau_k)} \tag{10}$$

Where τ_k and $P(\tau_k)$ are the amount of delay for the kth tap, and kth tap of the channel PDP. These delays are measured relative to the first detectable signal arriving at the receiver at $\tau_0 = 0$ [12].

At the end of this section, this idea is introduced whether it is impossible for the transmitter to control and manage the number of pilot symbols in each OFDM symbol for the duration of time or not. As it was explained in [12] the number of pilot symbols can be changeable if there were a feedback branch between the receiver and the transmitter. This feedback branch could be helpful in the knowledge of the transmitter about the variations of the channel status. As it was explained about the channel conditions before, it seems that it can be possible to utilize the reminded feedback branch in every period of time which is equal to the average time of the explained uniform distribution of channel parameters.

III. SIMULATION RESULTS

The proposed MIMO-OFDM system in section II, with the number of 1024 sub-carriers is simulated and analyzed in this section, which 960 numbers of them are used for the transition of data and pilot symbols in each OFDM symbol. These simulations are surveyed in 3 types of SUI channel models, which are types I, III and V. each simulation is performed in three sets of the number of pilot symbols in each channel type, which are The maximum, the minimum, and the floating number of pilot symbols between them. The maximum and minimum numbers of pilot symbols are considered to be 40 and 4 symbols respectively. At the end, the results of these simulations are compared with the simulation results of the presented simple OFDM system in [12]. The statistical distribution of time variations of the channel is assumed to be uniform with the average of 10 OFDM symbols between 9 and 11 OFDM symbols. Therefore, the time duration of every feedback signal is supposed to be 10 OFDM symbols. It is clear that with the proposed technique the behavior of the system BER performance in the case that the floating numbers of pilot symbols are used is remain near to the BER performance in the case which the maximum number of pilot symbols are used.

On the other hand, in comparison with the case which the maximum numbers of pilot symbols are sent, there is a dramatic decrease in the average amount of sent pilot symbols when the floating algorithm is used. Another comparison can be performed between the OFDM and MIMO-OFDM systems. It is clear from the pictures 2 to 4 that the BER performance in the case which MRRC technique is used is quiet smaller than the case which not any MIMO technique is used.

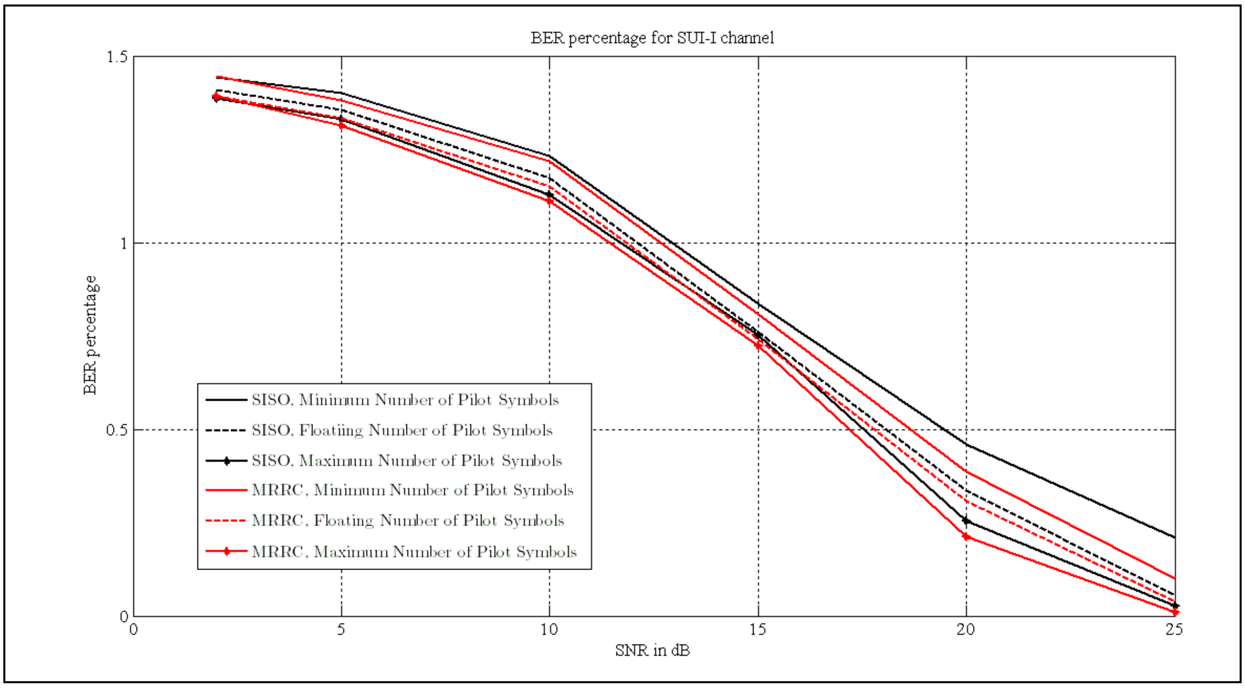

Figure 2. BER performance for a type I SUI channel

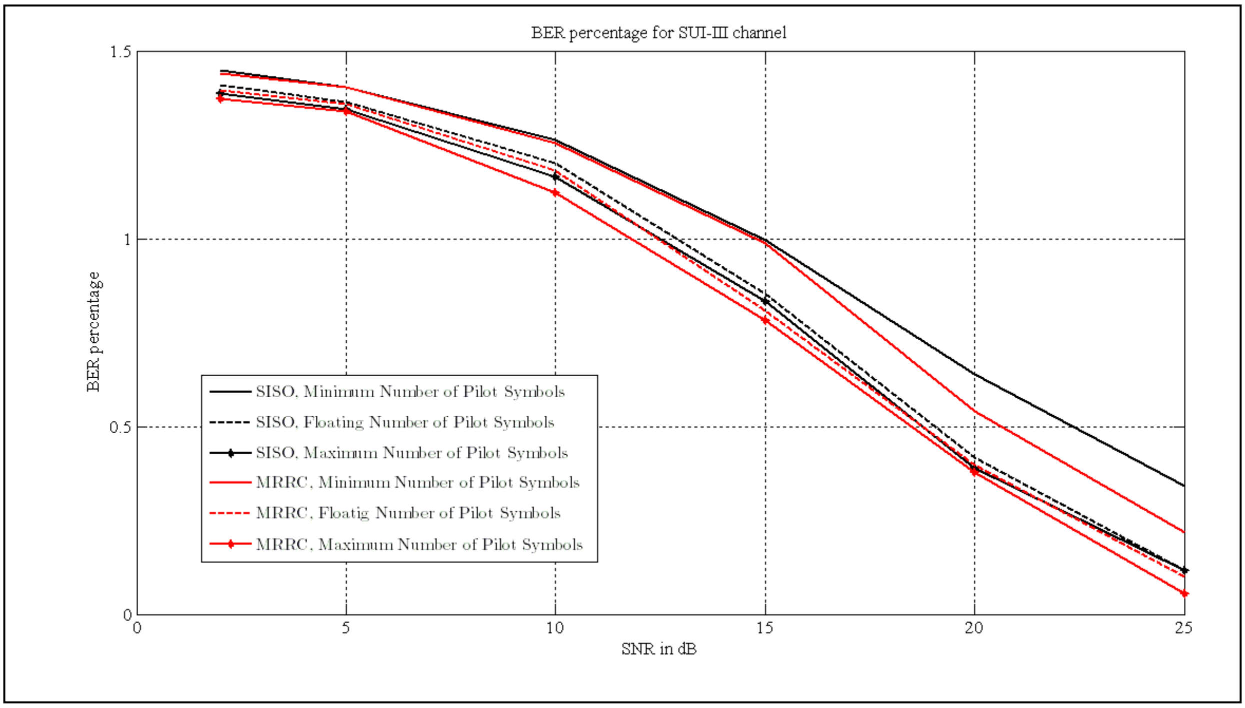

Figure 3. BER performance for a type III SUI channel

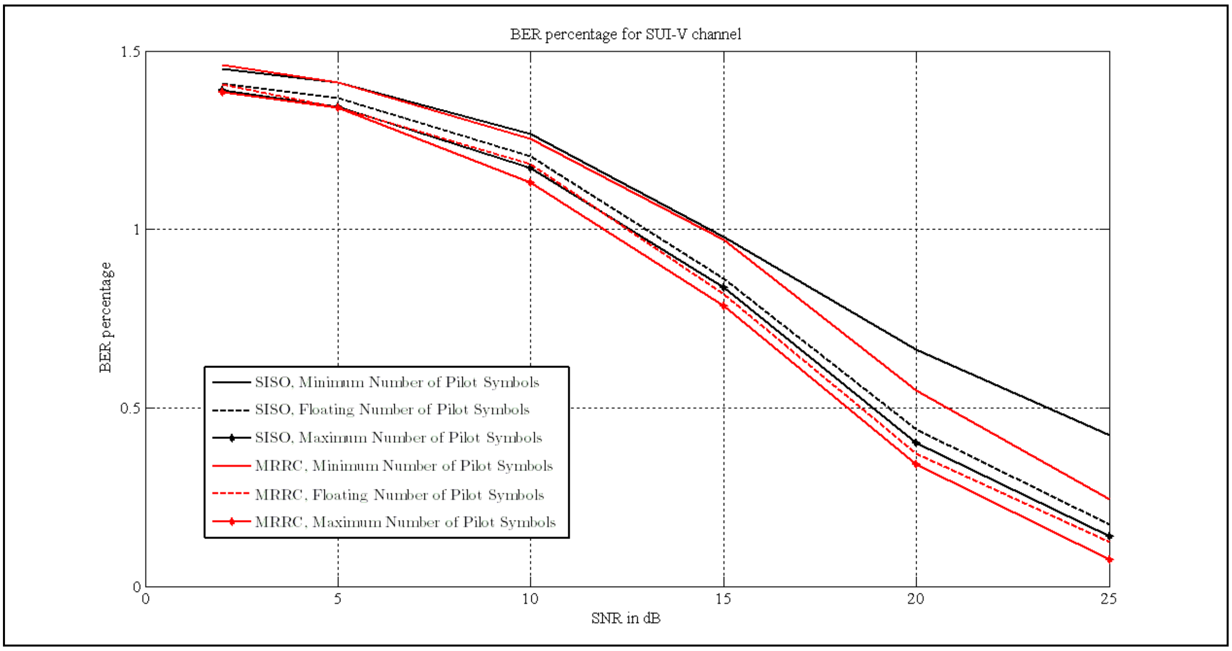

Figure 4. BER performance for a type V SUI channel

IV. CONCLUSION

It is clear that channel estimation is one of the vital stages of every wireless communication system. This paper focuses on pilot based channel estimation techniques. The main aim of the authors is introducing a new scheme for controlling and the management of assigned bandwidth for the pilot symbols, when the channel parameters change by passing of time. By this work, system can choose the optimum amount of pilot symbols and the efficiency of the channel improves clearly. The attention of this paper is on the assessment of this technique in a MIMO-OFDM system which uses the MRRC technique as a MIMO scheme, and making a comparison between the results of proposed system and a simple OFDM system.

As it can be seen from figures 2 to 4, by utilizing the MRRC technique, the performance of the proposed system in comparison with a simple OFDM system, has a significant growth, especially in higher amounts of SNR.

On the other hand, by adding a feedback branch, an obvious fall in the amount of assigned bandwidth for the pilot symbols in comparison with the case which the maximum number of pilot symbols is sent by the transmitter can be observed.

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