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Adaptive Channel Estimation Technique in MIMO-OFDM System for Wireless Communication System

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ABSTRACT: Multiple Input Multiple Output (MIMO) in combination with Orthogonal Frequency Division Multiplexing (OFDM) can provide spectrally efficient and ISI free communication. Channel estimation is of great importance in order to recover the signal at the receiver side. Therefore accurate channel state information is essential for proper detection and decoding in MIMO-OFDM wireless systems. To estimate channel state information various types of techniques are being deployed in these systems. Accuracy and precision of channel estimation depends on the techniques used for the purpose of estimating channel state information. The more accuracy of the technique more will be the accurate performance of the system. In this paper an enhanced adaptive channel estimation using normalized least mean square (NLMS) technique has been proposed. This technique provides better performance which can be judged by the BER performance compared than the previous algorithm i.e. least mean square (LMS) and recursive least square (RLS).

KEYWORDS: Least Mean Square (LMS), Recursive Least Square (RLS), Normalized Least Mean Square (NLMS)

I. INTRODUCTION

Orthogonal frequency division multiplexing (OFDM) has been accepted as a promising air –interface due to its high spectrum efficiency. High spectrum efficiency is provided due to the fact that in this whole spectrum is shared by all the OFDM sub carriers that are orthogonal to each other. FFT and IFFT operations are used in OFDM due to which the oscillators are not required at the transmitter and receiver side. Thus it reduces the complexity at transmitter and receiver and also they are fast algorithms for implementing DFT and IDFT which decreases the computation complexity as compared to DFT and IDFT. Moreover it provides ISI free communication due to the use of CP (cyclic prefix) which is just the repetition of tail of the symbol at the front part of the symbol. OFDM acts as a standard for many wireless applications like Digital Video Broadcasting (DVB), Digital Audio Broadcasting (DAB) [1], WIMAX, Wireless Local Area Network (WLAN) and ADSLs [2].

If multiple transmit and receive antennas are used then the capacity of the system can be increased. The systems which use multiple antennas at the transmitter and receiver are called MIMO systems [3]. The capacity of the MIMO system can be improved by a factor equal to minimum number of antennas employed at the transmitter and receiver. Transmission rate is increased in case of spatial multiplexing while BER enactment is improved in case of spatial diversity. Therefore, these are widely used in many wireless applications in combination with OFDM forming MIMO-OFDM system. Parallel transmission is done by dividing whole channel into many sub-channels, thus attaining high data rate and increasing symbol duration to battle ISI. STBCs are used to increase the diversity gain in MIMO systems. Channel capacity and multiplexing gain is increased by spatial multiplexing (SM) [4]. The challenging problem for wireless systems is channel estimation. In wireless systems channels are dynamic in nature as compared to guided media. The signal is received at the receiver after undergoing many adverse effects due to reflection, scattering and diffraction and that too from multipath. Channel response is time variant due to mobility of transmitters, receivers and other obstacles. The signal spreads over the statistics like frequency, time, phase. These statistics define the channel

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selectivity and has a great impact on received signal. These effects of the channel on its response have to be known which is known as channel estimation or channel state information estimation. For data detection and equalization we need channel State Information (CSI) at the receiver side. Broadly if we classify channel estimation then there are two ways for channel estimation- one is the Training based channel estimation and second one is blind channel estimation. There is also one more of its type called semi blind channel estimation because it employs both of the techniques. It is the combination of the above two. Training based channel estimation uses two types of pilot types i.e. block type and comb type [5]. In comb type the pilots are inserted into certain sub-carriers of each OFDM symbol and not in all the subcarriers while in case of block type the pilots are inserted into all sub-carriers of OFDM symbol within some predefined period. Also comb type is mostly used for fast fading channels while the bock type is used for slow fading channels. Comb type pilot organization outperforms block type pilot organization. Other type is the blind channel estimation which exploits the statistical facts of the symbols that are received at the receiver. But this type of channel estimation can only be used for slow time varying channels. Moreover this type of channel estimation technique increases the complexity at the receiver. Although pilot based channel estimation (CE) consumes bandwidth more than blind type but it is a good candidate for fast time varying channels [6]. Adaptive CE algorithms are gaining more attention these days. Least Mean Square (LMS) is widely used for its simplicity. If complexity is not an issue then Recursive Least Square (RLS) is a good choice. Moreover to use the best part of the above given Adaptive Channel Estimation (ACE) algorithms they can be combined to build the hybrid algorithms. Leaky Least Mean Square (LLMS) [7] algorithm is such an algorithm.

II. SYSTEM MODEL

MIMO in combination with OFDM is widely used nowadays due its best performance in terms of capacity of channels, high data rate and good outcome in frequency selective fading channels. In addition to this it also improves reliability of link. This is attained as the OFDM can transform frequency selective MIMO channel to frequency flat MIMO channels [8]. So it is widely used in future broadband wireless system/communications. Cyclic prefix is the copy of last part of OFDM symbol which is appended to the OFDM symbol that is to be transmitted. It is basically 0.25% of the OFDM symbol. We can say that one fourth of the OFDM symbol is taken as CP (cyclic prefix) and appended to each OFDM symbol. IFFT is used at the transmitter and FFT is used at the receiver which substitutes the modulators and demodulators. Doing so eliminates the use of banks of oscillators and coherent demodulators. Moreover the complex data cannot be transmitted as it is, therefore it is first converted to analog form which is accomplished by IFFT. It basically converts the signal from frequency domain to time domain. Prior to IFFT operation symbol mapping is performed which is nothing but the modulation block. Any of the widely used modulation techniques can be applied like BPSK, QPSK, QAM, PSK etc. Further there are higher order modulations are also available which provide more capacity at little expense of BER performance degradation. After IFFT block pilot insertion is done and then CP (cyclic prefix) is added. Figure 1 below shows the block diagram constituting MIMO and OFDM. Any antenna configuration for the MIMO can be used according to the system requirement. Higher the configuration more will be the capacity and more will be the computational complexity of the transceiver design. It is seen that in the case of estimating channel the computational complexity is increased. Mapper defines the modulation to be used. Symbol encoder takes the shape of the STBC (Space Time Block Code) if spatial diversity is to be used and it takes the shape of the de-multiplexer/multiplexer if spatial multiplexing is to be used.

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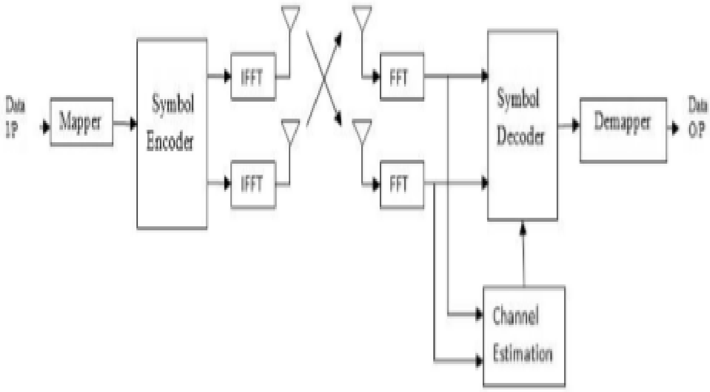

Figure 1: MIMO-OFDM system model

The received signal at j^{th} antenna can be expressed as

$$R_j[n.k] = \sum H_{ij}[n,k]\, X_i\, [n,k] + W[n,k] \qquad (1)$$

Where H is the channel matrix, X is the input signal and W is noise with zero mean and variance. Also $b_i[n,k]$ represents the data block i^{th} transmit antenna, n^{th} time slot and k^{th} sub channel index of OFDM. Here i and j denoted the transmitting antennas index and receiving antenna index respectively.

The MIMO-OFDM system model [9] with NR receives antennas and NT transmits antennas can be given as:

$$\begin{bmatrix} Z_1 \\ Z_2 \\ \vdots \\ Z_N \end{bmatrix} = \begin{bmatrix} H_{1,1} & H_{1,2} & \dots & H_{1,NT} \\ H_{2,1} & H_{2,2} & \dots & H_{2,,NT} \\ \vdots & \vdots & \ddots & \vdots \\ H_{NR,1} & H_{NR,2} & \dots & H_{NR,NT} \end{bmatrix} \begin{bmatrix} A_1 \\ A_2 \\ \vdots \\ A_{NT} \end{bmatrix} + \begin{bmatrix} M_1 \\ M_2 \\ \vdots \\ M_{NT} \end{bmatrix} \qquad (2)$$

Where, Z represents O/P data vector, H denotes Channel matrix, A denotes I/P data vector and M represents Noise vector. The wireless channel used is AWGN channel. After receiving the signal the CP is removed then the pilots are also removed from main signal received. After this the signal that is in time domain can be again converted to frequency domain by taking FFT of the received signal.

The sequence on each of the OFDM block is then provided to channel estimation block where the received pilots altered by channel are compared with the original sent pilots. Channel estimation block consists of the algorithms that are applied to estimate the channel [10].

III. ADAPTIVE CHANNEL ESTINATION

CE (channel estimation) methods are divided into two types. One is training based and the other one is blind i.e. without training sequences. There are various types of channel estimations and broadly they can be classified as Training based estimation, semi blind estimation and blind channel estimation. Training based requires pilot bits to be sent along with the data. Arrangement of pilot bits can be block type and comb type [11]. In block type transmission of pilot is done on each and every subcarrier at successive intervals of time. While in comb type pilots are sent for whole time i.e. pilots are implanted into apiece OFDM emblem. Blind channel approximation is done by exploiting the statistical [12] properties of the network. It is advantageous to use as it does not wastes bandwidth as no pilots are needed. But it has performance less than pilot based so rarely used. Moreover it makes the receiver more complex.

Adaptive CE (channel estimation) methods or algorithms are being widely deployed in channel estimation. As we know that the wireless channel is time varying and totally random in nature. Therefore to keep track of it an adaptive

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algorithm best suits it. This CE algorithm after successive iterations converges to the optimum solution [8]. Also they provide good tracking capability. Various adaptive CE estimators available are LMS, RLS, and NLMS etc. They continuously update their parameters until they reach the optimum solution. Moreover they need only the received signal which includes the training sequences which were sent at the transmitter. These are known to the receivers which are used by these adaptive CE algorithms to check the error value or we can say that to minimize the error value in order to reach the optimum solution. Updating the parameters is dependent on the step size parameter in case of stochastic gradient algorithms.

The greater the step size the more will be the convergence speed. The time required by the algorithm to reach the optimum solution decreases hence the steady state error is reached. While if it increases too much then there is a chance that system may become unstable. If the case of recursive algorithms is seen we see that they are not dependent on the step size parameter, thus making them good and fast estimators. But there is a con in them i.e. they are very complex. Their complex structure requires more hardware cost also. Though they are faster than stochastic gradient algorithm but complexity marks them as unusable but now the scenario is changing with the improved hardware structures in use.

Least mean squares (LMS) algorithms are class of adaptive filter used to mimic a desired filter by finding the filter coefficients that relate to producing the least mean squares of the error signal (difference between the desired and the actual signal). It is a stochastic gradient descent method in that the filter is only adapted based on the error at the current time. The basic idea behind LMS filter is to approach the optimum filter weights (R-1 P), by updating the filter weights in a manner to converge to the optimum filter weight. The algorithm starts by assuming a small weights (zero in most cases), and at each step, by finding the gradient of the mean square error, the weights are updated. That is, if the MSE-gradient is positive, it implies, the error would keep increasing positively, if the same weight is used for further iterations, which means we need to reduce the weights.

Structure and Operation of NLMS:-

In the form of constructional view, the normalized LMS filter is exactly the same as the standard LMS filter, as shown in the Figure 2. Fundamental concept of both the filter is transversal filter.

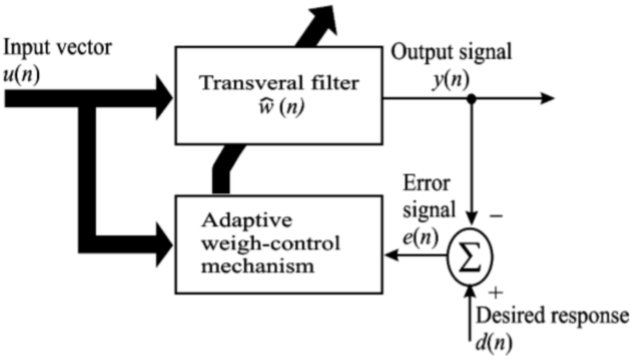

Figure 2: Block diagram of adaptive transversal filter

The normalized LMS filter gives minimal disturbance and may be stated as follows: gradually by different iterations weight vector will change in straight weight will change step by step, it is controlled by updated filter output and its proposed values.

IV. FLOW OF ALGORITHM

The MIMO-OFDM system was implemented with the aid of MATLAB/SIMULINK. The execution process is binary data that is modulated using BPSK and mapped into the constellation points.

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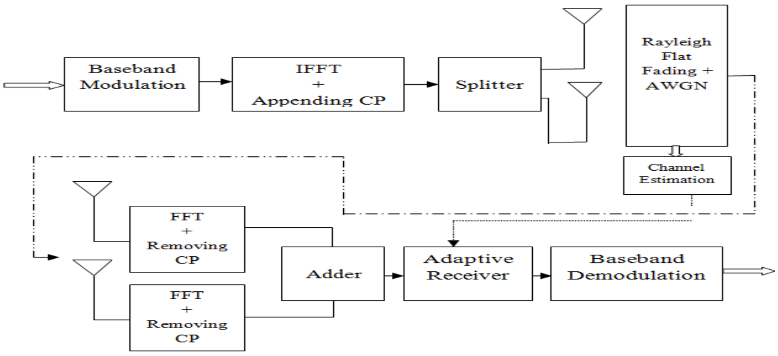

Figure 3: 2x 2 MIMO-OFDM System Models with Adaptive Filter

The digital modulation scheme will transmit the data in parallel by assigning symbols to each sub channel and the modulation scheme will determine the phase mapping of sub-channels by a complex I-Q mapping vector show in Figure 3. The complex parallel data stream has to be converted into an analogue signal that is suited to the transmission channel. This is performed by the Inverse Fast Fourier Transform (IFFT). IFFT converts the signal to the time domain since OFDM treats the transmitted symbols as they are in the frequency domain.

V. SIMULATION RESULT

In simulations it is assumed that the system is perfectly synchronized. Different values of SNR are taken and the performance is checked.

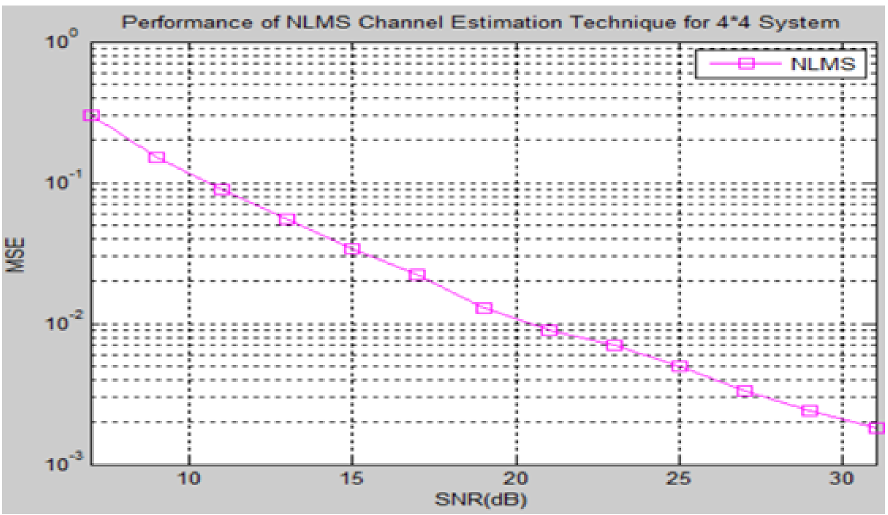

Figure 4: Performance MSE for 4×4 MIMO-OFDM Systems

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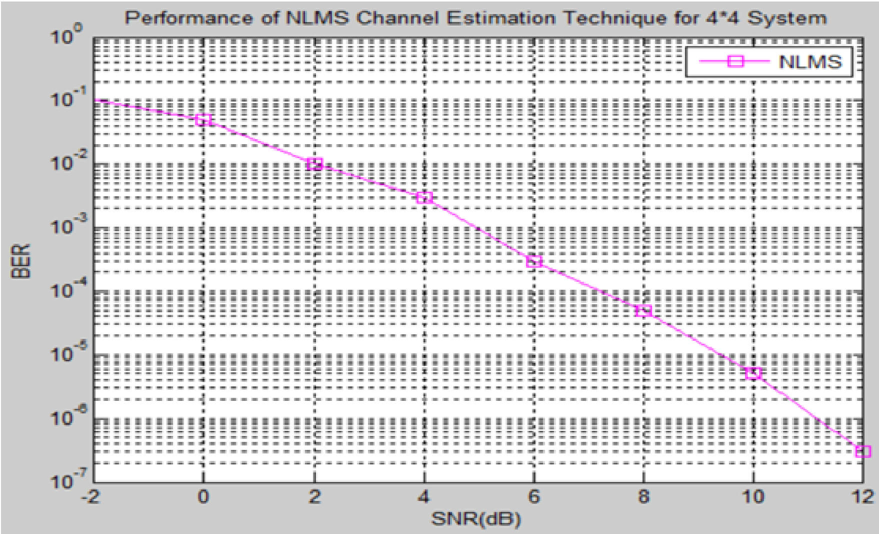

Figure 5: Performance BER for 4×4 MIMO-OFDM Systems

VI. CONCLUSION

Estimation of the channel coefficients is a challenging task in MIMO-OFDM systems. Moreover it complex task than in simple OFDM systems. In this paper an enhanced technique for channel state information estimation in MIMO-OFDM systems has been presented. The technique discussed above is based on training sequence based channel estimation. It is concluded that NLMS algorithm outperforms LMS, RLS algorithm. But the former has a disadvantage as it is more complex than latter.

NLMS is complex but the MSE value is less than the LMS, RLS algorithm. Means convergence speed is more than LMS. Its error floor is also lower. BER performance of NLMS is better than LMS and RLS algorithm.

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