PILOT BASED CHANNEL ESTIMATION FOR MIMO- OFDM SYSTEMS

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***Abstract*— In this paper to improve the channel estimation accuracy in OFDM system , channel state information is required for signal detection at receiver and its accuracy affects the overall performance of system and it is essential to improve the channel estimation for more reliable communications. This paper addresses channel estimation based on time-domain channel statistics, using a general model LS (least square), MMSE (minimum mean square estimation) and BLUE (best linear unbiased estimation) estimators for a slowly fading channel. Depending upon estimator complexity, up to 30 dB in SNR can be gained over the LS estimator. In this work we have compared different type of channel estimation algorithm for Orthogonal Frequency Division Multiplexing systems. Mat lab simulation results the Bit error rate for the algorithms LS, MMSE, BLUE are compared.**

Keywords- MIMO- OFDM , LS, MMSE, BLUE

I. INTRODUCTION

OFDM is becoming widely applied in wireless communications systems due to its high rate transmission capability with high bandwidth efficiency and its robustness with regard to multi-path fading and delay. It has been used in digital audio broadcasting systems, digital video broadcasting systems, digital subscriber line standards, and wireless LAN standards and its European equivalent HIPRLAN/2.The use of Binary phase-shift keying (BPSK) in OFDM systems avoids need to track a time varying channel. Coherent modulation allows arbitrary signal constellations, but efficient channel estimation strategies are required for coherent detection and decoding. There are two main problems in designing channel estimators for wireless OFDM systems. The first problem is the arrangement of pilot information, where pilot means the reference signal used by both transmitters and receivers. The second problem is the design of an estimator with both low complexity and good channel tracking ability. The two problems are interconnected. In general, the fading channel of OFDM systems can be viewed as a two-dimensional signal time and frequency[1]. The combination of high data rates and low bit error rates in OFDM systems necessitates the use of estimators that have both low complexity and high accuracy, where the two constraints work against each other and a good trade-off is needed. The channel estimations are usually adopted in OFDM systems to accomplish the trade-off between complexity and accuracy. The basic channel estimations are block-type pilot channel estimation and comb type pilot channel estimation, in which the pilots are inserted in the frequency direction and in the time direction, respectively. The block-type pilot arrangement has been estimated for its higher accuracy and reduced complexity. To reduce the Bit-Error Rate in the channel, three algorithms namely Least square algorithm (LS),Minimum mean square algorithm (MMSE), Best Linear Unbiased Estimation algorithm (BLUE) have been implemented.[2]

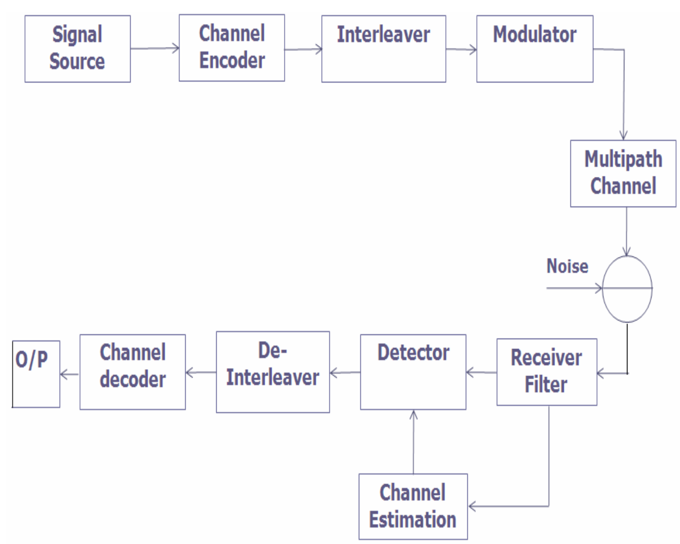

Figure 1.Block Diagram of OFDM System

II. CHANNEL ESTIMATION

A wideband radio channel is normally frequency selective and time variant. For an OFDM mobile communication system, the channel transfer function at different subcarriers appears unequal in both frequency and time domains. Therefore, a dynamic estimation of the channel is necessary[3]. Pilot-based approaches are widely used to estimate the channel properties and correct the received signal There are two types of pilot arrangements. The first kind of pilot arrangement is denoted as block-type pilot arrangement. The pilot signal assigned to a particular OFDM block, which is sent periodically in time-domain This type of pilot arrangement is especially suitable for slow-fading radio channels. Because the training block contains all pilots, channel interpolation in frequency domain is not required.

Therefore, this type of pilot arrangement is relatively insensitive to frequency selectivity. The second kind of pilot arrangement is denoted as comb-type pilot arrangement. The pilot arrangements are uniformly distributed within each OFDM block[4]. assuming that the payloads of pilot arrangements are the same, the comb-type pilot arrangement has a higher re-transmission rate. Thus the comb-type pilot arrangement system is provides better resistance to fast-fading channels. Since only some sub-carriers contain the pilot signal, the channel response of non-pilot sub-carriers will be estimated by interpolating neighboring pilot sub-channels. Thus the comb-type arrangement is sensitive to frequency selectivity when comparing to the block-type pilot arrangement system.

In block-type pilot based channel estimation, OFDM channel estimation symbols are transmitted periodically, in which all sub-carriers are used as pilots. If the channel is constant during the block, there will be no channel estimation error since the pilots are sent at all carriers. The estimation can be performed by using either LS , MMSE and BLUE[5]

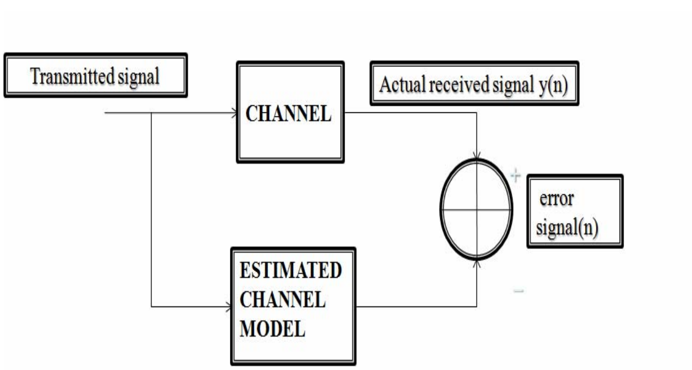

Figure 2. Channel estimation Model

III. MINIMUM MEAN SQUARE ESTIMATION

In orthogonal frequency division multiplexing (OFDM) systems, the frequency domain channel coefficients at the different subcarriers are correlated. If this correlation between the channel coefficients at the different subcarriers is known, minimum mean-square error (MMSE) channel estimation can be performed in the frequency domain. Time domain maximum likelihood estimator can achieve highly accurate impulse response estimation by using a time domain long preamble of an OFDM frame. On the other hand, the impulse response estimation based on the minimum mean square error criterion can achieve superior channel estimation in low SNR conditions. However, it requires prior statistical information such as delay profiles of channel[6]. In addition, the computational complexity becomes large because of the inverse matrix calculation in order to overcome these implementation issues, to estimate the statistical values based on the observed information of the channel. The MMSE showed superior BER performance in low SNR_s. however, the implementation of MMSE was difficult because it requires prior information of the delay profile. It is the task of the receiver to exploit both the structure of the transmit symbol constellation and the structure of the code to detect and decode the transmitted data sequence. When the data has been protected with a convolution code, improvements in the BER can be easily obtained through the use of a soft-input convolution decoder, with negligible increase in computational complexity. There is an increase in hardware complexity. Most practical communication systems also insert an interleaver after the encoder in the transmitter and a deinterleaver before the decoder. The process of interleaving permutes the symbols within a given block of data and, therefore, tends to decorrelate error events introduced by the equalizer between neighboring symbols.

Consider an N-subcarrier OFDM system. Let X_k be the frequency domain symbol modulated onto the k^{th} subcarrier. There are no null subcarriers. The complex baseband time domain data x_n for n=0,1,…..N-1 is given by the Inverse Discrete Fourier Transform(IDFT) of the N-point sequence $X=[X_0\ X_{1\dots\dots\dots}X_{N-1}]$. Prior to transmission, a cyclic prefix of N_g complex symbols is put at the beginning of the time domain sequence $x=[x_0\ x_1\dots\dots\dots x_{N-1}]$. This $N+N_g$ term complex sequence by x^{CP} and the n^{th} term of the sequence x^{CP} by x_n^{CP}. The sequence x^{CP} is transmitted through the multipath channel.

Consider a sample spaced multi path channel described by an L-tap complex random vector h, such that

$h= [h_{0\ ,}h_1\ \dots\dots\dots h_{N-1}]^T$

where h_i are independent zero mean complex Gaussian random variables. The channel PDP is given by an l-element vector p, whose element p_i are

$p_i=\frac{1}{2}E\left(|h_i|^2\right)$ i=0,1,…….,L-1

The channel is normalized such that $\sum_{i=0}^{L-1} pi = 1$

The time domain channel output when the sequence x^{CP} is transmitted through the channel h is given by,

$$y_m = \sum_{i=0}^{L-1} h_i x_{m-1}^{CP} + w_m \quad \text{m=0,1,…..,N+N}_g\text{+L-2} \qquad (1)$$

Where w_m represents additive Gaussian noise(AWGN). In deriving above equation assumed that the $x_i^{CP} = 0 \forall i < 0$.

This is equivalent to ignoring the impact of the previous OFDM symbols[7]. The timing synchronization mechanism extracts an N-point sequence y^{τ} from the received data with discrete random variable N_o , which represents the timing offset in the number of samples, counted from the perfect synchronization point, If $N_0=n_0$, we have

$$y^{\tau} = \left[yN_g - n_0 yN_g - n_0 + 1......yN_g - n_0 + N - 1 \right]^T \quad (2)$$

An N-point Discrete Fourier Transform transforms the sequence y^{τ} into the frequency domain.

If the channel vector g Gaussian and uncorrelated with channel noise n, MMSE estimate of g becomes

$$\hat{g}_{MMSE} = R_{gy} R_{yy}^{-1} y$$

Where

$$R_{gy} = E\left\{ g y^H \right\} = R_{gg} F^H X^H$$

$$R_{yy} = E\left\{ Y Y^H \right\} = X F R_{gg} F^H X^H + \sigma_n^2 I_N$$

are the cross covariance matrix between g and y and the auto covariance matrix of y. Further, R_{gg} is the auto covariance matrix of g and σ_n^2 denotes the noise variance $E\left\{ | n_k |^2 \right\}$ These two quantities are assumed to be known. Since the columns in F are orthogonal, $\hat{g}_{MMSE}$ generates the frequency domain MMSE estimate $\hat{h}_{MMSE}$ by

$$\hat{h}_{MMSE} = F \hat{g}_{MMSE} = F Q_{MMSE} F^H X^H y \quad (3)$$

$$Q_{MMSE} = R_{gg} \left[\left(F^H X^H X F \right)^{-1} \sigma_n^2 + R_{gg} \right]^{-1} \left(F^H X^H X F \right)^{-1}$$

IV. BEST LINEAR UNBIASED ESTIMATION

Minimize the error variance for each of the *n* parameters if the estimator to be linear in data and find the linear estimator that is unbiased and minimum variance then the estimator is called Best Linear Unbiased Estimator . BLUE can be determined with the knowledge of only the first and second moment of the PDF. Since complete knowledge of the PDF is not necessary, the BLUE is more suitable for practical implementation. This has formulated the BLUE channel estimate for communication systems which utilize a periodically transmitted training sequence. Due to high complexity BLUE channel estimator has limited implementation[8]. This algorithm is best suited for communication systems which utilizes a periodically training sequence within a continuous stream of information symbols, and the receiver for this particular system are expected to work in a severe frequency selective multipath environment with long delay spreads relative to the length of the training sequence. The properties and the length of the training sequence are generally different depending on the particular communication system's standard specifications. However the accuracy of most channel estimation schemes is degraded due to the correlation of the stored copy of the training sequence with the unknown symbols adjacent to transmitted training sequence, as well as the additive channel noise.

The data can be modeled in the following linear form

Y=XH+W

Where X is a known N × p matrix and H is a p × 1 vector of parameters to be estimated, and W is a N × 1 noise vector with zero mean and covariance C, then BLUE of H is given by

$$H_{BLUE} = \left(H^{Ht} C^{-1} H \right)^{-1} H^{Ht} C^{-1} X \quad (4)$$

Where $C = \left(X - E\{x\} \right)\left(X - E\{x\} \right)^{Ht}$ (5)

H^{Ht} is the conjugate transpose or Hermitan Transpose and the minimum variance of $\hat{H}_i$ is

$$\operatorname{var}\left(\hat{H}_i \right) = \left[\left(H^{Ht} C^{-1} H \right)^{-1} \right] \quad (6)$$

Among all linear unbiased estimators the noise covariance matrix is known to be

$$\operatorname{cov}\{v\} = K_v = \frac{1}{2} E\left\{ v v^H \right\} = \sigma_v^2 I \quad (7)$$

Unbiased and efficient variance for each of the n parameters

$$z(k) = H(k)\theta + v(k)$$

$$\hat{\theta}_{BLUE}(k) = F(k) Z(K)$$

V. LEAST SQUARE ESTIMATION

The receiver uses the estimated channel conditions to decode the receive data inside the block until the next pilot symbol arrives. The estimation can be based on least square . The task here is to estimate the channel conditions given the pilot signal and received signals[9]. Without using any knowledge of the statistics of the channels, the LS estimators are calculated with very low complexity, but they suffer from a high mean-square error.

The most conventional way of estimating the propagation conditions in mobile radio systems is to model the channel by a Finite Impulse Response filter and to transmit a data sequence known to the receiver. If the channel noise is additive, white and Gaussian, the Maximum likelihood estimator based on the observations generated by the training sequence consists in minimizing the mean square error between the signal received during the emission of the TS and its noiseless counterpart , which is a Least-square estimator.

It is well known that the performance of the Least-Square channel estimator is roughly inversely proportional to the training sequence length. Therefore, a simple idea to increase the number of training symbols is to use the hard decisions associated with the outputs of the symbol detector or channel decoder.

As the decoder output is generally more reliable than the symbol detector output, it is more efficient to use the decoded bits. The latter are then re-encoded and used to extend the initial training sequence. Generally, several iterations are performed in order to improve the overall receiver performance[10]. The channel estimator only needs to compute a complex matrix-matrix multiplication followed by scaling a real value 1K . In OFDM systems, the number of subcarriers are usually chosen to be a power of two due to the FFT used in modulation and demodulation.

In the case where all subcarriers are used for data transmission, i.e., K = NC the multiplication can therefore be performed with a simple shift operation. Therefore, the computation of a single CIR vector equation takes L computing cycles in total. As there are no data dependencies between the different CIR vectors, it is possible to compute all of them simultaneously. In the proposed architecture, all of the NTNR vector product units are parallel, and, therefore, CIR matrix $\hat{H}$ can be computed in L computing cycles[11].

Computing the LS channel estimator by using the pre computed matrix C requires memory to store the NTLK complex matrix coefficients. As matrix C consists of diagonal matrices multiplied by the partial DFT matrix F , it is possible to reduce the memory needed for the pre computed data. With this approach, only the pilot sequences c_i and the partial DFT matrix FLK, i.e., K(L + NT) complex coefficients in total need to be stored in memory[12].

This is, however, done on the expense of the computational complexity as an additional complex multiplication is required in each vector product unit[13]. In practical applications, fixed point presentation of the numbers is usually preferred over floating point because of its lower complexity. The downside of using fixed point number is the limited range of signals and loss of precision. A word length study of the LS estimator is used to obtain the minimum word lengths for which the fixed point implementation does not exhibit significant performance degradation[14].

Here channel is estimated by using three algorithms like Least Square (LS) , Minimum Mean Square Estimation (MMSE) and Best Linear Unbiased Estimation (BLUE) in the multiple input multiple output Orthogonal Frequency Division Multiplexing (MIMO-OFDM) Systems.

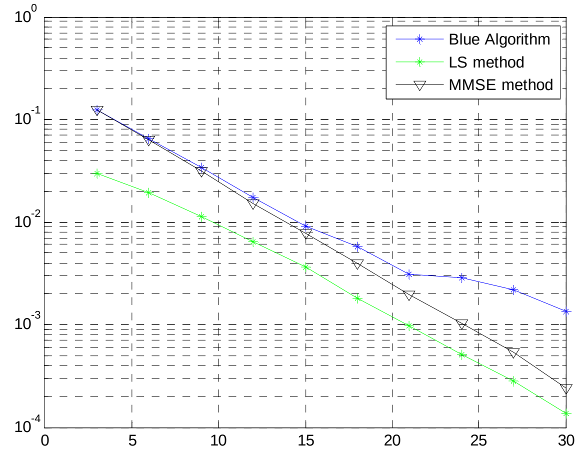

Figure 3. SNR vs BER curves for different algorithms

VI. CONCLUSION AND FUTURE WORK

The estimation in this project can be used to efficiently estimate the channel in OFDM system given a certain knowledge about the channel statistics. The MMSE estimator assume a priori knowledge of noise variance and channel covariance. moreover, its complexity is large compared to LS (least square) estimator. The computational complexity of the MMSE increases exponentially as the number of carrier increases. The bit error rate for MMSE is almost constant for high SNR_s. BLUE gives very marginal improvement to LS. The reason for this performance increase is because of the covariance matrix used in the BLUE. As noise is AWGN and it has variance of 1 so the BLUE algorithm performance is all most that of LS algorithm. For high SNR_s the LS estimator is both simple and adequate.

For improving accuracy of channel estimation, LMS iterative algorithm will be added to receiver which includes a feedback of output and improves the BER performance of system, closed to the ideal channel performance and also the method to determine the pilots location, to improve efficiency of the system may be considered.

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