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Channel Estimation in OFDM systems: A Survey paper

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Abstract—The OFDM (Orthogonal Frequency Division Multiplexing) is a modulation technique which can offer high speed voice, video and data facility up to the customer end. Developing an understanding of the Channel estimation of OFDM can be best achieved by studying two types of estimation techniques. This paper discusses the model building of channel estimation of OFDM. This model is a beneficial tool serving as a helpful reserve for the students and the scholars who want to base their studies and research in the meadow of OFDM. The performance can be enriched by using some kind of Intelligence technique. This paper also discusses the benefits of using channel estimation in an OFDM system.

Keywords— orthogonal frequency division multiplexing (ofdm), channel estimation, block type pilot arrangement, comb type pilot arrangement.

I. Introduction

The major challenge which is to be tackled by ensuing wireless communication systems is to bestow immense data rates and better quality of service (QoS). There are also some of the other challenges like resource deficiency and transmission is troubled by fading and interference from other users [1]. As the data rate increases symbol duration gets abridged and ISI will also be present as a result of dispersive fading. Orthogonal frequency division multiplexing (OFDM) is a novel technique which is propitious for future high data rate wireless communication systems and also is robust to multipath fading and ISI as cyclic prefix and guard band are used in transmitter of OFDM system. Thus it is used as a principle technique in many of the major wireless communication applications such IEEE 802.11/a(WLAN), 802.16 (WiMAX), DAB (digital audio broadcasting) and HIPERLAN/2.[2]

OFDM is basically a type of MCM (multicarrier modulation) in which several sub-carriers are sent parallel to each other information is sent over these sub-carriers, total signal bandwidth are divided into number of sub-carriers. OFDM can be assumed that OFDM is a type of frequency division multiplexing in which subchannels are overlapping without interference. Spectrum efficiency of OFDM is due to the overlapping of sub-carriers. Spacing between each subcarrier is to be selected carefully in such a way that each subcarrier is orthogonal to another subcarrier. Two signals are said to be orthogonal over an interval when the integral of both signals over that period of interval is zero [1].

Due to the frequency selective and time variant nature of channel effective and dynamic channel state information is necessary to be known before the demodulation stage. Generally it is assumed that the channel is slow fading for which channel characteristics are not changing rapidly in one OFDM block and is stationary. In fast fading channels there are several changes in channel characteristics in one OFDM block. Sub-carriers used in modulation comprise to form one OFDM block.

Coherent and Differential are two types of receivers available in wireless communication. Coherent detection requires estimation of channel's effect on the transmitted signal where as it is not required in the case of differential detection though we have to suffer a 3-4 dB deficit in signal to noise ratio (SNR) [1,4].

Channel Estimation can be broadly divided into two types blind and non-blind channel estimation. Blind channel estimation requires heaps of data and utilizes statistical behaviour of receiver and has a degraded performance for fast fading channel. Another type estimation which is non-blind channel estimation utilizes knowledge of previous channel estimates available at the receiver end. This estimation is further divided into two categories: data/pilot aided or decision directed channel estimation (DDCE).

Further, pilot aided estimation is divided into block type channel estimation and comb type channel estimation.In block type estimation pilot tones are inserted into each of the subcarrier of OFDM symbol. This technique assumes that the channel is slow fading and channel characteristics are not changing quickly even with the use decision feedback equalizer.

Block type Channel estimation technique is based on either Least Square (LS) or Minimum Mean Square (MMSE). The gain in SNR is more in MMSE as compared to LS estimation with a difference of 10-15 dB.(vetec). On the other hand comb type channel estimation is done by inserting pilot tones into each of the OFDM symbol and is suitable for fast fading channels. It is based on LS, MMS or least mean square (LMS) where MMSE is observed to have a better gain performance than LS [5].

In block type estimation when the channel transfer function of pilot tones is estimated it can be interpolated using different interpolation algorithms such as linear interpolation, second order interpolation, low-pass interpolation, spline cubic interpolation, and time domain interpolation[5].

Rest of the paper is organized as follows, Section II contains the system description for OFDM system, Section III discusses types of channel estimation, Section IV & V discusses data aided techniques, Section V concludes research work with future directions).

II. OFDM SYSTEM MODEL

The fundamentalprototype of a classic OFDM system, is exhibited in Fig. 1[6]. In mapper, mapping of binary data which is to be propagated to the receiver is performed in relevance to the digital modulation scheme used. Some of the modulations used are binary phase shift keying (BPSK), quadrature phase shift keying (QPSK) or quadrature amplitude modulation (QAM). After mapping over a modulation scheme data symbols are changed to parallel form. The pilots (data symbols) are added to the sub-carriers either to all sub-carriers or uniformly between data. [6].Each OFDM symbol is transformedfrom frequency to time domain by performing inverse DFT (IDFT) . The frequency domain data sequence X(k) having length N is transformed into time domain x(n) as follow:

$$x(n) = IDFTX(k)$$

$$= \frac{1}{N}\sum_{0}^{N-1} X(k)\, e^{\frac{j2\pi k}{n}} \qquad (1)$$

A cyclic prefix (CP) is used in OFDM system to combat the effect of ISI present at receiver end due to multipath fading and other factors. It is the imitation of uttermost section of OFDM symbol and is present in the guard band which is inserted to the OFDM symbol. The resultant OFDM symbol is given by:

$$x(g) = \begin{cases} x(N+n)n = -N_g, \dots, -1 \\ x(n)n = 0, \dots, N-1 \end{cases} \qquad (2)$$

after addition of cyclic prefix to the OFDM symbol it is converted back into serial form in order to be transmitted over the wireless channel.

Channel through which the signal x(g) is to be transmitted trough is frequency selective time varying fading type with AWGN (Additive White Gaussian Noise) present. The received signal is represented as:

$$y(n) = h(n)x(n) + w(n) \qquad (4)$$

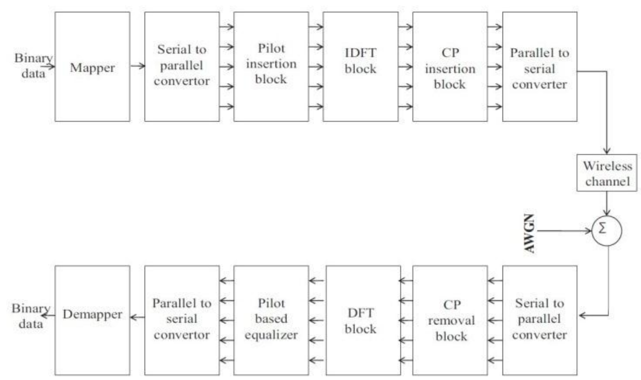

Figure 1: OFDM Block Diagram

Once the symbols are received at the receiver end, they are transformed into parallel type and cyclic prefix is received detached. Now the leftover symbols are directed through DFT block which gives out equivalent frequency symbols as output. Channel Estimation of these received symbols is performed using pilot based equalizer. Later on the received symbols are changed to serial form and using demapper are obtained as binary equivalent of transmitted data.[6].

III. CHANNEL ESTIMATION

In this paper we will be discussing non-blind pilot aided channel estimation techniques. There are two types of arrangements in transmitting the pilots over the channel. Pilots are the known signals, at the receiver end these received pilots helps the receiver to estimate the channel state information [5]. Block type pilot arrangement and comb type pilot arrangement are discussed ahead:

BLOCK TYPE PILOT ARRANGEMENT

In this section LS and MMSE are discussed. LS is the simplest technique for estimating the channel estimate information.If the effect of ISI is reduced by the guard band used [5], we can modify (4) as:

$$\boldsymbol{Y} = \boldsymbol{XFh} + \boldsymbol{W}$$

Where

$$X = diag\{X(0), X(1), \dots, X(N-1)\} \quad (6)$$
$$Y = [Y(0)Y(1) \dots Y(N-1)]^T \quad (7)$$
$$W = [W(0)W(1) \dots W(N-1)]^T (8)$$

$$H = [H(0)H(1) \dots H(N-1)]^T = DFT_N\{h\} \quad (9)$$

$$F = \begin{bmatrix} W_N^{00} & \cdots & W_N^{0(N-1)} \\ \vdots & \ddots & \vdots \\ W_N^{(N-1)0} & \cdots & W_N^{(N-1)(N-1)} \end{bmatrix} \quad (10)$$

$$W_N^{nk} = \frac{1}{N} e^{-j2\pi\left(\frac{n}{N}\right)k} \quad (11)$$

For the Gaussian time domain channel vector h uncorrelated with W (channel noise), its channel estimation can be drafted as

$$H_{MMSE} = FR_{hy}R_{yy}^{-1}Y \quad (12)$$

Where

$$R_{hY} = E\{hY\} = R_{hh}F^H X^H \quad (13)$$

$$R_{YY} = E\{YY\} = XFR_{hh}F^H X^H + \sigma^2 I_N \quad (14)$$

R_{hY} is cross covariance matrix for h and Y

R_{YY} is auto co-variance matrix for Y

$R_{hh}$is the auto co-variance matrix for h .

Channel estimation for LS can be given as:

$$H_{LS} = X^{-1}Y, \quad (15)$$

Minimizing $(Y - XFh)^T(Y - XFh)$.

The performance of block type channel estimate is contrived by fast fading channel. Comb type pilot arrangement discussed in the succeeding section performs better for fast fading channels.

COMB TYPE PILOT ARRANGEMENT

In Comb type pilot arrangement pilots are transmitted over $X(k)$ uniformly in each OFDM symbol in time domain. Comb type pilot arrangement is more resistant to fast fading due to high retransmission rates. Estimation of sub-carriers not containing pilot symbols is done by interpolating adjoining subcarriers [7].

Pilot signal is transmitted using foremost subcarrier of every OFDM symbol, N_P pilot signals are insertedhomogeneously into $X(k)$. Separation between two pilots is given byL= number of carriers/N_P

$$X(k) = X(mL + 1) \;\; 0 \le l \le L$$
$$= \begin{cases} x_p(m) l = 0 \\ data l = 1,2 \dots \dots L - 1 \end{cases} \quad (16)$$

$x_p(m)$ is m^th^ pilot symbol.

Conventional comb type pilot arrangements are based on LS or MMSE. LS estimation based channel estimate can be given by:

$$Hc = \frac{Yp}{Xp} k = 0,1, \dots, Np - 1 \quad (17)$$

$Y_P(k)$ isoutputatkth pilot sub-carrier,

$X_P(k)$ is input at atkth pilot sub-carrier.

LS estimate is receptive to AWGN noise and ISI whereas MMSE is found to be more complex than LS but has a relatively 10-15 dB more gain than LS[7]. In this paper, complexity is further reduced using singular value decomposition.

INTERPOLATION TECHNIQUES IN COMB TYPE ARRANGEMENT

For comb type pilot arrangement channel estimation, with the help of channel information available with pilotsestimation can be done by applying Interpolation techniques.

The linear interpolation method is more proficient related to piecewise-constant interpolation as according to [8].

Linear interpolation can be given as:

$$H_e(k) = H_e(mL + l) \; 0 \le l < L$$

$$= \left(H_P(m+1) - H_P(m)\right)\frac{l}{L} + H_P(m) \quad (18)$$

Second order Interpolation can be given by:

$$H_e(k) = H_e(mL + l) \; 0 \le l < L$$

$$= c_1 H_P(m-1) + c_0 H_P(m) + c_{-1} H_p(m+1)$$

Where $\begin{cases} c_1 = \frac{\alpha(\alpha-1)}{2} \\ c_0 = -(\alpha-1)(\alpha+1), \alpha = \frac{l}{N} \\ c_{-1} = \frac{\alpha(\alpha+1)}{2} \end{cases}$

Several other interpolation techniques can be practiced like low pass interpolation and CSI (cubic spline interpolation).

IV. CONCLUSION AND FUTURE SCOPE

In this paper the channel estimation of OFDM has been studied which shows that OFDM is more suitable choice improving spectral efficiency and reliable transmission and using channel estimation OFDM outshines with respect to BER, bandwidth efficiency and fading atmosphere. Future works can be describing the combined work of a unique or a different techniques or schemes with Channel estimation of OFDM system and defining how effectively it would work as per user present-day requirements

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