Channel Estimation Techniques for OFDM traffic based on Fast Fourier Transform

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Abstract: *The rapid pace of development in wireless technology has put substantial requirements on various system parameters e.g. handling large number of users, huge data transfers, efficient time usage, higher transmission rates and improves transmission quality are required.*

Numerous papers have been published in wireless channel estimations techniques like pilot allocation schemes, lest square estimation, minimum mean square estimation. In this paper we are focusing on OFDM (Orthogonal Frequency Division Multiplexing) and the estimation of channel in an OFDM system by allocation of Pilots (known as reference signals).

Keywords – OFDM, Channel estimation, MIMO

I. Introduction

Until only a few years ago, research on the current topic was mainly focused on point to point communications; while the more recent works focusses on real time applications on the area of transmission of data blocks over heterogeneous networks. Network management is distributed in space and spatial diversity is expected to be the solution for reliable networks.

Within wireless communications one of the main problems facing a robust infrastructure is fading. Transmission degraded drastically if fading occurs in an uncontrolled fashion. In order to minimize fading, multiple replicas of transmitted signal are sent to the receiver. There replicas are independent of each other so that the transmitted information can be successfully recovered with optimal probability, al all replicas will not fade simultaneously. Thus space diversity is of crucial importance and plays an important role by using multiple transmission and reception antennas [1].

The randomness or the uncertainty, is the primary feature of space. It can be the mobility of the users, randomness of transmission channels or change in geographical location. Spatial diversity is the tool fir reliable wireless communication through multiple antennas and to multiple users. The antennas are spatially separated and used to provide replicas of the transmitted signals to the receiver.

II. Attenuation Characteristics

In wireless communications, signal attenuation occurs primarily due to three factors [1].

- Path loss (Due the physical distance between communicating nodes).
- Shadowing loss (Due to absorption)
- Fading Loss (Because of constructive and destructive interference of multiple reflected radio waves path).

There are a large number of unanswered questions for frequency selective fading (the channel is said to be frequency selective if the symbol period is smaller than the delay spread of the channel). For example, unknown capacity of time varying ISI (Inter Symbol Interference) fading channel; unknown capacity when channel is not flat.

The capacity of MIMO (Multiple Input Multiple Output) channel for various cases are unknown. The techniques which improve the throughput or reliability of wireless communication over broad band MIMO channels are [1]:

- Spatial Multiplexing (improves throughput)
- Transmit diversity (improves reliability)
- STC (Space time trellis or block code provide coding gain)
- 4 OFDM (Mitigates the channel's frequency selectivity)

The quality of wireless link can be best described by transmission range, transmission rate and transmission reliability. Anyone can be improved but at the expense of the other two. With MIMO OFDM the three parameters can be improved simultaneously. Recent research suggests implementation of MIMO OFDM, because of its simple processing my matrix algebra [2].

III. OFDM (Orthogonal Frequency Division Multiplexing)

The information at the transmitter is modulated by using the QAM (Quadrature Amplitude Modulation), as illustrated in Figure 1. In OFM large number of carriers are required, it means large number of local oscillators are required which makes the system more complex. Here the digital signal processing techniques like IFFT (Inverse Flat Fourier Transform) and FFT (Fast Fourier Transform) comes and handles the situation quite easily. The modulated signal is then converted to parallel for applying IFFT (inverse Flat Fourier Transform) so that the signals are placed at orthogonal distances, as illustrated in Figure 2. IFFT is an efficient algorithm which generated OFDM symbols by performing both processes (Modulation and Multiplexing). The transmitted signal can be represented as

$$x\ (t) = \sum_{n=0}^{N-1} a_n\, p_n\ (t) \qquad (1)$$

Where a_n is the QAM symbol and p_n (t) is the rectangular pulse shifted in frequency,

$$P_h = \begin{cases} 1/T e^{\frac{j2\pi nt}{T}} & 0<t<T \\ 0 & otherwise \end{cases} \qquad (2)$$

Where T is the pulse duration.

The discrete time representation of the pulses if they are sampled at $t_k = K\frac{T}{N}$ t is

$$X(k) = \frac{1}{T}\sum_{n=0}^{N-1} A_n e^{j2\pi n\frac{k}{n}} \qquad (3)$$

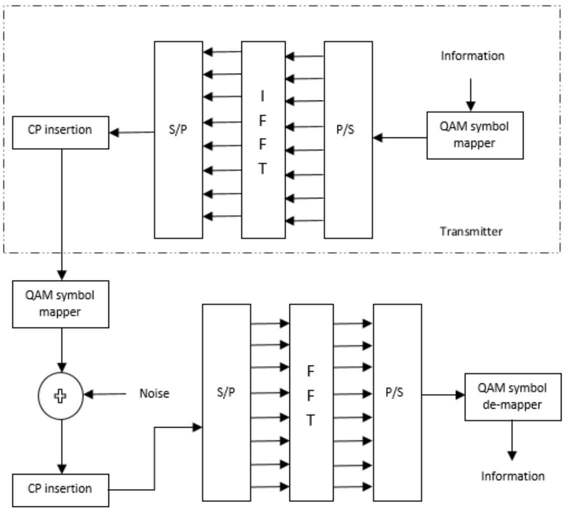

Fig.1 OFDM Block diagram [8]

The output of the IFFT consists of N values. The output thus converted from parallel to serial (as illustrated in Figure 1) then cyclic prefixes are added to make signals ready for transmission.

As illustrated in Figure [2], the IFFT places the infinitely long sinusoids close to each other such that they are not interfering, as they are orthogonal to each other. This is how the high bandwidth efficiency is achieved.

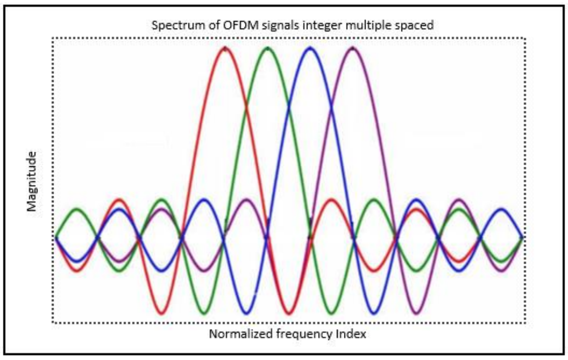

Fig. 2 OFDM signals spaced on frequency domain

IV. Cyclic Prefix (CP)

The insertion of cyclic prefix is to deal with the problem of time dispersion. When the received signal is undistorted, the demodulation performed gives the original signal. But if the channel is dispersive (Inter symbol/carrier Interference with in the sub carrier between the subcarriers) as illustrated in Figure 3, the OFDM signal lost its orthogonality.

To make OFDM signals independent of dispersive effects, cyclic prefix is used [3]. The CP is added at the beginning of the OFDM symbol whose length is equal or greater than the channel dispersion. Obviously it increases the length of the OFDM

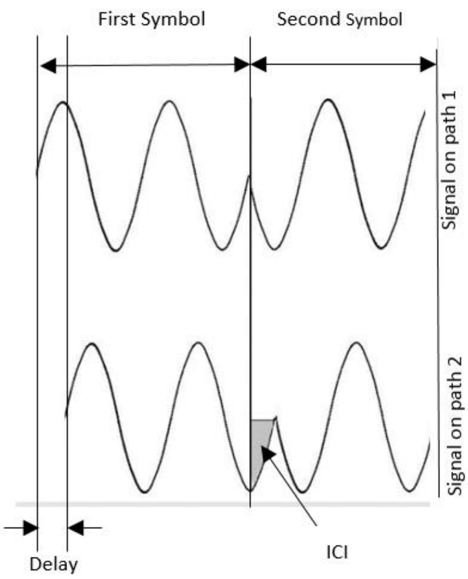

Fig.3 Inter Carrier Interference [7]

symbol, but it serves as a guard interval, as illustrated in Figure 3. When the data is transmitted over a delay dispersive channel, the received signal is the linear convolution of the transmitted signal and the channel impulsive response. This linear convolution is then converted to cyclical convolution because of cyclic prefix. According to the DFT theory, multiplication of two DFTs is circular convolution in time domain.

V. CHANNEL ESTIMATION

A particular wireless channel cannot be perfectly known therefore we estimate the channel. It basically beans we have to find the channel transfer function or its impulse response. There are many techniques for estimating the channels like pilot based estimation. Adaptive estimation and frequency time correlation based estimation [4]

A. Pilots Allocation schemes

To find the behavior of wireless channel, pilots are placed in the data, thus it is required to use less pilots as much as possible. There are various methods for placing in time frequency domain of OFDM systems.

B. Block and Comb Type Pilots allocation.

In block type, the pilots are placed on each subcarrier frequency having some time period (as illustrated in figure 4a) and in comb type, the pilots are placed on sub carriers apart from each other (as illustrated in figure 4b). The former is useful in high frequency dispersive and low Doppler frequency channel at the cost of data rate [5]. The latter type is useful in moderate frequency selective and high Doppler frequency channels [5]. They are called block type pilot placement method

In block type, at every sub carrier frequency the channel is known, while in comb type the condition of the channel is not known at every sub carrier frequency so at the intermediate sub carrier frequencies the channel can be estimation by interpolation.

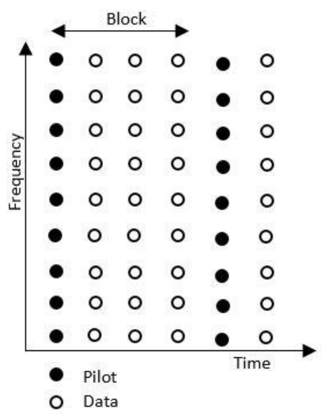

Fig. 4a Block Type Pilot Channel Estimation [6].

The receiver decodes the received symbol by estimated channel condition until the next pilot symbol arrives [6].

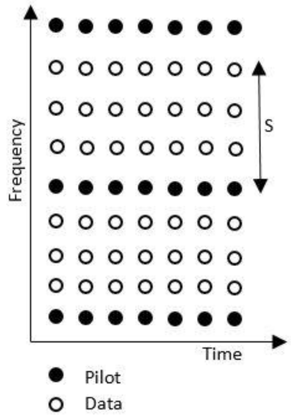

Fig. 4b Comb Type Pilot Channel Estimation [6].

The same channel estimation is used the whole block in block type channel estimation; while in comb type, some reserved sub carriers are used for each block. The time and frequency spacing between the subcarriers should be acceptable for estimating the channel perfectly.

Initially the pilots (known signals) are transmitted over the channel and since the output known, one can easily find the channel characteristics by its transfer function. If X(t) is the known pilot signal, expected output is y(t) then h(t) is the impulse response of the channel, therefore the transfer function can be found. Once the channel transfer function is known, the channel can be estimated.

VI Conclusion

The paper describes the orthogonal frequency division multiplexing technique. It shows how the OFDM technique optimizes bandwidth efficiency and the use of cyclic prefix makes the signal independent of dispersive effects. The Block and Comb type channel estimations by using pilot's allocation schemes are discussed and shown how the channel transfer function can be found by transmitting the known signals (pilots). Block type pilot allocation is advantageous in high frequency selective and low Doppler Frequency channels. While the comb type is advantageous in moderate frequency selective and high Doppler frequency channels.

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