A Survey on Channel Estimation in OFDM

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Abstract— This paper presents a brief review on Channel estimation. Channel estimation in OFDM is mainly performed with the help of pilot symbols. For these systems pilot-symbol assisted modulation (PSAM) on flat fading channels is used. This involves the insertion of known pilot symbols in a stream of data symbols. An advantage of using Pilot-symbol modulation in OFDM systems is allowance the use of the frequency correlation properties of the channel.

Keywords—*Channel Estimation; OFDM; FDM; PSAM; Pilot symbol.*

I. INTRODUCTION

The origins of OFDM development started in the late 1950's with the introduction of Frequency Division Multiplexing (FDM) for data communications. In 1966 Chang presented the structure of OFDM and propose the concept of using orthogonal overlapping multi-tone signals for data communications. In 1971 Weinstein and Ebert [1] gives an idea of using a Discrete Fourier Transform (DFT) for implementation of the generation and detection of OFDM signals, eliminating the requirement for banks of analog subcarrier oscillators. This presented a way for an easy implementation of OFDM, especially with the use of Fast Fourier Transforms (FFT), which are an efficient implementation of the DFT.

Orthogonal Frequency Division Multiplexing (OFDM) is an alternative radio modulation technique to CDMA. OFDM has the potential to overcome the capacity of CDMA systems and provide the wireless access for 4G systems. OFDM is a modulation technique that allows digital information to be efficiently and reliably transmitted over a radio channel, even in multipath fading environments. OFDM is very useful method in higher data rate transmission and it acts as the base of the 4G communication systems. Orthogonal Frequency Division Multiplexing (OFDM) based systems are strong enough for an air interface of future 4G mobile wireless systems, which provide higher data rates and higher mobility. The main reasons to use OFDM are to increase the robustness against narrowband interference and to use available bandwidth efficiently[2]. The tracking of a time varying channel in OFDM system can be avoided using differential Phase-Shift Keying (DPSK). However, this will limit the boud rate and results in a 3 dB loss in Signal power-to-Noise Ratio(SPNR) [3]. If the receiver has a channel estimator, multi-amplitude signaling technique may be used.

II. CHANNEL ESTIMATION

Channel estimation in OFDM is done with the help of pilot symbols. These systems use Pilot-Symbol Assisted Modulation (PSAM) on flat as well as multipath fading channels [7] and this involve the sparse insertion of known pilot tones in a stream of data symbols. The attenuation of the pilot tones is calculated and the attenuations of the data symbols in between these pilot symbols are mainly interpolated using time-correlation properties of the fading channel. In OFDM systems, the PSAM [8] also useful in frequency correlation properties of the channel. The time-frequency grid in Figure 1.1 illustrates the ways of inserting pilots tones among stream of data symbols. The first pilot pattern inserts in a completely known OFDM symbols. The second modulates pilot symbols on a specific set of sub carriers.

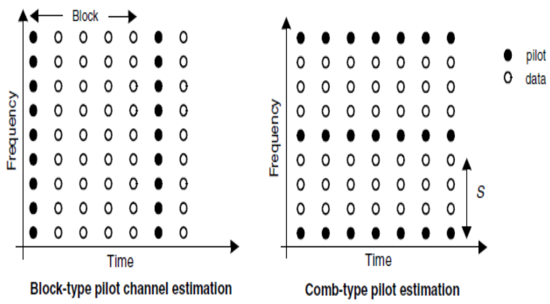

Fig. 1: Pilot Arrangement

In OFDM systems where Doppler effects are kept much small (i.e. the OFDM symbol is small compared with the coherent time of the channel) the time correlation between the channel attenuations of consecutive OFDM symbols is higher. Moreover, in a properly designed OFDM system the sub carrier space is made small compared with the coherent bandwidth of the channel. Therefore, there is a substantial frequency correlation between the channel attenuations of adjacent sub carriers. Both the time and frequency correlation can be exploited by a channel estimator. The choice of pilot pattern determines the class of the channel estimator.

Most channel estimator consist of two steps, one or both of which utilize the correlation of the channel. First, the attenuations at the pilot positions are measured and possibly smoothed using the channel correlation. These measurements then serve to interpolate the complex-valued attenuations of the data symbols in the second step. This second step uses the channel correlation properties either with interpolation filters or with a decision-directed scheme. Depending on the pilot pattern of Fig. 1, the estimation strategies diverge in this second step.

Completely known OFDM symbols are sparsely inserted in the stream of OFDM symbols. The channel degradation in between these OFDM symbols are then either interpolated using the channel time correlation or the estimator is applied on consecutive OFDM symbols in a decision-directed scheme by Wilson [9]. Orthogonal Frequency-Division Multiplexing (OFDM) is now used as a feasible alternative to the conventional single carrier generation techniques for higher data rate communication systems, mainly because of its inherent equalization simplicity.

III. FEATURES OF CHANNEL ESTIMATION

- Pilot symbol transmission represents overhead in the OFDM system. Thus, it is desirable to minimize pilot transmission as much as possible. However, because of noise and other distortion in the radio channel, a sufficient amount of pilot tones need to be transmitted in order for the receiver to receive an accurate estimation of the channel response. Moreover, the pilot transmissions need to be repeated to account for variations in the channel over time due to fading and changes in the multipath delay. Consequently, channel estimation for an OFDM system consumes a noticeable portion of the system resources.
- In the downlink of a wireless communication system, a single pilot transmission from a base station may be used by a number of points or terminals to estimate the actual response of the different downlink channels from the base station to each of the terminals. However, in the uplink, each terminal needs to send a pilot transmission separately in order to enable the access point to estimate the uplink channel from the terminal to the access point. Consequently, the overhead due to pilot transmissions is exacerbated due to uplink pilot transmissions[10].
- There is therefore a need in the art for techniques to more efficiently estimate the channel response in an OFDM system, particularly in the uplink.
- OFDM effectively partitions the overall system bandwidth into a number of N orthogonal sub bands. These sub bands are also referred to as tones, frequency bins, and frequency sub channels. With OFDM, each sub band is associated with a respective sub carrier upon which data can be modulated. Each sub band may thus be viewed as an independent transmission channel that may be used to transmit data stream.
- In a wireless communication system, an RF modulated signal from a transmitter may reach a receiver via a number of propagation paths. For an OFDM system, the N sub bands may experience different effective channels due to different effects of fading and multipath and may consequently be associated with different complex channel gains[11].

IV. CONCLUSION

Orthogonal Frequency Division Multiplexing (OFDM) has been widely used in wireless communication systems due to its higher data rate transmission capability with higher bandwidth efficiency and its robustness to multipath delay. Channel estimation can be performed mainly in two ways: either inserting pilot tones into all of the sub carriers of OFDM symbols with a specific period or inserting pilot tones into each and every OFDM symbol. Study of channel estimation based on block type pilot arrangement as well as comb type pilot arrangement is presented, and it is observed that block type of arrangement performs better when the channel is changing slowly.

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