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An Analysis of Channel Estimation for OFDM Systems through a Literature Survey

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Abstract:-Radio transmission has allowed people to communicate without any physical connection for more than hundred years. When Marconi managed to demonstrate a technique for wireless telegraphy, more than a century ago, it was a major breakthrough and the start of a completely new industry. May be one could not call it a mobile wireless system, but there was no wire! Today, the progress in the semiconductor technology has made it possible, not to forgot affordable, for millions of people to communicate on the move all around the world.

Keywords- Channel estimation, Leakage nulling,OFDM.

1. INTRODUCTION

The Mobile Communication Systems are often categorized as different generations depending on the services offered. The first generation comprises the analog frequency division multiple access (FDMA) systems such as the NMT and AMPS (Advanced Mobile Phone Services). The second generation consists of the first digital mobile communication systems such as the time division multiple access (TDMA) based GSM (Global System for Mobile Communication), D-AMPS (Digital AMPS), PDC and code division multiple access (CDMA) based systems such as IS-95. These systems mainly offer speech communication, but also data communication limited to rather low transmission rates. The third generation started operations on 1st October 2002 in Japan.

During the past few years, there has been an explosion in wireless technology. This growth has opened a new dimension to future wireless communications whose ultimate goal is to provide universal personal and multimedia communication without regard to mobility or location with high data rates. To achieve such an objective, the next generation personal communication networks will need to be support a wide range of services which will include high quality voice, data, facsimile, still pictures and streaming video. These future services are likely to include applications which require high transmission rates of several Mega bits per seconds (Mbps).In the current and future mobile communications systems, data transmission at high bit rates is essential for many services such as video, high quality audio and mobile integrated service digital network. When the data is transmitted at high bit rates, over mobile radio channels, the channel impulse response can extend over many symbol periods, which lead to inter symbol interference (ISI). Orthogonal Frequency Division Multiplexing (OFDM) is one of the promising candidates to mitigate the ISI. In an OFDM signal the bandwidth is divided into many narrow sub channels which are transmitted in parallel. Each sub channel is typically chosen narrow enough to eliminate the effect of delay spread. By combining OFDM with Turbo Coding and antenna diversity, the link budget and dispersive-fading limitations of the cellular mobile radio environment can be overcome and the effects of co-channel interference can be reduced.

Orthogonal Frequency Division Multiplexing (OFDM) has proven to be a modulation technique well suited for high data rates on time dispersive channels. There are some specific requirements when designing wireless OFDM systems, for example, how to choose the bandwidth of the sub-channels used for transmission and how to achieve reliable synchronization. The latter is especially important in packet-based systems since synchronization has to be achieved within a few symbols.

In order to achieve good performance the receiver has to know the impact of the channel. The problem is how to extract this information in an efficient way. Conventionally, known symbols are multiplexed into the data sequence in order to estimate the channel. From these symbols, all channel attenuations are estimated with an interpolation filter.

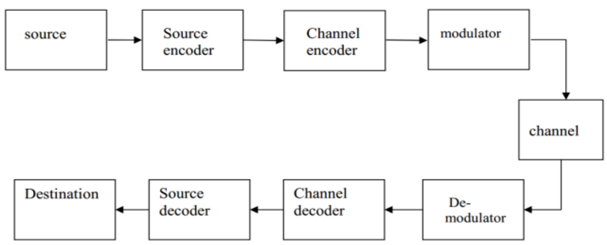

Figure 1.1: Functional Block in a Communication System

Propagation Characteristics of Mobile Radio Channels

In an ideal radio channel, the received signal would consist of only a single direct path signal, which would be a perfect reconstruction of the transmitted signal. However, in a real channel the signal is modified during transmission. The received signal consists of a combination of attenuated, reflected, refracted, and diffracted replicas of the transmitted signal. On top of all this, the channel adds noise to the signal and can cause a shift in the carrier frequency if either of the transmitter or receiver is moving (Doppler Effect). Understanding of these effects on the signal is important because the performance of a radio system is dependent on the radio channel characteristics.

Attenuation

Attenuation is the drop in the signal power when transmitting from one point to another. It can be caused by the transmission path length, obstructions in the signal path, and multipath effects. Any objects which obstruct the line of sight of the signal from the transmitter to the receiver, can cause attenuation. Shadowing of the signal can occur whenever there is an obstruction between the transmitter and receiver. It is generally caused by buildings and hills, and is the most important environmental attenuation factor. Shadowing is the most severe in heavily built up areas, due to the shadowing from buildings. However, hills can cause a large problem due to the large shadow they produce. Radio signals diffract off the boundaries of obstructions, thus preventing total shadowing of the signals behind hills and buildings. However, the amount of diffraction is dependent on the radio frequency used, with high frequencies scatter more than low frequency signals. Thus high frequency signals, especially, Ultra High Frequencies (UHF) and microwave signals require line of sight for adequate signal strength, because these scatter too much. To overcome the problem of shadowing, transmitters are usually elevated as high as possible to minimize the number of obstructions.

Multipath Effects

Rayleigh Fading

In a radio link, the RF signal from the transmitter may be reflected from objects such as hills, buildings, or vehicles. This gives rise to multiple transmission paths at the receiver. Fig.1.2 shows some of the possible ways in which multipath signals can occur. The relative phase of multiple reflected signals can cause constructive or destructive interference at the receiver. This is experienced over very short distances (typically at half wavelength distances), which is given the term fast fading. These variations can vary from 10-30dB over a short distance. The Rayleigh distribution is commonly used to describe the statistical time varying nature of the received signal power. It describes the probability of the signal level being received due to fading.

Frequency Selective Fading

In any radio transmission, the channel spectral response is not flat. It has dips or fades in theresponse due to reflections causing cancellation of certain frequencies at the receiver. Reflectionsoff near-by objects (e.g. ground, buildings, trees, etc) can lead to multipath signals of similarsignal power as the direct signal. This can result in deep nulls in the received signal power due todestructive interference. For narrow bandwidth transmissions if the null in the frequencyresponse occurs at the transmission frequency then the entire signal can be lost. This can bepartly overcome in two ways. By transmitting a wide bandwidth signal or spread spectrum as inthe case of CDMA, any dips in the spectrum only result in a small loss of signal power, ratherthan a complete loss. Another method is to split the transmission up into many carriers carryinglow rate data, as is done in a COFDM/OFDM

Delay Spread

The received radio signal from a transmitter consists of typically a direct signal plus signals reflected off object such as buildings, mountains, and other structures. The reflected signals arrive at a later time than the direct signal because of the extra path length, giving rise to a slightly different arrival time of the transmitted pulse. This can cause significant errors in high bit rate systems, especially when using time division multiplexing (TDMA). As the transmitted bit rate is increased the amount inter symbol interference also increases. The effect starts to become very significant when the delay spread is greater than 50% of the bit time.

2. SYSTEM MODEL

OFDM

The channel estimation concept exploits the frequency correlation of the channel. In many OFDM systems this concept can improve channel estimation significantly, even if the channel statistics are not exactly known at a receiver. In addition to publications associated with this research, other recent OFDM channel estimation.

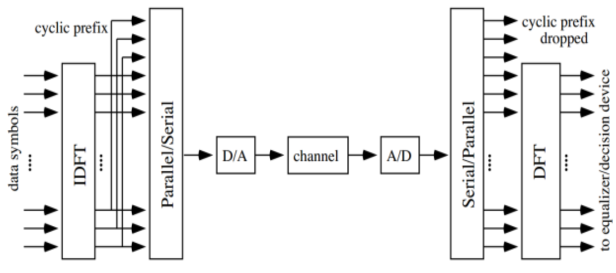

Figure 1.2: An OFDM System.

Channel estimators that are designed using the different methods in this research work, are applicable to those of the above OFDM applications employing coherent demodulation of the subcarriers. In particular, DVB receivers could be equipped with channel estimators based on the channel estimation concept may be taken further improvement.

3. LITERATURE SURVEY

SR. NO.	TITLE	AUTHORS	YEAR	METHODOLOGY
1	Low-Complexity DFT-Based Channel Estimation with Leakage Nulling for OFDM Systems	K. J. Kim, H. G. Hwang, K. J. Choi and K. S. Kim	Mar-14	A low-complexity but near-optimal DFT-based channel estimator with leakage nulling is proposed for OFDM systems using virtual subcarriers.
2	An equalizer initialization algorithm for IEEE802.11a and HIPERLAN/2 receivers	M. Belotserkovsky	Nov-02	A hardware-efficient equalizer initialization algorithm.
3	Analysis of Pilot-Aided Channel Estimation with Optimal Leakage Suppression for OFDM Systems	J. Seo, S. Jang, J. Yang, W. Jeon and D. K. Kim	Sep-10	Using discrete Fourier transform (DFT)-based interpolation in orthogonal frequency division multiplexing (OFDM) systems with virtual carriers.
4	A New DFT-Based Channel Estimation Approach for OFDM with Virtual Subcarriers by Leakage Estimation	K. Kwak, S. Lee, J. Kim and D. Hong	Jun-08	Analyze the leakage using the DFT-inverse DFT process. The pilot subcarriers inside virtual subcarriers area are estimated by the inverse of the estimated leakage.
5	Optimal Pilot Sequence Design for Multi-Cell MIMO-OFDM Systems	J. W. Kang, Y. Whang, H. Y. Lee and K. S. Kim	Oct-11	Optimal pilot sequence designs for MIMO-OFDM systems in multi-cell environments are provided.

K. J. Kim, H. G. Hwang, K. J. Choi and K. S. Kim, [1] In this letter, a low-complexity but near-optimal DFT-based channel estimator with leakage nulling is proposed for OFDM systems using virtual subcarriers.

The proposed estimator is composed of a time-domain (TD) index set estimation considering the leakage effect followed by a low-complexity TD post-processing to suppress the leakage. The performance and complexity of the proposed channel estimator are analyzed and verified by computer simulation. Simulation results show that the proposed estimator outperforms conventional estimators and provides near-optimal performance while keeping the low complexity comparable to the simple DFT-based channel estimator.

M. Belotserkovsky,[2] This paper proposes a hardware-efficient equalizer initialization algorithm. The algorithm stems from the author's work on a broadband wireless home networking ASIC based on IEEE 802.11a/HIPERLAN/2 standards. It can also be relevant for other transmission systems that use orthogonal frequency division multiplexing (OFDM).

J. Seo, S. Jang, J. Yang, W. Jeon and D. K. Kim, [3] This letter analyzes the effect of the leakage on the mean square error (MSE) performance of the pilot-aided channel estimator using discrete Fourier transform (DFT)-based interpolation in orthogonal frequency division multiplexing (OFDM) systems with virtual carriers. The optimal linear estimator for leakage suppression is derived to minimize the MSE. Numerical results show that the pilot-aided channel estimator with optimal leakage suppression improves the MSE performance significantly over the conventional one.

K. Kwak, S. Lee, J. Kim and D. Hong, [4] Equidistance in pilot spacing is an essential condition for discrete Fourier transform (DFT)-based channel estimation in OFDM systems. However, virtual subcarriers break this condition, degrade the estimation performance, and cause the interference (called "leakage') because the orthogonality of Fourier matrix is broken. To solve this problem, authors first analyze the leakage using the DFT-inverse DFT process. The pilot subcarriers inside virtual subcarriers area are estimated by the inverse of the estimated leakage. Thus, the equidistance condition is satisfied. The proposed estimator operates well in realistic environment such as IEEE 802.16, and it is robust to an increase of virtual subcarriers.

J. W. Kang, Y. Whang, H. Y. Lee and K. S. Kim, [5] In this paper, optimal pilot sequence designs for MIMO-OFDM systems in multi-cell environments are provided. The proposed multi-cell optimality criterion is to minimize the worst-case MSE of an LS-based channel estimator. To satisfy the multi-cell optimality, it is found that the pilot sequence set, having the perfect auto-correlation property, should meet the Welch bound and the maximum magnitude of the cross-correlation function should be further minimized. Multi-cell optimal pilot sequence designs for various pilot types and their DFT representations are proposed by adopting Chu sequences and a tight upper-bound on the maximum size of the pilot sequence set is derived for a given pilot sequence length and the maximum allowed cross-correlation value. Simulation results show that the proposed pilot sequences can improve both the MSE performance and the system performance in multi-cell environments.

4. PROBLEM IDENTIFICATION

In this research work, a low-complexity DFT-based channel estimator with leakage nulling was proposed for OFDM systems using virtual subcarriers. The proposed estimator first estimates the MST set by considering the leakage effect and then performs a low-complexity leakage suppression using a regularized TD post-processing. From the results, it is confirmed that the proposed estimator can provide the MSE and the achievable rate while keeping low complexity similar to the simplest DFT-based channel estimator. Note that the proposed approach can be extended for practical cellular systems using orthogonal frequency division multiple access or single-carrier frequency division multiple access by employing a proper interference cancellation scheme. Thus, it would be fruitful to develop a practical channel estimator suitable for LTE or LTE-advanced systems as the future work.

5. CONCLUSION

Orthogonal frequency division multiplexing (OFDM) is a multi-carrier transmission technology in wireless environment, and can also be seen as a multi-carrier digital modulation or multi-carrier digital multiplexing technology. A large number of orthogonal sub-carriers are used to transmit information. OFDM system has high utilization of frequency spectrum and satisfactory capability of reducing multi-path inference. So, OFDM has been considered as one of the core technologies of 4 th generation (4G) wireless communication system in the future. Channel estimation plays a very important role in OFDM system. As a research hotpot, many related algorithms have been presented these years, which can be generally separated into two methods, pilot-based channel estimation and blind channel estimation. Pilot-based channel estimation estimates the channel information by obtaining the impulse response from all sub-carriers by pilot. Compared with blind channel estimation, which uses statistical information of the received signals, pilot-based channel estimation is a practical and an effective method.

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