International Journal of Electrical, Electronics and Computer Engineering **5**(1): 115-128(2016)
ISSN No. (Online): 2277-2626

Channel Estimation in Long Term Evolution Using Multicarrier & Multipath MIMO OFDM Communication System

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(Received 14 May, 2016 Accepted 12 June, 2016)
(Published by Research Trend, Website: www.researchtrend.net)

ABSTRACT: Beyond third generation (3G) and fourth generation (4G) wireless communication systems are targeting far higher data rates, spectral efficiency and mobility requirements than existing 3G networks. By using multiple antennas at the transmitter and the receiver, multiple input multiple-output (MIMO) technology allows improving both the spectral efficiency (bits/s/Hz), the coverage, and link reliability of the system. Multicarrier modulation such as orthogonal frequency division multiplexing (OFDM) is a powerful technique to handle impairments specific to the wireless radio channel. The combination of multicarrier modulation together with MIMO signaling provides a feasible physical layer technology for future beyond 3G and fourth generation communication systems, high data rate, low complexity requirements of the future mobile communication systems. Channel estimation is also studied. The channel estimation techniques for pilot-based OFDM systems are investigated. The channel estimation is studied for low delay spread and high delay spread channels.

Keywords: Fourth generation, MIMO, OFDM, Channel State information, Channel Estimation, multi-path fading.

I. INTRODUCTION

Due to ever increasing human needs, 3GPP (Third Generation Partnership Projects) introduces a new system called Long Term Evolution in order to achieve downlink peak rate of 100Mbps and uplink peak rate of 50Mbps for data transmission and also provides compatibility with existing technologies. Multi-input Multi-output (MIMO) systems have gained a lot of attention in the past years due to their promising improvements in terms of performance and bandwidth efficiency in wireless communications systems. MIMO-OFDM system model is used in LTE which improves the performance of wireless communication system. MIMO along with OFDM systems provide better spectral efficiency with no additional power requirement. MIMO system involves multiple antennas at both transmitter and receiver which enhances system's capacity and mitigates the effect of fading due to increased diversity. There is an increasing demand for the high data rates with effective utilization of available limited spectrum. To satisfy these requirements Multiple Input Multiple Output-Orthogonal Frequency Division Multiplexing (OFDM-OFDM) techniques have been adopted. MIMO technology is one of the major attracting techniques in wireless communications because; it offers significant increases in data throughput and coverage without additional bandwidth or transmitter power. It also provides high spectral efficiency and link reliability. Because of these properties, MIMO is an important part of modern wireless communication standards such as IEEE 802.11n (Wi-Fi), 4G, 3GPPLTE, WiMAX and HSPA+. In Mobile communication systems prior to transmit the information certain characteristics of the radio waves are changed in accordance with the information bits. At the receiving end the information bits are retrieved accurately, if the channel characteristics are known. The channel may vary instantaneously because of the propagating medium, which leads to the signal degradation. The Channel State information (CSI) provides the known channel properties for a wireless link. It provides the effects of fading and scattering on a signal propagating through the medium. Normally the CSI estimated at the receiver fed back to the transmitter. If it is not estimated accurately at the receiver, leads to system degradation. It can be estimated by using different channel estimation algorithms. This estimation can be done with a set of well known sequence of unique bits for a particular transmitter and the same can be repeated in every transmission burst.

Thus the channel estimator estimates the channel impulse response for each burst separately from the well known transmitted bits and corresponding received samples. This paper describes the fundamentals of MIMO-OFDM system and study of various channel estimation techniques and their performance. In order to satisfy the exponential growing demand of wireless multimedia services, a high speed data access is required. Therefore, various techniques have been proposed in recent years to achieve high system capacities. Among them, we interest to the multiple-input multiple output (MIMO). The MIMO concept has attracted lot of attention in wireless communications due to its potential to increase the system capacity without extra bandwidth [1]. Multipath propagation usually causes selective frequency channels. To combat the effect of frequency selective fading, MIMO is associated with orthogonal frequency-division multiplexing OFDM) technique. OFDM is a modulation technique which transforms frequency selective channel into a set of parallel flat fading channels. A cyclic prefix CP is added at the beginning of each OFDM symbol to eliminate ICI and ISI. The inserted cyclic prefix is equal to or longer than to the channel [2]. The 3GPP Long Term Evolution (LTE) is defining the next generation radio access network. LTE Downlink systems adopt Orthogonal Frequency Division Multiple Access (OFDMA) and MIMO to provide up to 100 Mbps (assuming a 2x2 MIMO system with 20MHz bandwidth). The performance of a MIMO-OFDM communication system significantly depends upon the channel estimation. However, in most of these research works, the CP length is assumed to be equal or longer than the maximum propagation delay of the channel. But in some cases and because of some unforeseen channel behavior, the cyclic prefix can be shorter than channel length. In this case, both ICI and ISI will be introduced and this makes the task of channel estimation more difficult. Equalization techniques that could flexibly detect the signals we will focus on the study of the performance of LS and LMMSE channel estimation techniques for LTE Downlink systems under the effect of the channel length. wireless services require high-bit-rate transmission over mobile radio channels. To reduce the effect of inter symbol interference (ISI) caused by the dispersive Rayleigh-fading environment [1], the symbol duration must be much larger than the channel delay spread. In orthogonal frequency-division multiplexing (OFDM) the entire channel is divided into many narrow sub channels, which are transmitted in parallel, thereby increasing the symbol duration and reducing the ISI. Therefore, OFDM is an effective technique for combating multipath fading and for high-bit-rate transmission over mobile wireless channels. To eliminate the need for channel estimation and tracking, differential demodulation can be used in OFDM systems, at the expense of a 3–4-dB loss in signal-to-noise ratio (SNR) compared with coherent demodulation. Accurate channel estimation can be used in OFDM systems to improve their performance by allowing for coherent demodulation. Furthermore, for systems with receiver diversity, optimum combining can be obtained by means of channel estimators. A channel estimator for OFDM systems has been proposed based on the singular-value decomposition or frequency-domain filtering. Time-domain filtering has been proposed to further improve the channel estimator performance. However, the *best* time- or frequency-domain filtering shapes for channel estimation has not been studied. Investigate minimum mean-square-error (MMSE) channel estimation for OFDM systems. We first derive the MMSE estimator, which makes full use of the correlation of the channel frequency response at different times and frequencies. In particular, for mobile wireless channels, the correlation of the channel frequency response at different times and frequencies can be separated into the multiplication of the time- and frequency-domain correlation functions. Hence, our MMSE channel estimator can be a frequency-domain filter using the fast Fourier transform (FFT), followed by time domain filters. Since the channel statistics, which depend on the particular environment, are usually unknown, we present a *robust* estimator, that is, an estimator that is not sensitive to the channel statistics. Computer simulation demonstrates that the performance [24] of OFDM systems using coherent demodulation based on our channel estimator can be significantly improved. Frequency-division multiplexing (OFDM) to wireless and mobile communications are currently under study. Although multicarrier transmission has several considerable drawbacks (such as high peak to average ratio and strict requirements on carrier synchronization), its advantages in lessening the severe effects of frequency selective fading without complex equalization are very attractive features. In order to obtain the high spectral efficiencies required by future data wireless systems , it is necessary to employ multilevel modulation with non constant amplitude 16QAM [2]). This implies the need for coherent receivers that are capable to track the variations of the fading channel. The channel estimation (tracking) in OFDM systems is generally based on the use of pilot subcarriers in positions of the frequency-time grid.

For fast-varying channels (e.g., in mobile systems), non negligible fluctuations of the channel gains are expected between consecutive OFDM symbols (or even within each symbol) so that, in order to ensure an adequate tracking accuracy, it is advisable to place pilot subcarriers in each OFDM symbol. In particular, in this paper, we consider the comb pilot pattern arrangement, which has been shown to satisfy different criteria of optimality such as mean square error on the channel estimate and capacity In this framework, the traditional approach to channel estimation, that may be used as an initial estimate in iterative or decision directed receivers, consists of two steps. First, the least squares (LS) estimates of the channel gains over the pilot subcarriers are obtained by simply back rotating the received signal according to the knowledge of the pilot symbols. OFDM (Orthogonal Frequency Division Multiplexing) is becoming a very popular multi-carrier modulation technique for transmission of signals over wireless channels. OFDM divides the high-rate stream into parallel lower rate data and hence prolongs the symbol duration, thus helping to eliminate Inter Symbol Interference (ISI). It also allows the bandwidth of subcarriers to overlap without Inter Carrier Interference (ICI) as long as the modulated carriers are orthogonal. OFDM therefore is considered as an efficient modulation technique for broadband access in a very dispersive environment. In this new information age, high data rate and strong reliability in wire-less communication systems are becoming the dominant factors for a successful exploitation of commercial networks. MIMO-OFDM (multiple input multiple output orthogonal frequency division multiplexing), a new wireless broadband technology, has gained great popularity for its capability of high rate transmission and its robustness against multi-path fading and other channel impairments. The arrangement of multiple antennas at the transition end and reception end results increase in the diversity gain refers the quality of signal and multiplexing gain refers the transmission capacity. Space time block coding used to transmit multiple copies of a data stream across a number of antennas and to exploit the various received versions of data to improve reliability of data transfer.

II. CHANNEL ESTIMATION

While evaluating OFDM system performance in previous sections, we assumed perfect knowledge of the channel for equalization. While perfect channel knowledge can be used to find the upper limit of OFDM system performance, such perfect channel knowledge is not available in real-life and needs to be estimated. Channel estimation can be done in various ways: with or with the help of a parametric model, with the use of frequency and/or time correlation properties of the wireless channel, blind or pilot (training) based, adaptive or not. Non-parametric methods attempt to estimate the quantities of interest (for example the frequency response) without relying on a specific channel model.

Conversely, parametric estimation assumes a certain channel model, determines the parameters of this model and infers the quantities of interest.

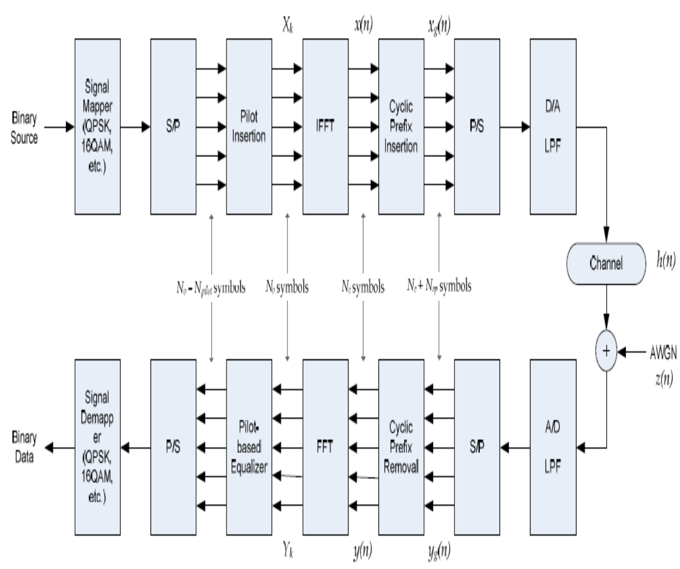
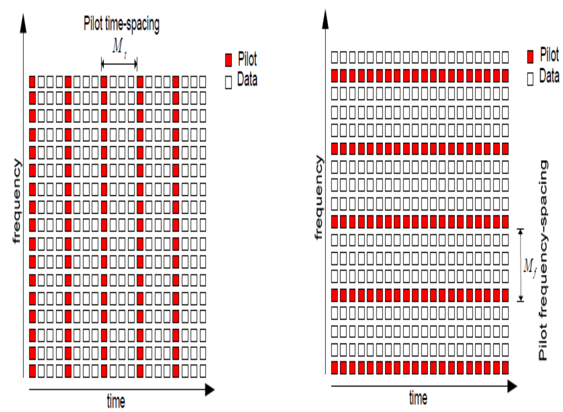


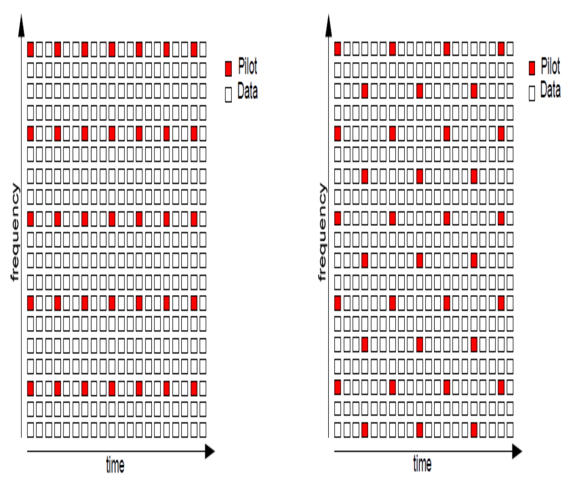
Fig. 1. Pilot-based OFDM system model.

Spaced-time and spaced-frequency correlations are specific properties of channel that can be incorporated in the estimation method, improving the quality of estimate. Pilot based estimation methods are the most commonly used methods which are applicable in systems where the sender emits some known signal. Blind estimation, on the other hand, relies on some properties of the signal (cylco-stationary of the signal) and is rarely used in practical OFDM systems. Adaptive channel estimation methods are typically used for rapidly time-varying channel.

Different possibilities exist for allocating pilots in the time-frequency domain of an OFDM system. We discuss three such possibilities as illustrated in Figure An entire OFDM symbol may be allocated as pilot as shown in Figure a. Such an allocation will be highly beneficial for channel estimation in highly frequency-dispersive and low Doppler channels at the expense of sacrificing data rate we show that the raw channel estimate in an all frequency pilot is indeed the least-squares solution to channel in frequency domain Pilots may be transmitted on individual sub-carriers during the entire transmission period as shown in Figure b. Such a strategy will be advantageous in moderately frequency-selective and high Doppler channels Pilots may be allocated in spaced intervals in time and frequency as illustrated in Figure c. and Figure d. Depending upon the time-frequency pilot spacing and channel properties, such an allocation strategy will work well in both high frequency-selective and high Doppler channels. In orthogonal frequency division multiplexing (OFDM) systems over fast-varying fading channels, channel estimation and tracking is generally carried out by transmitting known pilot symbols in given positions of the frequency-time grid. The traditional approach consists of two steps.



(a) All frequency-time spaced pilot allocation (b) Frequency spaced - all time pilot allocation.



(c) Frequency spaced - time spaced pilot allocation (d) Frequency spaced - time spaced pilot allocation

Fig. 2. Different possibilities for pilot allocation.

First, the least-squares (LS) estimate is obtained over the pilot subcarriers. Then, this preliminary estimate is interpolated/smoothed over the entire frequency-time grid we propose to add an intermediate step, whose purpose is to increase the accuracy of the estimate over the pilot subcarriers. The presented techniques are based on the observation that the wireless radio channel can be parameterized as a combination of paths, each characterized by a delay and a complex amplitude. The amplitudes show fast temporal variations due to the mobility of terminals while the delays (and their associated delay-subspace) are almost constant over a large number of OFDM symbols. We propose to track the delay-subspace by a subspace tracking algorithm and the amplitudes by the least mean square algorithm (or modifications of the latter). The approach can be extended to multiple input multiple output OFDM or multicarrier code-division multiple-access systems. Analytical results and simulations prove the relevant benefits of the novel structure. of orthogonal frequency-division multiplexing (OFDM) to wireless and mobile communications are currently under study. Although multicarrier transmission has several considerable drawbacks (such as high peak to average ratio and strict requirements on carrier synchronization), its advantages in lessening the severe effects of frequency selective fading without complex equalization are very attractive features. In order to obtain the high spectral efficiencies required by future data wireless systems [1], it is necessary to employ multilevel modulation with nonconstant amplitude (e.g., 16QAM [2]). This implies the need for coherent receivers that are capable to track the variations of the fading channel. The channel estimation (tracking) in OFDM systems is generally based on the use of pilot subcarriers in given positions of the frequency-time grid. For fast-varying channels (e.g., in mobile systems), no negligible fluctuations of the channel gains are expected between consecutive OFDM symbols (or even within each symbol) so that, in order to ensure an adequate tracking accuracy, it is advisable to place pilot subcarriers in each OFDM symbol [3], [4]. In particular, the comb pilot pattern arrangement such as mean square error on the channel estimate [5] and capacity [6]. In this framework, the traditional approach to channel estimation, that may be used as an initial estimate in iterative or decision directed receivers [7], [8], consists of two steps. First, the least squares (LS) estimates of the channel gains over the pilot subcarriers are obtained by simply backrotating the received signal according to the knowledge of the pilot symbols. This step can be equivalently seen as the two-dimensional (2-D) (i.e., in frequency and time) sampling of (a noisy version of) the wide sense stationary uncorrelated scattering (WSSUS) process [9] represented by the mobile radio channel. Then, the LS estimates are interpolated/smoothed over the entire frequency-time grid. This task can be accomplished by means of a minimum mean square error(MMSE)filter (2-D or separable) [10]–[12], by simply transform (IFFT)/fast Fourier transform (FFT)-based interpolation)[13] or by a combination of the two approaches [14]. The design of the optimal (MMSE) interpolator requires knowledge of the 2-D correlation function of the channel, i.e., of the power delay profile and the Doppler spectrum. Since this information is not easily available at the receiver, the design problem becomes that of finding the most robust estimator with respect to a mismatch in the channel correlation [15]. We propose a subspace-based technique for channel estimation over the pilot subcarriers that is based on the exploitation of the slowly-varying delay-subspace. From a practical point of view, the method is a preinterpolation channel estimation and it adds an intermediate step between the LS estimator over the pilot subcarriers and the interpolator. The purpose of such a modification of the conventional approach is that of improving the accuracy of the LS estimate of the channel gains over the pilot subcarriers before the interpolation [4]. The key observation is that the channel can be parameterized as a sum of contributions, each related to a different multipath component, characterized by a delay and a complex amplitude. The delays present much slower variations in time than the amplitudes, allowing the two types of parameters to be handled pilot pattern each OFDM symbol carries.

III. CLASSIFICATION OF FADING CHANNELS

Based on the parameters of the channels and the characteristics of the signal to be transmitted, time-varying fading channels can be classified as: Frequency non-selective versus frequency selective. If the bandwidth of the transmitted signal is small compared with then all frequency components of the signal would roughly undergo the same degree of fading. The channel is then classified as frequency non-selective (also called flat fading). We notice that because of the reciprocal relationship between and the one between bandwidth and symbol duration, in a frequency non-selective channel, the symbol duration is large compared with In this case, delays between different paths are relatively small with respect to the symbol duration. We can assume that we would receive only one copy of the signal, whose gain and phase are actually determined by the superposition of all those copies that come within [7].

On the other hand, if the bandwidth of the transmitted signal is large compared with then different frequency components of the signal (that differ by more than would undergo different degrees of fading. The channel is then classified as frequency selective. Due to the reciprocal relationships, the symbol duration is small compared with Delays between different paths can be relatively large with respect to the symbol duration. We then assume that we would receive multiple copies of the signal.

IV. SLOW FADING VERSUS FAST FADING

If the symbol duration is small compared with then the channel is classified as slow fading. Slow fading channels are very often modeled as time-invariant channels over a number of symbol intervals. Moreover, the channel parameters, which are slow varying, may be estimated with different estimation techniques. On the other hand, if is close to or smaller than the symbol duration, the channel is considered to be fast fading (also known as time selective fading). In general, it is difficult to estimate the channel parameters in a fast fading channel. We notice that the above classification of a fading channel depends on the properties of the transmitted signal. The two ways of classification give rise to four different types of channel:

- Frequency non-selective slow fading
- Frequency selective slow fading
- Frequency non-selective fast fading
- Frequency selective fast fading

Diversity techniques can be used to improve system performance in fading channels. Instead of transmitting and receiving the desired signal through one channel, we obtain L copies of the desired signal through M different channels. The idea is that while some copies may undergo deep fades, others may not. We might still be able to obtain enough energy to make the correct decision on the transmitted symbol. There are several different kinds of diversity which are commonly employed in wireless communication systems

V. SIMULATION RESULT

For comb type pilot arrangement we consider an OFDM system with N=1024 sub carriers. The frequency selective Rayleigh channel has L= 40 zero-mean uncorrelated complex Gaussian random taps.

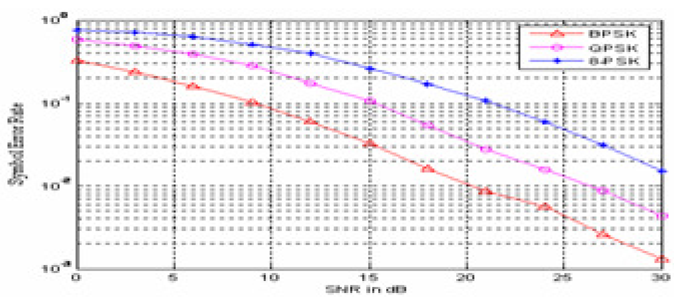


Fig. 3. SER (MMSE channel Estimation) for M-PSK modulation for different SNRs.

The spacing between pilots are taken as 4. So the number of pilots are 256 and number of information symbols are 768. In the simulation we consider BPSK, QPSK and PSK . Figure 3and Figure4 demonstrate Symbol Error Rate (SER) performance (SNR versus SER) for different modulations in MMSE and LSE estimators respectively. It shows that as SNR increases the Symbol error rate decreases and also by going higher order modulation Symbol Error Rate increases which is coming true as we expected.

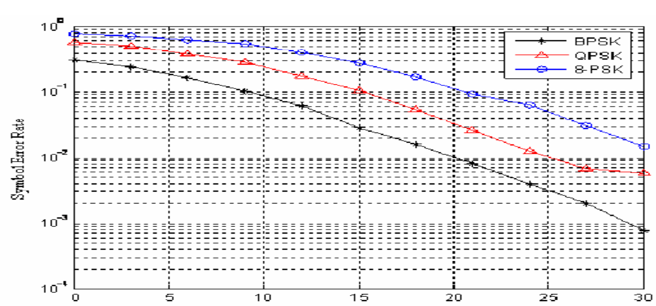


Fig. 4. Bit Error rate versus SNR (LSE channel Estimation) for M-PSK modulation.

VI. CONCLUSION

In this work, we have studied LSE and MMSE estimators for both block type and comb type pilot arrangement. The estimators in this study can be used to efficiently estimate the channel in an OFDM system given a certain knowledge about channel statistics. The MMSE estimators assume a priori knowledge of noise variance and channel covariance. Moreover, its complexity is large compare to the LSE estimator. For high SNRs the LSE estimator is both simple and adequate. The MMSE estimator has good performance but high complexity. The LSE estimator has low complexity, but its performance is not as good as that MMSE estimator basically at low SNRs. In comparison between block and comb type pilot arrangement, block type of pilot arrangement is suitable to use for slow fading channel where channel impulse response is not changing very fast. So that the channel estimated, in one block of OFDM symbols through pilot carriers can be used in next block for recovery the data which are degraded by the channel. In our simulation of block type pilot arrangement we used two ray static channel for 16-QAM modulation. Here 64 numbers of carriers are used in one OFDM block. We So comb type of pilot arrangement can not be used in this case. We used both data and pilot carriers in one block of OFDM symbols. Pilot carriers are used to estimate the channel impulse response. The estimated channel can be used to get back the data sent by transmitter certainly with some error. In the simulation we used 1024 number of carriers in one OFDM block. In which one fourth are used for pilot carriers and rest are of data carriers. We calculated BER for different SNR conditions for M-PSK signaling. We also have compared performance of LSE with MMSE estimator. It is found that higher order interpolation technique (spline) is giving better performance than lower order interpolation technique (linear). In simulation we have also calculated MSE for estimation of channel with number of pilot arrangement. MSE decreases when number of pilots increase. But we have to limit the number pilots when mean square error comes constant.

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