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"Efficient Channel Estimation in OFDM System using MIMO"

Dr. Manish Jain

Associate Professor, Department of Electrical & Electronics Engineering, Mandsaur University, Mandsaur (M.P.)

ABSTRACT: High data rate and high user mobility demands has driven present day wireless communications into another time, in which best in class advances are created to encourage the satisfaction of such requests, and additionally to ensure the nature of service of transmissions under unfriendly channel conditions. In past large amount of work has been made on the past years on channel estimation in OFDM systems still it is considered as area of concern in wireless communication. OFDM is currently viewed as a possible contrasting option to the customary single carrier modulation procedures for high data rate communication systems, for the most part due to its intrinsic balance effortlessness. Channel estimation can be performed for analyzing effect of channel on signal by either inserting pilot tones into all of the subcarriers of OFDM symbols with a specific period or inserting pilot tones into each OFDM symbol. Decision-directed and pilot-symbol-aided methods are two different ways for channel estimation. Pilot-symbol-aided channel estimation can be further divided in two types: block-type-pilot channel estimation and comb-type-pilot channel estimation. Different types of channel estimation technique with virtual sub carriers are discussed in this paper.

KEYWORDS: AWGN, Channel Estimation, Pilot carrier, QAM, MMSE

I. INTRODUCTION

Orthogonal frequency Division Multiplexing (OFDM) is a very attractive technique for high bit-rate transmission in 4G wireless communication systems, where bandwidth is very precious, and service providers are continuously met with the challenges of including more number of users with in a limited allocated bandwidth. Orthogonal Frequency Division Multiplexing (OFDM) is modulation technique most widely used for high-bit-rate wireless communication. Especially the wireless local area network systems such as WiBro, WiMax, WiFi and the emerging fourth-generation mobile systems are all of used of OFDM as the core modulation technique. Wireless communication systems use two different signaling schemes which are: coherent and general signaling schemes. Coherent signaling scheme such as Quadrature Amplitude Modulation (QAM) requires channel estimation and tracking of the fading channel. In a general modulation scheme such as Differential Phase Shift-Keying (DPSK) no channel estimation is required. DPSK is used for low data rate wireless transmission. For example European Digital Audio Broadcast (DAB) uses DPSK modulation scheme. For more efficient digital wireless communication systems, the coherent modulation scheme such as QAM is appropriate [7].

In OFDM system, the channel is usually assumed to have a finite impulse response. To avoid the inter-symbol interference, a cyclic extension is put between the consecutive blocks, where the cyclic extension length is longer than the channel impulse response. There are two different ways for channel estimation such as Decision-directed and pilot-symbol-aided methods. Pilot-symbol-aided channel estimation can be further divided in two types: block-type-pilot channel estimation and comb-type-pilot channel estimation. In the block-type-pilot method, all sub-carriers are reserved for the pilot within a specific period. The estimation of the channel for the block-type-pilot arrangement can be based on Least Square (LS) or on Minimum Mean Square Error (MMSE). In the comb-type-pilot method, one sub-carrier is reserved as a pilot for each symbol. The estimation of the channel for the comb-type-pilot arrangement can be based on linear interpolation, second order interpolation, low-pass interpolation or on time domain interpolation.

The MMSE estimator performance is good but its complexity is high. Contrary the LS estimator complexity is low but its performance is poor [2]. For reducing complexity of the both estimators we

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proposed two different algorithms which reduce complexity without compromise in performance or with slightly lower performance.

1.1 Wireless Channels

The key distinction between wireless and wireline communications lies in the physical properties of the channels. When a radio-frequency (RF) signal is transmitted over a wireless channel, due to the presence of multiple propagation paths between the transmitter and receiver, there are multiple copies of the transmitted signal at the receiver. The multiple paths arise due to reflections, scattering, diffractions from objects in the environment as illustrated in Fig. 1.2. The combination of multiple copies of the transmitted signal affects many characteristics of the received signal. In general, the effects of a wireless channel can be categorized into two types: large-scale fading (or path loss, attenuation) and small-scale fading (typically referred simply to as fading). The large-scale fading is due to signal attenuation by large objects such as buildings, hills, etc.

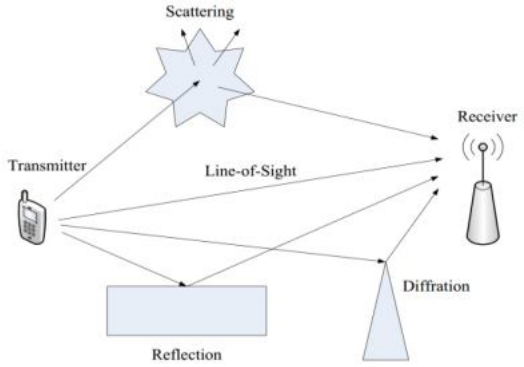

Figure 1.1: Wireless channel view

The small-scale fading is due to the constructive and destructive combinations of the multiple signals arrived over different propagation paths at the receiver. Dealing with small-scale fading is one of the most challenging issues in designing a robust wireless communication system. Hence, in what follows, we discuss a channel model for the wireless link that is affected by the small-scale fading.

II. OFDM Systems

OFDM is a multicarrier transmission method proposed in the mid-1960. In a frequency-particular channel, the postpone spread of the channel impulse reaction presents between image impedance (ISI) in a solitary carrier framework, which causes extreme framework execution corruption if not dealt with. OFDM adequately counters the channel postpone spread by changing over the channel into various covering however commonly orthogonal subchannels in the frequency domain. The spectrum of an OFDM signal is appeared in Figure 1.3 for instance. The fundamental flap of each subcarrier lies on the nulls of all different subcarriers so that there is no common obstruction. OFDM was as of late broadly perceived as a perfect technique for rapid wireless data transmission, for the most part because of the accessibility of fast usage of FFT by present day VLSI outline. OFDM has been effectively received in numerous frameworks, for example, Digital Video Broadcasting-Terrestrial (DVB-T), Asymmetric Digital Subscriber Line (ADSL), and in wireless LAN standards, for example, IEEE 802.11a and IEEE 802.11g. OFDM is additionally being considered as a promising contender for future era fast digital correspondence frameworks, for example, IEEE 802.

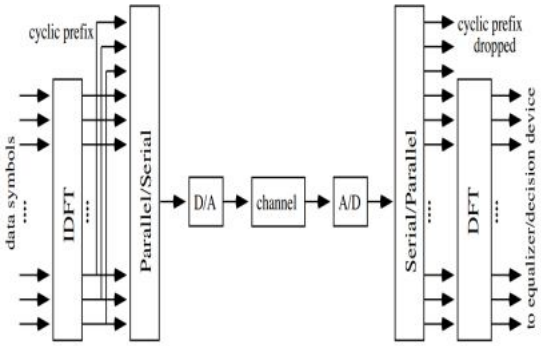

Figure 1.2 An OFDM systems.

The communications channels in wireless conditions are portrayed by the impression of the transmitted radio signal from the articles in the earth. In case of an observable pathway (LOS) communications, the optional reflections from the articles in the earth may negligibly affect the execution of the radio correspondence. However in numerous situations, there is either no LOS segment or the reflections from the articles are too solid to ever be overlooked.

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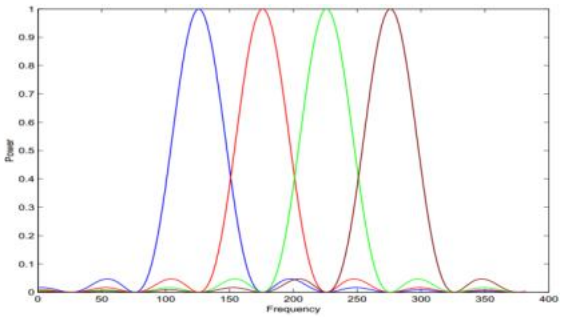

Figure 1.3 Power Spectrum of Sub Carrier in OFDM system.

2.1 Narrowband wireless channels

In the event of no line of sight (NLOS), the simplest example of a narrowband channel is the existence of one reflecting object in the wireless environment. As a result, the wireless channel response is composed of a single tap. However, in the majority of practical cases, multiple reflecting objects exist. But, if the reflections from the objects arrive at the receiver in a sufficiently narrow time interval such that the receiver cannot resolve the individual reflections, the sum of the reflections constitutes a single tap which categorizes it as a narrowband channel.

2.2 Wideband wireless channels

In the event of multiple resolvable reflections, the single-tap channel model does not hold any more and a more general description needs to be sought. Thus, for a wide sense stationary uncorrelated scattering (WSSUS) wireless channel with M resolvable components,

2.3 Multi-Carrier Communications

Single-carrier communications were once dominating the high-speed wireless communications arena. In a single-carrier system binary data, after going through various source and channel coding stages, is modulated and and transmitted over the air. To maximize the throughput the symbols are inserted sequentially in a compact pulse train before transmission. In the meantime, the symbol duration in a conventional single-carrier system is reduced to provide the opportunity for high rate signaling. Had the transmission been materialized in a flat-fading wireless channel, this method would have provided an efficient alternative for fast data transmission. However, the majorities of wireless channels in practice are frequency selective and exhibit a substantial amount of fading. As a result, the symbols experience severe inter symbol interference (ISI) before arriving at the receiving end, requiring sophisticated equalization techniques to retrieve the data. The effect of ISI would become more detrimental in the event of higher frequency selectivity and a shorter symbol interval.

To combat the frequency selectivity in wide-band channels, multi-carrier modulation was proposed an alternative [11]. The idea behind multi-carrier modulation is to restrict the occupied BW of each symbol to a sufficiently narrowband, called sub channel, sub band, or tone so that each symbol experiences little or no fading upon transmission through a frequency selective channel. In other words, the symbol time is increased so much as the wireless channel's delay spread becomes negligible in comparison. The original idea behind multi-carrier modulation, as described above, suffered from the fact that one cannot arbitrarily narrow down the symbol BW without increasing its length in time. Considering the fact that the symbol duration in time has to be limited, a penalty factor in terms of increased BW needs to be paid. Besides, such a scheme suffers from expensive narrowband filters while requiring a large number of modulators/demodulators at the transceiver.

III. Block Diagram of OFDM system

After giving a brief introduction of OFDM system, this section provides the block diagram and which briefly describes the system details. At the transmitter, the user data bit sequence is initially subjected to channel encoding to lessen the probability of error at the receiver because of the channel impacts.

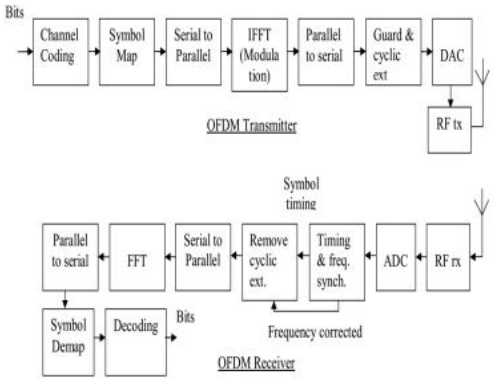

Figure 1.5 OFDM Systems

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Ordinarily, convolution encoding is favored. At that point the bits are mapped to symbols of either 16-QAM or QPSK. The symbol arrangement is changed over to parallel configuration and IFFT (OFDM modulation) is connected and the succession is at the end of the day changed over to the serial organization. Guard time gave between the OFDM symbols and the guard time loaded with the cyclic augmentation of the OFDM symbol. Windowing is applied to the OFDM symbols to make the fall-off rate of the spectrum steeper. The subsequent sequence is changed over to a simple signal utilizing a DAC and passed on to the RF modulation arrange. The subsequent RF regulated signal is, then, transmitted to the receiver utilizing the transmit antennas. Here, directional shaft framing can be accomplished utilizing antenna exhibit, which takes into account spectrum reuse by giving spatial diversity.

The channel estimator provides the knowledge on the Channel Impulse Response (CIR) to detectors. The channel estimation depends on the known sequence of bits which is one of a kind for a specific transmitter and which is rehashed in every transmission burst. The channel estimator is able to estimate the CIR for each burst separately by the exploiting transmitted bits and the corresponding received bits. Distinctive sort of channel estimation strategies are exist to assess the channel: the square sort pilot channel estimation and the brush sort pilot channel estimation.

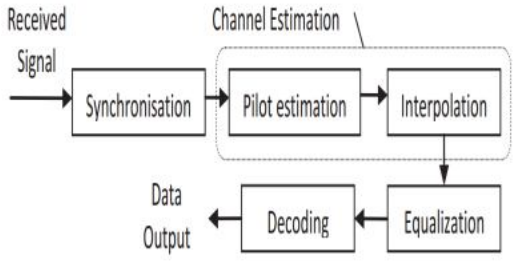

Figure 1.6 Block Diagram of a simplified OFDM receiver.

In wideband OFDM radio communication system, the channel estimation becomes necessary. In this chapter we investigate two types of pilot arrangements: block and comb types of arrangement. OFDM has become a popular modulation technique for wideband signals in recent years due to its superiority in combating inter-symbol interference (ISI) and facilitation of low complexity frequency-domain equalization over conventional single-carrier systems

IV Types of Channel Estimation

Channel estimation is used to obtain the channel state information to know the channel properties using blind channel estimation and pilot - based channel estimation [2].This information describes how a signal gets propagate from the transmitter to the receiver and represents the combined effect of fading, scattering etc. and power decay with distance. The Channel State Information (CSI) makes it possible to adapt transmissions to current channel conditions, which is crucial for achieving reliable communication.

4.1. Sparse Channel Estimation: An approach for obtaining the optimal h is to consider l0 norm minimization which aims at finding the sparsest solution in the feasible solution set.

$$\hat{\mathrm{h}} = \arg_h \min \left(\|\mathrm{R} - \Theta\mathrm{h}\|_2^2 + \lambda \|\mathrm{h}\|_0 \right),$$

Where ^his the estimation vector of h. However, equation is an NP-hard problem. There have many sparse approximation methods to obtain sub-optimal channel estimators, such as CoSaMP, OMP. Sparsely-based estimators, our method are based on an iterative technique which improves the estimates in each step starting at an initial value. However, the sensitivity of our algorithm to this initial state is not restricting; better initial values result in faster convergence

4.2. SL0 Estimation: The main idea of SL0 algorithm [10] is to approximate the l_0 norm by a smooth function, then utilize the gradient based methods to minimize the l_0 norm.

We define

$$v(\alpha) = \begin{cases} 1 & \alpha \neq 0 \\ 0 & \alpha = 0 \end{cases},$$

Then the l_0 norm is $\|h\|_0 = \Sigma ni=1$ v (hi). The discontinuities of the function v leads to the discontinuities of the l0 norm. In order to conquer this disadvantage, asmooth estimation of the l_0 norm is utilized to replace the function v.

Usually, the zero-mean Gaussian family is used inSL0 algorithm as the smooth function

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4.3. Least Square Error (LSE) Estimation: In wireless communication, the channel is usually unknown a priori to the receiver. Therefore to do the channel estimation, a pilot symbol aided modulation is used, where known pilot signals are periodically sent during the transmission. In general, the performance of channel estimation depends on the number, the location, and the power of pilot symbols inserted into OFDM blocks. To mathematically analyze this, consider a fading multipath channel with the multipath delay spread τmax and the maximum Doppler frequency (fd).

$fdTdt \leq 1/2$

$\tau max \Delta f df \leq 1$

Where T is the OFDM block duration, Δf is the subcarrier spacing; $dt$and df are the numbers of samples between pilot symbols in the time domain and frequency domain.

4.4. Regularized Orthogonal Matching Pursuit (ROMP) Estimation: In order to improve the accuracy of channel estimation in OFDM system, an improved algorithm Regularized Orthogonal Matching Pursuit (ROMP) Algorithm is proposed. The algorithm avoids choosing the wrong group and makes the group of atoms' energy more concentrated which is selected by modified regularized principle, then adds the secondary screening of estimation results, achieves an accurate reconstruction of original signal. Simulation results show that, in OFDM system, compared with ROMP and Orthogonal Matching Pursuit (OMP) algorithms, the proposed algorithm can get better performance in Mean Squared Error (MSE) and Symbol Error Rate (SER), improve the accuracy of sparse channel estimation.

In OFDM system, transmission signal { X(i), €,i[0,N -1] }is inserted with pilots and guard band, and then an N-point IDFT transforms the signal into the time domain, demoted by x(n),i▪ [0,N -1] , where a cyclic prefix is added to avoid inter-symbol interference. We assume that the coherence time of the channel is much greater than OFDM symbol periods, in an OFDM symbol period; the channel response is time invariant:

$$h(n) = \sum_{l=0}^{L-1} h_l \delta(n-l)$$

ROMP algorithm for sparse recovery will perform correctly for all measurement matrices Θ satisfying the restricted isometric condition, and for all sparse signals. Firstly, ROMP algorithm make use of the k(sparsely level) biggest coordinates of the observation vector u =Θ*r. Next using the regularization process | u(i) |< 2 u(j) ,i, j € J ,J € J select only the coordinates with comparable sizes. Finally choose 0 J with the maximal energy || u||$_{J0}$2.

4.5. Orthogonal Matching Pursuit (OMP) Estimation: The Orthogonal Matching Pursuit (OMP) algorithm is an enhanced version of the MP algorithm. It works iteratively so as to recover the sparse signal h. It works through the identification of basis and their respective coefficient, which when combined can reconstruct the sparse signal. The algorithm assumes after initialization, that all bases are orthogonal. Hence, the correlation value calculated with basis informs the degree to which the basis influences the signal. If the correlation value is high, the basis is recognized as part of the signal. The initialization algorithm is first initialized and then the normalization to unity is assumed for all atoms.

5. Conclusion: The combination of OFDM with Multiple Input and Multiple Output has fulfilled the future needs of high transmission rate and reliability. The quality of transmission can be further improved by reducing the effect of fading, which can be reduced by properly estimating the channel at the receiver side. For high SNRs the LSE estimator is both simple and adequate. The MMSE estimator has good performance but high complexity. To further improve the performance of LSE and MMSE, DFT based channel estimation is applied. Due to simplicity of LS method, however, the LS method has been widely used for channel estimation. It is clear that the MMSE estimation shows better performance than the LS estimation does at the cost of requiring the additional computation and information on the channel characteristics.

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Dr. Manish Jain obtained Ph.D. in 2015 in ECE. He has a rich teaching experience of 17 years & worked in various Engg. Colleges. He has 20 papers published in International journal and listed in IEEE conference Proceedings. He conducted couples of Conferences, workshop and FDP , he is life member of IE, CEGR, IAENG and Editorial board members & Reviewer of some International Journal. He has authored 1 research book on DSP. Under his guidance Student project have been sanctioned for Financial Assistance by Department of Science & Technology (DST). Under his guidance 10 M. Tech and 1 Ph. D has been awarded.

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