CHANEL ESTIMATION IN MULTICARRIER COMMUNICATION SYTEM

Manju[1], Tilak Raj[2]
[1]PG Student, [2]Assistant Professor, ECE Department, S(PG)ITM Rewari, Haryana, India

I. INTRODUCTION

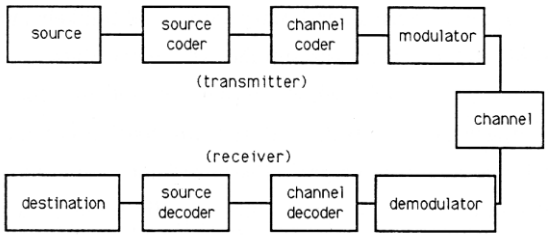
The current wireless communication standards are progressing towards 5G. Further, energy efficiency is a major concern in many applications including wireless communications. Energy efficiency is also one of the challenges in 5G communication systems. Such systems can be realized by incorporating multi input multi output OFDM (MIMO–OFDM) technology. MIMO–OFDM promises higher energy and spectral efficiencies, while mitigating inter symbol interference (ISI). Starting with 3G, the wireless communications standards have incorporated OFDM technology, to reduce the inter symbol interference; obtain higher data rates and better system spectral efficiency. The heart of any OFDM receiver is the channel estimation block. Efficiency of the channel estimation has a direct impact on the bit error rate (BER) performance of the OFDM system. This thesis considers data aided (pilot aided) channel estimation in frequency domain. Frequency domain channel estimation techniques employ known symbols called pilots at known positions in the OFDM symbol grid. These pilots are arranged in a regular manner as comb-type, block-type or 2D-grid type. In a comb-type arrangement, the pilots are present in few subcarriers of all OFDM symbols, while in block-type arrangement, the pilots are present in few OFDM symbols on all subcarriers. In 2D-grid type arrangement, the pilots are present in few subcarriers of few OFDM symbols. Thus the number of pilots in 2D-grid type is less than that in comb-type or block-type arrangements. However, reliability in terms of system BER is better for comb-type arrangement in fast fading channel environments. At the receiver, the channel is estimated using known and the received pilot symbols. Frequency domain channel estimation techniques are either LS based, MMSE based or maximum likelihood (ML) based ones. In this paper, LS and MMSE techniques have been primarily considered. The MMSE based techniques utilize second order KCS and render near optimal performance than the LS based techniques. However, they suffer from the drawbacks of higher computational complexity and the practical unavailability of second order channel statistics. The LS based frequency domain channel estimation methods are simple to implement and do not require any KCS. To improve the MSE performance of the LS based channel estimator, many denoising threshold based strategies have been developed in the literature.

II. MULTICARRIER MODULATION

Multicarrier modulation (MCM) is an effective technique for broadband wireless communication. It partitions the entire bandwidth into parallel independent sub channels to transmit parallel low-bit-rate data streams. Thus, MCM has a relative longer symbol duration which provides great immunity to inter symbol interference (ISI) and impulse noise. The independence among sub channels simplifies the design of the equalizer and provides an easy method for transmitter optimization. Since the channel information is required in both equalization and transmitter optimization, channel estimation plays an important role in MCM system design. Most channel estimation schemes try to exploit the correlation of the channel responses of sub channels to reduce the noise and improve the estimates, though the sub channels are considered to be independent in principle when performing signal detection. Minimum mean squared error (MMSE) estimation can be obtained if the channel correlation function of is known by using the singular value decomposition of the correlation matrix . However, in practice, the correlation function is usually not known and the channel statistics may vary by time. Our goal is to design an estimation scheme under the condition that the channel statistics are not known or not completely known. One such scheme proposed in assumes that the channel correlation matrix can be diagonalized by a Fourier transform. The assumption is true when we consider infinite samples of the channel responses. In practice, we can only have finite observations, which may cause severe leakage using this type of approach. The transmission of information from the sender to the recipient through some medium is called as communication. Communication enables us to know what is happening around us. It helps us to share our knowledge with others and also gain from other individual's thoughts and ideas. Communication takes place through various routes and channels and with the help of a medium. A person can chat with his distant relative over the phone and thus the medium of communication in this case is the telephone.

III. COMMUNICATION SYSTEM

Communication can also take place with the help of light. The airport officials give various signals through light to the pilots for their safe landing. In this case communication is through light and hence is termed as Optical communication. Satellites also play a vital role in communication by receiving signals from the earth station, amplifying it and then resending it back to the earth. Communication can take place with the aid of an artificial satellite between two points on the earth. In the same way signal can also be sent in a digitalized form as in case of Digital communication. The process of communication is initiated the moment the sender gets some thought in his brain. To share his ideas with others, the thoughts must be converted into a meaningful content by careful selection of words. This process is also called as encoding. In digital communication, the thought is converted in a digital format for the recipient to understand. In this mode of communication, the data or the information is transferred electronically with the help of computers.



IV. CHAPTER 4

1 OFDM

OFDM is an acronym that stands for Orthogonal Frequency Division Multiplexing. Orthogonal Frequency Division Multiplexing (OFDM) is a multicarrier transport technology for high data rate communication system. The OFDM concept is based on spreading the high speed data to be transmitted over a large number of low rate carriers. The carriers are orthogonal to each other and frequency spacing between them are created by using the Fast Fourier transform (FFT).

OFDM originates from Frequency Division Multiplexing (FDM), in which more than one low rate signal is carried over separate carrier frequencies. In FDM, separation of signal at the receiver is achieved by placing the channels sufficiently far apart so that the signal spectrum does not overlap. Of course, the resulting spectral efficiency is very low as compared with OFDM, where a comparison is depicted.

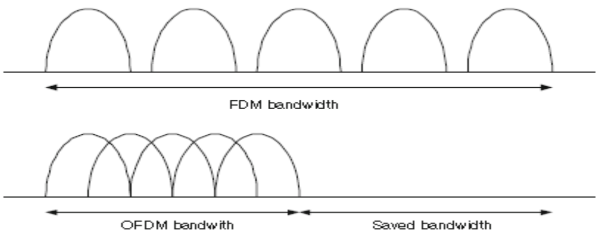


Fig Comparison of OFDM with FDM

FDM is first utilized to carry high-rate signals by converting the serial high rate signal into parallel low bit streams. Such a parallel transmission scheme when compared with high-rate single carrier scheme is costly to build. On the other hand, high-rate single carrier scheme is more susceptible to inter symbol interference (ISI). This is due to the short duration of the signal and higher distortion by its wider frequency band as compared with the long duration signal and narrow bandwidth sub channels in the parallel system.An analogy of OFDM against single carrier and FDM in terms of spectral efficiency.

Comparison of OFDM over FDM and single-carrier systems. OFDM and FDM are resilient to interference, since flow of water can be easily stopped in single-carrier systems. OFDM is more spectral efficient than FDM, since it utilizes the surface effectively with adjacent tiny streams. The technique involved assembling the input information into blocks of N complex numbers, one for each sub-channel as seen in fig. An inverse FFT is performed on each block, and the resultant transmitted serially. At the receiver, the information is recovered by performing an FFT on the received block of signal samples. The spectrum of the signal on the line is identical to that of N separate QAM signals as seen in Fig., where N frequencies separated by the signaling rate. Each QAM signal carries one of the original input complex numbers. The spectrum of each QAM signal is of the form $\sin(kf)/f$ with nulls at the center of the other subcarriers as seen in Fig. This ensures orthogonality of subcarriers.

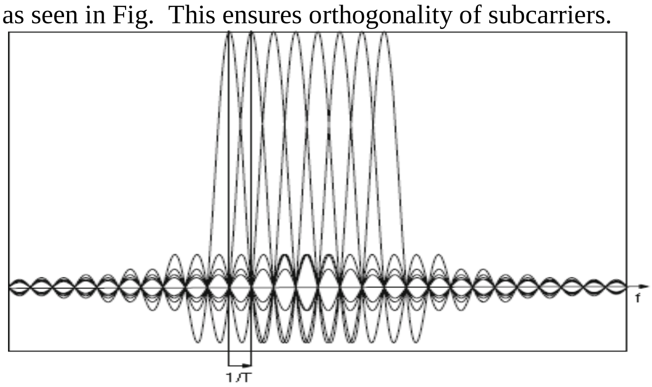


Fig OFDM spectrum for each QAM Signal

Table History of OFDM

1957 Kineplex, multicarrier HF modem
1966 Chang, Bell Labs: OFDM paper and US patent 3488445
1971 Weinstein and Ebert proposed use of FFT and guard interval
1985 Cimini described the use of OFDM for mobile communications
1985 Telebit Trailblazer Modem incorporates a 512-carrier Packet Ensemble Protocol
1987 Alard and Lasalle: Coded OFDM for digital broadcasting
1988 TH-CSF LER, first experimental Digital TV link in OFDM, Paris area
1989 OFDM international patent application PCT/FR 89/00546, filed in the name of THOMSON-CSF, Fouche, de Couasnon, Travert, Monnier and others
1990 TH-CSF LER, first OFDM equipment field test, 34 Mbps in a 8-MHz channel,experiments in Paris area
1990 TH-CSF LER, first OFDM test bed comparison with VSB in Princeton, USA
1992 TH-CSF LER, second generation equipment field test, 70 Mbit/s in a 8-MHz channel, twin polarizations. Wuppertal, Germany
1992 TH-CSF LER, second generation field test and test bed with BBC, near London, UK
1993 TH-CSF show in Montreux SW, 4 TV channel and one

HDTV channel in a single 8-MHzchannel
1993 Morris: Experimental 150 Mbit/s OFDM wireless LAN
1994 US patent 5282222, method and apparatus for multiple access between transceivers in wireless communications using OFDM spread spectrum
1995 ETSI Digital Audio Broadcasting standard EUreka: First OFDM-based standard
1997 ETSI DVB-T standard
1998 Magic WAND project demonstrates OFDM modems for wireless LAN
1999 IEEE 802.11a wireless LAN standard (Wi-Fi)
2000 Proprietary fixed wireless access (V-OFDM, Flash-OFDM, etc.)
2002 IEEE 802.11g standard for wireless LAN
2004 IEEE 802.16-2004 standard for wireless MAN (WiMAX)
2004 ETSI DVB-H standard
2004 Candidate for IEEE 802.15.3a standard for wireless PAN (MB-OFDM)
2004 Candidate for IEEE 802.11n standard for next-generation wireless LAN
2005 OFDMA is candidate for the 3GPP Long Term Evolution (LTE) air interface E-UTRA downlink.
2007 The first complete LTE air interface implementation was demonstrated, including OFDM-MIMO, SC-FDMA and multi-user MIMO uplink

Threats to Orthogonality:
Orthogonality is threatened by inter symbol interference (ISI), which is caused by leakage of symbols into another due to multipath interference. To combat for ISI, a guard time is introduced before the OFDM symbol. Guard time is selected longer than impulse response or multipath delay so as not to cause interference of multipath components of one symbol with the next symbol.
Orthogonality is also threatened by inter carrier interference (ICI), which is crosstalk between subcarriers, since now the multipath component of one subcarrier can disturb the another one. ICI in OFDM is prevented by cyclically extending the guard interval to ensure integer number of cycles in the symbol time as long as the delay is smaller than the guard time.

Simple OFDM System:
Let us consider a simple OFDM system to understand the mechanics behind it. The incoming data is converted from serial to parallel and grouped into bits each to form a complex number x after PSK or QAM modulation in order to be transmitted over N low-rate data streams. Each low-rate data stream is associated with a subcarrier of the form

$$\phi_k(t) = e^{j2\pi f_k t}$$

where f_k is the frequency of the kth subcarrier. Consequently, one baseband OFDM symbol with N subcarrier,

$$\mathrm{s(t)} = \frac{1}{\sqrt{\mathrm{N}}}\sum_{\mathrm{k=0}}^{\mathrm{N-1}} \mathrm{x_k}\phi_{\mathrm{k}}(\mathrm{t}) \qquad 0<t<T,$$

Where x_k the kth complex data symbol and T is is the length of the OFDM symbol.
When signal is transmitted over a channel, channel dispersion destroys the orthogonality between subcarries and causes ICI, and delay spread causes ISI between successive OFDM symbols. As we mentioned before, cyclic prefix (CP) is used to preserve the orthogonality and avoid ISI. The CP is utilized in the guard period between successive blocks and constructed by the cyclic extension of the OFDM symbol over a period τ.

$$\mathrm{s(t)} = \frac{1}{\sqrt{\mathrm{N}}}\sum_{\mathrm{k=0}}^{\mathrm{N-1}} \mathrm{x_k}\phi_{\mathrm{k}}(\mathrm{t}) \qquad -\tau < t < NT$$

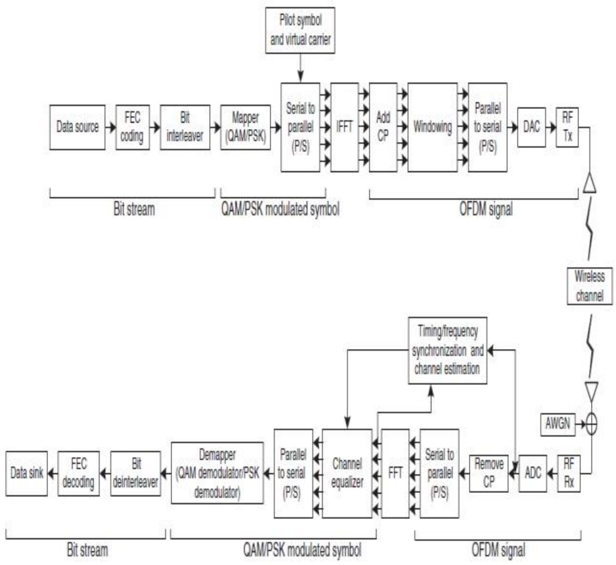


Fig Simplified Block Diagram of OFDM system

The CP converts a discrete time linear convolution into a discrete time circular convolution. Thus, transmitted data can be modeled as a circular convolution between the channel impulse response and the transmitted data block, which in the frequency domain is a point wise multiplication of DFT samples. Then received signal becomes

$$y(t) = s(t) * h(t) = \frac{1}{\sqrt{N}}\sum_{k=0}^{N-1} H_k x_k \phi_k(t), \qquad 0 < t < NT$$

$$H_k = \int_0^{\tau_h} h(t) e^{j2\pi f_k t} dt$$

Where

Hence, k^{th} subcarrier now has a channel component H_k, which is the Fourier transform of $h(t)$ at the frequency f_k
The OFDM symbol is sampled ($t = nT$ and $f_k = k/NT$) in the receiver and demodulated with an FFT. Consequently, the received data has the following form

$$y_k = H_k x_k \qquad \text{k=0, 1, 2, 3...N-1}$$

The received actual data can be retrieved with N parallel one-tap equalizers. One-tap equalizer simply uses the estimated channel ($\hat{H}_k$) components and use it to retrieve estimated $\hat{x}_k$ as follows

$$\hat{x}_k = \frac{y_k}{\hat{H}_k}$$

Details of OFDM components:

Coding:

Coding used in OFDM systems is to correct the certain number of errors in order to enable high rates in the presence of fading and interference from other wireless channels. Various coding schemes are defined below:

Block Coding:

Block coding is a way of mapping *k* symbols to *n* symbols with *n* > *k*. We call the block of *k* symbols a message word, and the block of *n* symbols a codeword. The process of mapping *k* message symbols to *n* code symbols is called *encoding*, and the reverse process is called *decoding*. Block codes, in particular the Reed-Solomon class, are used to combat for bursty errors. In OFDM system, an impulsive noise with a wide-frequency content causes burst error to affect several adjacent subcarriers if coherence bandwidth of the channel is wider than the subcarrier spacing.

Convolution Encoding:

Convolutional coding is another famous coding technique that operates on serial streams of symbols rather than blocks. A convolutional encoder is usually described by two parameters: the code rate and the constraint length. The code rate is *k/n*, where *k* is the number of bits into the convolutional encoder and *n* is the number of channel symbols output by the convolutional encoder in a given encoder cycle. The constraint length parameter, *K*, denotes the “length” of the convolutional encoder, which denotes the number of stages and the cycles an input bit retains in the convolutional encoder. Viterbi decoding or sequential decoding are used for convolutional encoding. Sequential decoding performs well with long-constraint-length convolutional codes, but it has a variable decoding time. Viterbi decoding on the other hand has a fixed decoding time.

Concatenated Coding:

Concatenated coding has emerged from the need to achieve better error correcting capabilities with less-complex structures. The concatenated coding uses two or more codes after each other or, in parallel, usually with some kind of interleaving. The constituents of the codes are decoded with their own decoders. Concatenated coding provides means to constructing long codes, and it also confirms Shannon’s channel coding theorem by stating that if the code is long enough, any error can be corrected.

LDPC Coding:

Low-density parity check (LDPC) is an emerging new technique that gets even closer to Shannon rate with long code words. LDPC codes are linear block codes that show good block error correcting capability and linear decoding complexity in time. An LDPC code operates on an H matrix containing a low count of ones – hence the name low-density parity-check codes. This is used in encoding in order to derive equations from the H matrix to generate parity check bits. Iterative decoding utilizes “soft inputs” along with these equations in order to generate estimates of sent value.

Synchronization:

Synchronization is the essential part of the receiver since oscillator impairments and clock differences along with phase noise during demodulation degrade the performance. OFDM needs to employ time and frequency synchronization. Time synchronization is to decide for the symbol boundaries. Commonly, a sequence of known symbols-preamble is used to detect the symbol boundaries. It has less sensitivity to timing offset as compared with single-carrier systems, since timing offset does not violate the orthogonality of subcarriers in OFDM system, but causes ISI in single-carrier systems.

Frequency synchronization, which is to estimate the frequency offset in the oscillators in order to align the oscillators in the transmitter and receiver, is essential otherwise ICI occurs, since subcarriers could be shifted from its original position and the receiver may experience nonorthogonal signals. Since the carriers are spaced closely in frequency domain, a small fraction of frequency offset is barely tolerable. Also, practically oscillators do not produce a carrier at exactly one frequency but rather a carrier with random phase noise. This phase noise in time domain corresponds to frequency deviation in frequency domain, thereby causing ICI.

Detection and Channel Estimation:

To estimate the transmitted bits at the receiver, channel knowledge is required in addition to the estimates of random phase shift and amplitude change, caused by carrier frequency offset and timing offset. The receiver applies either coherent detection or noncoherent detection to estimate the unknown phase and amplitude changes introduced by multipath fading channel.

The coherent detection of subscribers requires channel estimation. These are done by channel equalizer, which multiplies each subscriber in an OFDM symbol with a complex number.

Noncoherent detection on the other hand does not use any reference values but uses differential modulation where the information is transmitted in difference of the two successive symbols. The receiver uses two adjacent symbols in time or two adjacent subcarriers in frequency to compare one with another to acquire the transmitted symbol.

V. RESULT AND SIMULATION

Input to time domain

x (n)=IDFT{x(k)} n=0,1,2,…,N-1

Guard Interval

xf(n)={x(N+n), n=-Ng,-Ng+1,….,-1
{x(n), n=0,1,….N-1

Channel

Yf=xf(n)θh(n)+w(n)

Guard Removal

y(n)=yf(n) n=0,1,…N-1

Output to frequency domain

y(k)=DFT{y(n)} k=0,1,2,…N-1

Output

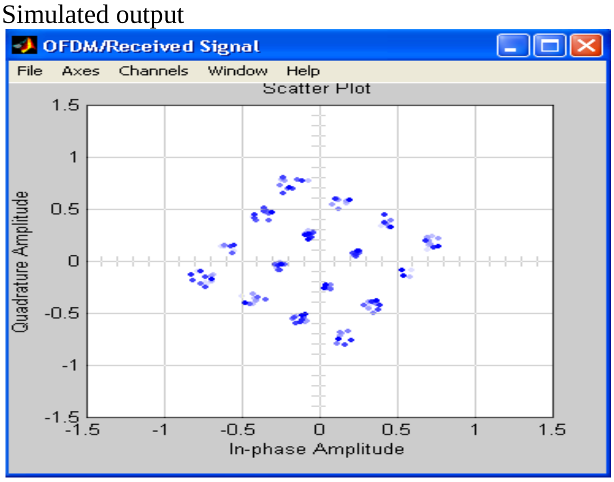
y(k) H(k)+ I(k)+W(k)
K=0,1,…,N-1
Channel Estimation
X(k)=y(k)/H(k) k=0,1,…,N-1

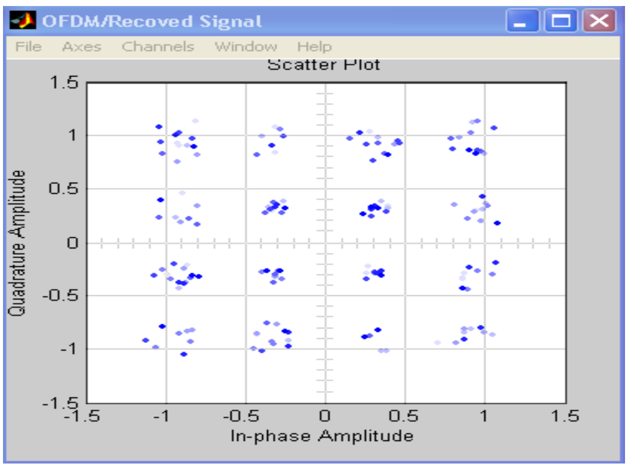
Channel Estimation of OFDM System

SIMULATION PARAMETERS

Parameter	Specifications
FFT Size	64
Number of Carriers	64
Pilot Ratio	1/16
Guard Length	16
Guard Type	Cyclic Extension
data rate of OFDM signal	1Mbps/sub-carrier
Signal Constellation	16QAM

Simulated output





Received and Recovered Signals

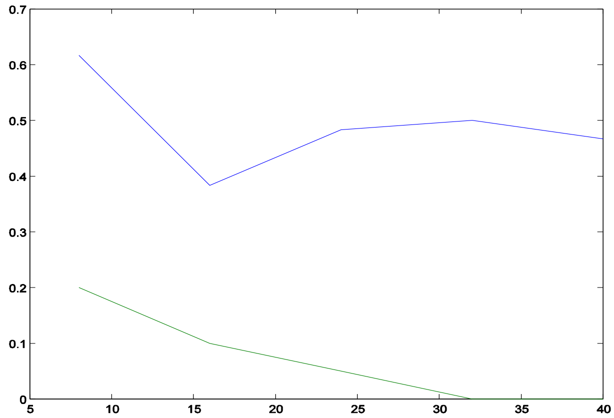


Fig. Received signal

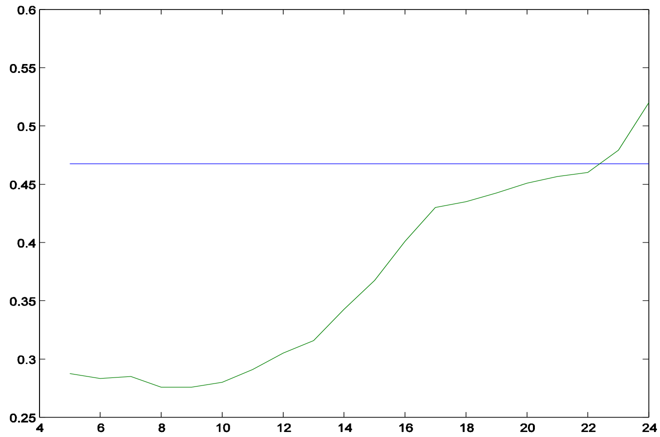


Fig. Recovered signal

VI. CONCLUSION AND FUTURE WORK

This chapter presents conclusions of the thesis and further work for the future. OFDM is very efficient in wireless communication over wideband channels. One of the major issues in OFDM systems is the estimation of Guard Interval and symbol timing. This thesis focuses on the development of novel signal processing algorithms for Pilot Ratio and symbol timing estimation in OFDM and Multiband OFDM systems. This thesis include Director Decision Feedback, comb type, LAS or LMS estimation at pilot frequency.

