OFDM & Its Channel Estimation

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Abstract: Orthogonal frequency division multiplexing (OFDM) gives a compelling and low intricacy method for taking out inter-symbol obstruction for transmission over frequency specific fading channels. This system has gotten a considerable measure of enthusiasm for versatile correspondence research as the wireless channel is normally frequency specific and time variation. Usually, CSI can be dependably evaluated at the recipient by transmitting pilots alongside information symbols. Pilot symbol helped channel estimation is particularly appealing for wireless communication, where the channel is time-changing. In this paper, we research and think about different effective pilot based channel estimation plans for OFDM systems. The channel estimation can be performed by either inserting pilot tones into all subcarriers of OFDM images with a particular period or insertigs pilot tones into each OFDM image. In this present study, two noteworthy sorts of pilot scheme, for example, block type and comb type pilot have been engaged utilizing Least Square Error (LSE) and Minimum Mean Square Error (MMSE) channel estimators. Block type pilot sub-carriers is particularly suitable for moderate fading radio channels though comb type pilots give better imperviousness to quick fading channels. Additionally comb type pilot scheme is delicate to frequency selectivity when contrasting with block type pilot scheme. The channel estimation calculation taking into account comb type pilots is partitioned into pilot signal estimation and interpolation of channel. The pilot signal estimation depends on LSE and MMSE criteria, together with interpolation of channel utilizing linear interpolation and spline cubic interpolation. The performance of symbol error rate (SER) of orthogonal frequency division multiplexing for both block type and comb type pilot subcarriers are also discussed in the paper.

Keywords: OFDM, Channel Estimation, Pilot based channel estimation, Block type pilot arrangement, Comb type pilot arrangement.

1. INTRODUCTION

OFDM is a mixture of modulation and multiplexing. Multiplexing by and large alludes to autonomous signals, those delivered by different sources. In OFDM the inquiry of multiplexing is connected to free signals yet these independent or free signals are a sub-set of the one principle signal. In OFDM, the signal itself is first divided into separate channels, modulated by carriers and then multiplexed to create the OFDM carrier. If the FDM system above had possessed the capacity to utilize a set of subcarriers that were orthogonal to one another, a larger amount of spectral efficiency could have been attained to. The guard bands that were important to allow individual demodulation of subcarriers in an FDM system would never again be fundamental. The utilization of orthogonal subcarriers would permit the subcarriers spectra to overlap, in this way expanding the spectral efficiency. As far as Orthogonality is sustained, it is still conceivable to recover the individual subcarriers signals regardless of their overlapping spectrums. It can be seen that practically a large portion of the bandwidth is spared by overlapping the spectra. As more carriers are included, the bandwidth approaches (N+1)/N Bits per Hz. Bigger number of carriers gives better spectral efficiency. The principle idea in OFDM is Orthogonality of the sub-carriers. The "orthogonal" piece of the OFDM shows that there is an exact scientific relationship between the frequencies of the carriers in the system. It is conceivable to arrange the carriers in an OFDM Signal so that the sidebands of the individual carriers overlap and the signals can still be received without neighbouring carrier‘s interference. The Orthogonality feature of OFDM among the carriers can be sustained if the OFDM signal is characterized by utilizing Fourier transform procedures. The OFDM system transmits a substantial number of narrowband carriers, which are nearly separated. Note that at the central frequency of the each sub channel there is no crosstalk from other sub channels. In an OFDM system, the data bit stream is multiplexed into N symbol streams, each with symbol period Ts, and each symbol stream is utilized to modulate parallel, synchronous sub-carriers. The sub-carriers are dispersed by 1/NTs in frequency, in this way they are orthogonal over the interval (0, Ts). A typical discrete-time baseband OFDM transceiver system is indicated in figure underneath. To start with, a serial-to-parallel (S/P) converter amasses the stream of data bits from the source encoder into gathering of $\log_2 M$ bits, where M is the letter in order of size of the digital modulation scheme employed on each sub-carrier. A sum of N such symbols, Xm, are made. Then, the N symbols are mapped to receptacles of an inverse fast Fourier transform (IFFT). These IFFT receptacles compare to the orthogonal sub-carriers in the OFDM symbol.

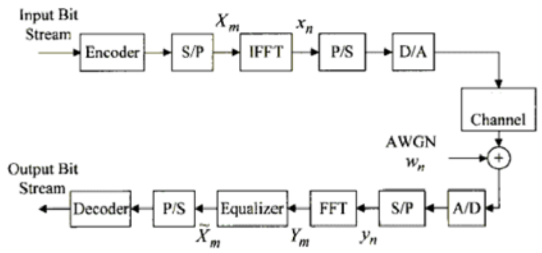

Fig. 1: Baseband OFDM transceiver system.

Therefore, the OFDM symbol can be expressed as

$$x(n) = \frac{1}{N}\sum_{m=0}^{N-1} X_m e^{j\frac{2\pi mn}{N}} \quad 0 \le n \le N-1$$

Where Xm are the baseband symbols on each sub-carrier. The digital-to-analog (D/A) converter then creates an analog time-domain signal which is transmitted through the channel.

At the receiver, the signal is converted back to a discrete N point sequence y(n), corresponding to each sub-carrier. This discrete signal is demodulated using an N-point fast Fourier transform (FFT) operation at the receiver. The demodulated symbol stream is given by:

$$Y(m) = \sum_{n=0}^{N-1} y(n) e^{-\frac{j2\pi mn}{N}} + W(m) \qquad 0 \le m \le N-1$$

Where W (m) corresponds to the FFT of the samples of w (n), which is the Additive White Gaussian Noise (AWGN) introduced in the channel. The fast speed data rates for OFDM are proficient by the simultaneous transmission of information at a lower rate on each of the orthogonal sub-carriers. In view of the low information rate transmission, distortion in the received signal impelled by multi-path delay in the channel is not as noteworthy as contrasted to single-carrier high-data rate systems. For instance, a narrowband signal sent at a high data rate through a multipath channel will encounter more noteworthy negative effects of the multipath delay spread, as the symbols are much closer together. Multipath distortion can also cause inter-symbol interference (ISI) where nearby symbols overlap with each other. This is counteracted in OFDM by the insertion of a cyclic prefix between successive OFDM symbols. This cyclic prefix is discarded at the receiver to cancel out ISI. It is because to the robustness of OFDM to ISI and multipath distortion that it has been considered for different wireless applications and standards.

Channel Estimation

The transmitter modulates the data bit into PSK/QAM symbols in an OFDM system and also performs IFFT on the symbols to convert them into time-domain signals, and then sends them out through a (wireless) channel. The received signal is generally distorted by the channel characteristics. In order to recuperate the transmitted data bits, the channel effect must be estimated and compensated in the receiver. As talked about over, each subcarrier can be regarded as an independent channel, as far as no ICI (Inter-Carrier Interference) occurs, and thus preserving the orthogonality among sub-carriers. The orthogonality permits each sub-carrier component of the received signal to be presented as the multiplication of the transmitted signal and channel frequency response at the sub-carrier. Thus, the transmitted signal can be recuperated by estimating or evaluating the channel response just at each sub-carrier. In general, the channel can be evaluated by using a preamble or pilot symbols known to both transmitter and receiver, which utilized different interpolation methods to estimate the channel response of the sub-carriers between pilot tones. In general, data signal as well as training signal, or both, can be used for channel estimation. In order to choose the channel estimation technique for the OFDM system under thought, a wide range of implementations, including the required performance, computational complexity and time-variation of the channel must be taken into account. If we consider wide-band wireless communication systems, the channel is time varying and dispersive fading, which results in distorting the transmitted signal. Thus, the accurate and real-time estimation of channel becomes a challenging task in OFDM systems. The channel estimation methods generally can be separated into two kinds. One kind rely on the pilots and the other is blind channel estimation which does not utilize pilot and have greater spectral efficiency. However, they often face problem due to high computation complexity and low convergence rate as they often need a greater amount of receiving input to obtain some statistical information induced by the cyclic prefix. Blind channel estimation methods are not suitable for applications with fast varying fading channels. In this paper, pilot based channel estimation method will be utilized to estimate the channel.

Channel Estimation Techniques:

Pilot Structure

Pilot sequences are the un-modulated data, we are transmitting along with the data. Pilots are used for synchronization and Channel estimation purposes. Depending on the arrangement of pilots, three different types of pilot structures are considered:Block type, comb type, and lattice type.In block type, OFDM symbols with pilots at all sub-carriers are transmitted periodically for channel estimation.

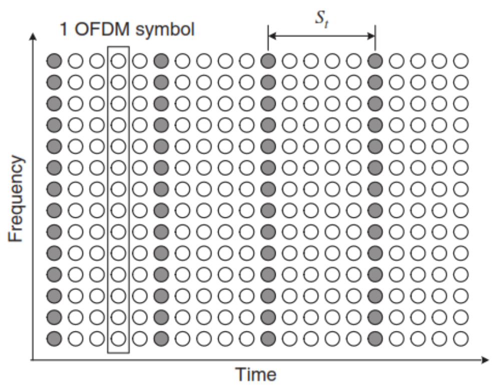

Fig. 2 Block Type Pilot Structure

In comb type, every OFDM symbol has pilot tones at the periodically-located subcarriers, which are used for a frequency-domain interpolation to estimate the channel along the frequency axis.

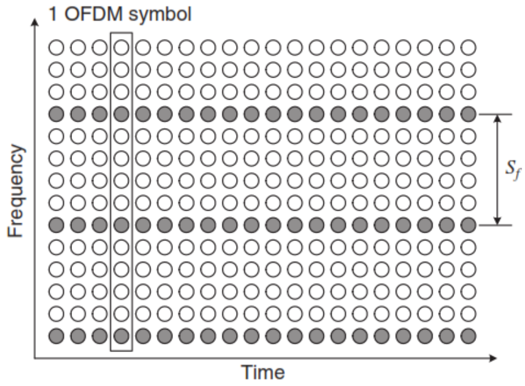

Fig. 3 Comb Type Pilot Structure

In lattice type, pilot tones are inserted along both the time and frequency axes with given periods. The pilot tones scattered in both time and frequency axes facilitate time/frequency-domain interpolations for channel estimation.

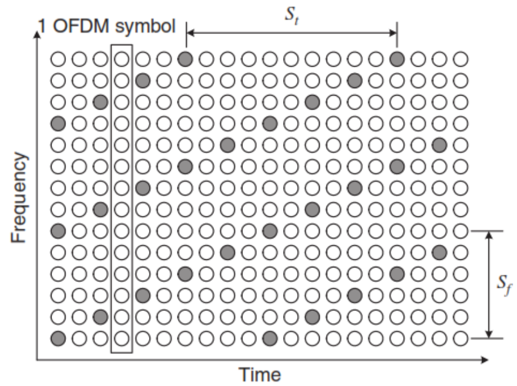

Fig.4 Lattice Type Pilot Structure

Few Other Channel Estimation Methods are:

Training Symbol-Based Channel Estimation

DFT-Based Channel Estimation

2. LITERATURE SURVEY

The first OFDM scheme was proposed by Chang [2] in 1966 for dispersive fading channels, which has also undergone a dramatic evolution then OFDM was selected as the high performance local area network transmission technique. A method to reduce the ISI is to increase the number of subcarriers by reducing the bandwidth of each sub-channel while keeping the total bandwidth constant. The ISI can instead be eliminated by adding a guard interval at the cost of power loss and bandwidth expansion. These OFDM systems have been employed in military applications since the 1960's, for example by Bello [6], Zimmerman [7] and others. The employment of discrete Fourier transform (DFT) to replace the banks of sinusoidal generators and the demodulators was suggested by Weinstein and Ebert [5] in 1971, which significantly reduces the implementational complexity of OFDM modems. Hirosaki [8], suggested an equalization algorithm in order to suppress both intersymbol and inter subcarrier interference caused by the channel impulse response or timing and frequency errors. Simplified model implementations were studied by Peled [9] in 1980. Cimini [6] and Kelet [10] published analytical and early seminal experimental results on the performance of OFDM modems in mobile communication channels. Most recent advances in OFDM transmission were presented in the impressive state of art collection of works edited by Fazel and Fettweis [11].OFDM transmission over mobile communications channels can alleviate the problem of multipath propagation. Recent research efforts have focused on solving a set of inherent difficulties regarding OFDM, namely peak-to mean power ratio, time and frequency synchronization, and on mitigating the effects of the frequency selective fading channels.

Channel estimation and equalization is an essential problem in OFDM system design. Basic task of equalizer is to compensate the influences of the channel [3]. This compensation requires, however, than an estimate of the channel response is available. Often the channel frequency response or impulse response is derived from training sequence or pilot symbols, but it is also possible to use nonpilot aided approaches like blind equalizer algorithms [12].

Channel estimation is one of the fundamental issue of OFDM system design, without it non coherent detection has to be used, which incurs performance loss of almost 3-4 dB compared to coherent detection [13]. If coherent OFDM system is adopted, channel estimation becomes a requirement and usually pilot tones are used for channel estimation. A popular class of coherent demodulation for a wide class of digital modulation schemes has been proposed by Moher and Lodge [14], and is known as Pilot Symbol Assisted Modulation, PSAM. The main idea of PSAM channel estimation is to multiplex known data streams with unknown data. Conventionally the receiver firstly obtain tentative channel estimates at the positions of the pilot symbols by means of remodulation and than compute final channel estimates by means of interpolation. Aghamohammadi [15] et al. and Cavers [16] were among the first analyzing and optimizing PSAM given different interpolation filters. The main disadvantage of this scheme is the slight increase of the bandwidth. One class of such pilot symbol assisted estimation algorithms adopt an interpolation technique with fixed parameters (two dimensional and one dimensional) to estimate the frequency domain channel impulse response by using channel estimates obtained at the lattices assigned to the pilot tones. Linear, Spline and Gaussian filters have all been studied [17].

Channel estimation using superimposed pilot sequences is also a completely new area, idea for using superimposed pilot sequences has been proposed by various authors for different applications. In [18], superimposed pilot sequences are used for time and frequencysynchronization. In [19], superimposed pilot sequences are introduced for the purpose of channel estimation, and main idea here is to linearly add a known pilot sequence to the transmitted data sequence and perform joint channel estimation and detection in the receiver.In [20], expectation maximization (EM) algorithm was proposed, and in [21] EM algorithm was applied on OFDM systems for efficient detection of transmitted data as well as for estimating the channel impulse response. Here, maximum likelihood estimate of channel was obtained by using channel statistics via the EM algorithm. In [22], performance of low complexity estimators based on DFT has been analyzed. In [23], block and comb type pilot arrangements have been analyzed. There are some other techniques, proposed for channel estimation and calculation of channel transfer function in OFDM systems. For example, the use of correlation based estimators working in the time domain and channel estimation using singular value decomposition [24]. Its basically based on pilot symbols but in order to reduce its complexity, statistical properties of the channel are used in a different way. Basically the structure of OFDM allows a channel estimator to use both time and frequency correlations, but particularly it is too complex.

In [24], they analyzed a class of block oriented channel estimators for OFDM, where only the frequency correlation of the channel is used in estimation. Whatever, their level of performance, they suggested that they may be improved with the addition of second filter using the time correlation.

In [25], they proposed a channel estimation algorithm based polynomial approximations of the channel parameters both in time and frequency domains. This method exploits both the time and frequency correlations of the channel parameters. Use of the pilot symbols for channel estimation is basically an overhead of the system, and it is desirable to keep the number of pilot symbols to a minimum.

In [26], Julia proposed a very good approach for OFDM symbol synchronization in which synchronization (correction of frequency offsets) is achieved simply by using pilot carriers already inserted for channel estimation, so no extra burden is added in the system for the correction of frequency offsets.

Similarly in [27], it has been shown that the number of pilot symbols for a desired bit error rate and Doppler frequency is highly dependent on the pilot patterns used, so by choosing a suitable pilot pattern we can reduce the number of pilot symbols, but still retaining the same performance. Most common pilot patterns used in literature are block and comb pilot arrangements [23], [28]. Comb patterns perform much better than block patterns in fast varying environments [23].

3. PROBLEM STATEMENT

The aim of future fourth-generation (4G) mobile systems is on supporting high data rate services and guaranteeing consistent provisioning of services across a multitude of wireless systems and networks, for indoor to outdoor, starting with one interface then on to the next, and from private to public network infrastructure. Higher data rates permit the arrangement of multi-media applications which include voice, information, pictures, and video over the wireless networks. Now, the data rate envisioned for 4G networks is 1 GB/s for indoor and 100Mb/s for outdoor environments. High data rate implies the signal waveform is really wideband, and the channel is frequency-selective from the waveform perspective, that is, an extensive number of resolvable multi-paths are available in the environment. Orthogonal frequency division multiplexing (OFDM), which is a modulation method for multicarrier communication systems, is a guaranteeing contender for 4G systems since it is less vulnerable to inter-symbol interference introduced in the multipath environment.

It is impractical to settle on reliable data decisions unless a good channel estimate is available. Therefore, an accurate and efficient channel estimation method is required to coherently demodulate the received data. As we said prior that although differential identification could be used to detect the transmitted signal in the absence of channel estimates, it would result in about 3-4dB loss [2] in signal to noise ratio contrasted with coherent detection. Additionally, rather than previous standards using OFDM modulation, the new norms rely on QAM modulation and consequently oblige channel estimation. Henceforth, the intricacy of channel estimation is of vital inperativeness, particularly for time varying channels, where it must be performed periodically or even continuously. A few channel estimation techniques related with OFDM systems have been described in literature [29]. A number of pilot symbols for a desired error rate and Doppler frequency is highly dependent on how we transmit pilots [27] in OFDM systems. Rearrangement of pilot symbols, in some cases, can handle 10 times higher Doppler frequencies then again reduced the required pilot symbols, as yet holding the same bit error rate [27].

4. METHODOLOGY TO BE ADOPTED

In this paper we will investigate and compare different proficient pilot based channel estimation techniques for OFDM systems. The channel estimation can be done by either adding pilot tones into all subcarriers of OFDM symbols with a specific period or adding pilot tones into each OFDM symbol. In this current scenario, two major types of pilot arrangement such as block-type and comb-type pilot have been considered using Minimum Mean Square Error (MMSE) and Least Square Error(LSE) channel estimators. Block type pilot sub-carriers is preferably best for slow-fading radio channels while comb- type pilots provide better obstruction to fast fading channels. Also comb-type pilot structure is sensitive to frequency selectivity as compared to block type arrangement. The channel estimation algorithm relying on comb-type pilots is splited into pilot signal estimation and channel interpolation. The pilot signal estimation rely on L.S.E. and M.M.S.E. criteria with channel interpolation method utilizing linear interpolation and spline cubic interpolation. The symbol error rate (SER) performances of OFDM system for both block-type and comb-type pilot sub-carriers are presented in the paper.

5. RESULTS

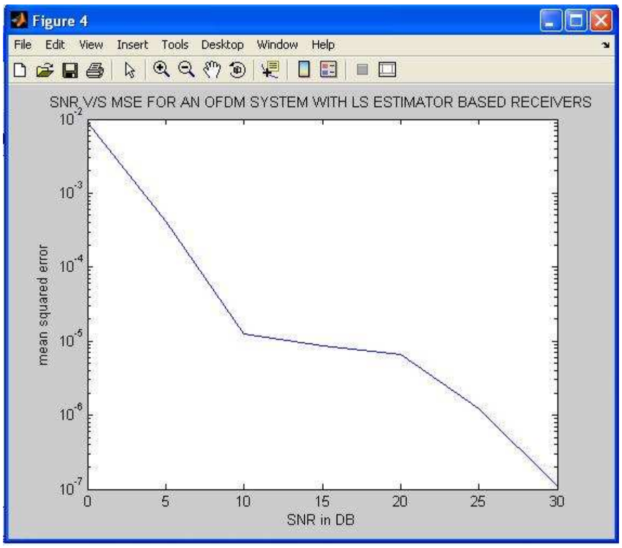

Fig 5. SNR vs MSE LS SISO Plot

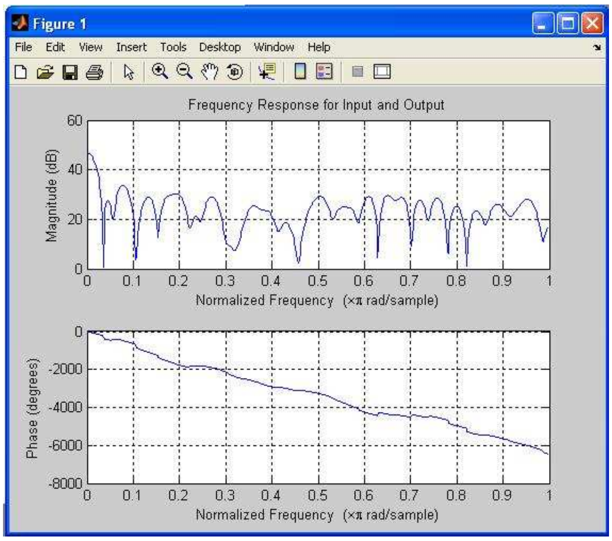

Fig.6 Frequency Response of LS SISO

6. CONCLUSION

In this paper titled OFDM and its channel estimation-using LS Estimation, we estimated the OFDM and its channel estimation by considering and defining OFDM with the help of its block diagram, the channel estimation and its different types with the help of literature survey and worked so far. Finally we presented the simulation result. Results are as per expectation.

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