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Enhanced Channel Estimation Based On Basis Expansion Using Slepian Sequences for Time Varying OFDM Systems

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Abstract— The Channel estimation in OFDM has become very important to recover the accurate information from the received data as the next generation of wireless technology has very high data rate along with the very high speed mobile terminals as users. In addition the fast fading channels, ICI, multipath fading channels may completely destroy the data. Also it is required to use less complex method for estimation. We are proposing the method which compares the number of techniques and gives the results in BER Vs SNR graphs. The LS estimation technique is less complex as compared to MMSE estimation but gives fails in accuracy. Using Prolate function we can reduce the complexity in calculation of parameters. If compared with state of art approach where the complexity is $O(N)^3$, the complexity using Prolate function is $O(N)^2$.The function depends upon maximum delay and maximum Doppler frequency spread thus parameter calculation is reduced. The technique dose not calculate particular channel characteristics. Slepian sequences utilizes the bandwidth as the sharp pulses replace the regular rectangular pulses which causes spectral leakage and thus ICI. The simulation of BER Vs SNR using CP and UW with and without Prolate is proposed that increases spectral efficiency with reduced calculations replacing rectangular pulses by Slepian pulses which increase energy concentration by Sharpe pulses thus reduction in inter carrier interference caused by multipath fading.

Index Terms*-Least square(LS), minimum mean square estimation (MMSE),cyclic prefix(CP),unique word(UW) , space time block coding(STBC)*

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I. INTRODUCTION

1.1. Need Of OFDM

Various wireless standards such as IEEE standard for local and metropolitan area network (LAN and MAN)also called WiMAX, Long term evolution (LTE), UTRAN make use of OFDM[9]. There are various algorithms with different complexity and accuracy of results. The no. of parameters to be calculated also varies along with algorithm. Frequency domain equalization (FDE) method is robust for the delay spread environment, where in each path the delay and the distortion is periodic and varies in adjacent subcarrier. Simply adding to more advantages include the use of Fast Fourier/Inverse Fourier Transform (FFT/IFFT) algorithm. Thus wide researches are done for more advantages of OFDM.

The transmission bandwidth is divided into many narrowband subcarriers in OFDM, thus the incoming data rate is divided into subsections and modulated on these subcarriers. This reduces the no. of bits per subcarrier but increases the data rate. Adding proper cyclic prefix (CP), these subcarriers become fully orthogonal and experience frequency flat fading conditions in time-invariant channels. Orthogonality of the subcarriers allows the reuse of part of subcarriers. This allows partial overlapping of the subcarriers and also simple equalization of the signal at the receiver, while keeping a high spectral efficiency. The frequency re-use in OFDM ,may also leads to the co-channel interference. If not orthogonal the co channel interference in subcarriers can induce a severe degradation of the receiver performance, especially at the cell edge.

OFDM uses the sub-carrier frequencies such that they are orthogonal to each other. That is the reason guard band between the sub-carriers is not required. This increases the data rate. Also the separate subcarrier filter is not required. To maintain the orthogonality sub carrier spacing essential is

The OFDM has partially overlapped sub-carriers (as orthogonal sub carriers). This provides the reuse of part of sub-carrier. This gives nearly equal Nyquist symbol rate. Also the complete frequency band can be utilized.

But the drawback of the OFDM system is its sensitivity to Doppler frequency shift. The frequency deviation disturbs the orthogonality between the adjacent sub-carriers. This leads to inter carrier interference. Thus it becomes necessary to synchronize the transmitter and receiver. For slowly varying channel such systems perform well for the duration of one OFDM symbol. In case of fast fading where the devices are roaming fading varies within one symbol duration. This produces ICI. To mitigate this intersymbol interference the use of cyclic prefix is preferred in which the data at the end of symbol is repeated at start of symbol thus reduced ICI.OFDM is used in conjunction with channel coding and interleaving. Frequency Interleaving mitigates the problem of frequency selective fading by changing the sequence of data bits. This avoids complete symbol fading at a time. Various channel coding techniques such as convolutional coding and Reed Solomon coding are used to detect and correct the errors. In this paper we are using Alamouty coding along with Viterbi decoding at receiver side. This coding technique is space time block coding(STBC).

The channel can be considered as 2 dimensional (time and frequency) signal.Channel estimation is the technique used to find the channel fading characteristics and estimating the interference caused by multi path fading or mobile roaming devises. The time varying channel has to be tracked to detect the signal at the receiver accurately. There are two main techniques while estimating the channel blind channel estimation and pilot based channel estimation. The use of pilot signals has two main problems. The addition of pilots provides accurate estimation of channel but decreases the data rate while the second problem is the design of less complex estimator. The arrangement of pilot can be done with block type and comb type. In block type of arrangement estimation can be done by least square (LS), minimum mean square error (MMSE).In comb type pilot arrangement maximum likelihood (ML) estimator can be used. In these estimators LS is simplest but less accurate where MMSE is more accurate at the cost of complexity. In this thesis we are going to compare the LS and MMSE estimation results using prolate function. This paper studies the use of sharp pulse instead of the regular rectangular pulses which utilizes the bandwidth effectively.

1.2. *Outline of project*

The next chapters of the dissertation are organized as follows.

- Chapter 2 describes the different techniques of channel estimation
- Chapter 3 explains problem definition
- Chapter 4 gives project methodology
- Chapter 5 is conclusion

II. CHANNEL ESTIMATION TECHNIQUES

Various techniques have been presented before on channel estimation previously. These channel estimations were preferred in different channel characteristics such as vast time varying environment, highly dispersive channel, using antenna arrays. These techniques are shortly discussed below.

In paper [1] tracking the delay-subspace by a subspace tracking algorithm and the amplitudes by the least mean square algorithm is proposed. The amplitudes show fast temporal variations due to the mobility of terminals while the delays (and their associated delay-subspace) are considered almost constant over a large number of OFDM symbols. In paper [2] introduced OFDM channel estimations for the AF cooperative channel. Considering the cooperative structure, the CRB (Cramer-Rao lower bound) for channel estimation and propose the MVU (minimum variance unbiased) estimator that achieves the CRB was developed. OFDM channel estimation suitable for the amply-and-forward (AF) cooperative channel was discussed.

The blind channel estimation technique was introduced in paper[3]. This method obtains accurate channel estimation and fast convergence with insensitivity to overestimates of the true channel order. If virtual carriers (VCs) are available, the method can work with no or insufficient cyclic prefix (CP), thereby potentially increasing channel utilization. As the length of CPs increases, the BER performance of the proposed method is significantly improved. The method is also used for MIMO-OFDM system with no CP. However, the blind technique is limited to slow time varying channels and has higher complexity at the receiver. Pilot-aided algorithm [4] for the estimation of fast time-varying channels in OFDM transmission. Channel estimation is performed in the frequency domain, to exploit the structure of the channel response (such as frequency and time correlations and boundedness), optimize the pilot group size and perform most of the computations offline resulting in high performance at substantial complexity reductions.

A discrete prolate spheroidal basis expansion model (DPS-BEM) to describe the time-varying channel was introduced in [5]. A periodic (nonrandom) training sequence is arithmetically added (superimposed) at low power to the information sequence at the transmitter before modulation and transmission; therefore, there is no loss in data transmission rate compared to time-multiplexed (TM) training. In this estimator the unknown information sequence acts as interference resulting in a poor signal-to-noise-and-interference ratio (SNIR) for channel estimation. Then applying a data-dependent superimposed training sequence, to either totally or partially cancel out the effects of the unknown information sequence at the receiver on channel estimation. The improvement in developing the new pilot aided algorithm [6] are exploiting the time and frequency correlations of the channel taps, the (approximately) banded structure of the frequency-domain channel matrix, the asymptotic equivalence of Toeplitz and circulant matrices, and reducing the dimensionality of the parameter estimation space by retaining only the dominant terms in an offline eigendecomposition. In paper [7] sending out pilots with random phases in order to "spread out" the sparse taps in the impulse response over the uniformly downsampled measurements at the low speed receiver ADC, so that the impulse response can still be recovered by sparse optimization. Thus helped to high resolution channel estimation with low speed ADCs,

Combination of least squares or a minimum norm channel slope estimation and the detection of the channel paths [8] sets any channel path power equal zero once the corresponding power estimate is smaller than a given threshold. This algorithm exploits the large channel correlations between the cyclic prefix and the successive OFDM symbol optimally. These maximum correlations reason the superiority of ICI mitigation with cyclic prefixes compared to channel slope estimation with adjacent OFDM symbols, which needs at least twice the number of pilot symbols.

III. PROBLEMS ASSOSIATED WITH TRADITIONAL METHOD

3.1 *Channel estimation techniques*

In time domain and frequency domain finding channel transfer function becomes very difficult as for various subcarriers it goes different. It becomes essential then to find unique method that works well on all the subcarriers. As pilot based method is more suitable than block coding, is widely used. MMSE (minimum mean square error) provides accurate results but more complexity as more calculations where LS estimator gives less accurate results having comparatively lesser calculations. In this paper we adapted simpler estimator.

3.2 Discrete Prolate Spheroidal Sequences

Having no training sequences or pilots Blind estimation requires longer data records and higher complexity [3].This method takes into account various previous data blocks for channel estimation. This implies slow convergence time and many possible misconvergence also add to its disadvantages. In this paper Superimposed training-based sequences are used where the training sequence is transmitted (at low power) concurrently with (superimposed on) the information. In fast time varying channel where fading varies within one symbol the utilization of pilot signals for channel estimation techniques along with packet data transmission systems as they provide most accurate estimate of the channel with less processing complexity (using LS estimation).

In OFDM the spectral concentration problem in finding that time sequence, whose DFT is maximum at given frequency interval can be solved by slepian sequences which are orthogonal in nature and also provide best sidelobe suppression. Discrete Prolate Spheroidal sequences can be considered as Discrete Time, finite length sequences whose Discrete Time Fourier Transformation (DTFT) is concentrated within a given band. Thus having N sub bands in OFDM with bandwidth W, DPSS function captures all the energy in any sample vector from uniformly sampled analog signal. DPSS with OFDM can also cancel the strong narrowband interferences.

3.3 BEM

BEM is especially used in mobile scenarios where strong reflection causes multipath signals. It is used where autoregressive model fails as it relies upon the previous receptions for estimation. BEM uses time domain estimation compared to frequency domain thus reduces the errors. BEM uses doubly selective channel estimation which is carried out before FFT.BEM is also used in frequency domain channel estimation using Slepian sequences. Slepian sequences are used to find the channel correlation in time.

BEM provides time varying channels. By taking channel impulse response and getting Fourier transform we can characterize the channel perfectly. This models lets us estimate fast time varying process by estimating some of its other slow varying parameters. BEM requires that length of pilot block should not be less than the number of BEM coefficient to be estimated. At detector side the extended Kalman filter is used for data detection. Accurate estimation is possible with lower complexity by finding frequency correlation of the channel. This type of channel estimator gives better results using basis expansion model considering the channel as combination of complex exponential function.

The project objectives are mentioned below.

- BEM based OFDM employing rectangular and slepian sequences
- Employing LS estimator method for less complex environment and comparing with MMSE estimation
- Developing the simulation using periodogram feature of dpss
- Developing alamouti space time coding and decoding
- Displaying experimental results: BER versus SNR graphs

IV. PROPOSED METHOD

Using CP in channel estimation means the receiver has no idea about the cyclic extension, whereas using unique word means the receiver has knowledge of the transmitted extension. The BER vs SNR graph of both the techniques is shown in figure 4.1 and figure 4.2.

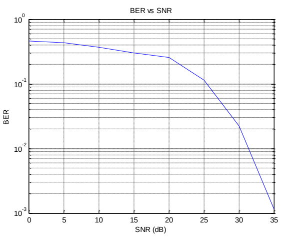

Fig4.1:BER Vs SNR with CP

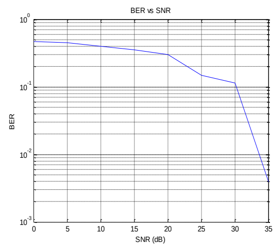

Fig 4.2:BER Vs SNR with UW

The Flow chart for channel estimation coding is shown in figure 4.3.The same process is reversed at the receiver side.

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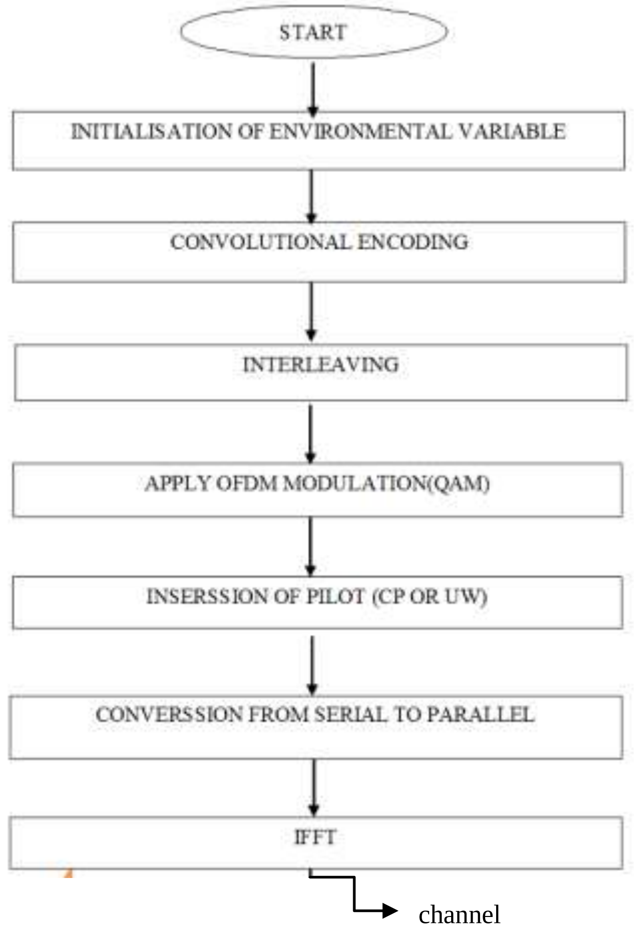

Fig. 4.3: Flow chart for channel estimation at OFDM Transmitter

The transmitter section of OFDM channel estimation consist of various steps as shown in flow chart. The random signal is encoded using convolutional encoding technique. This signal is then interleaved to reduce the effect of frequency selective fading which is then modulated using 6 64QAM.In this paper we are going to use both CP and UW insertion for synchronization and estimation. These results indicate the UW bit error rate is better than CP.We are also going to study the prolate based channel estimation and comparison between with and without prolate function BER. This paper also studies the LS estimator and MMSE estimator. LS (Least Square) scheme is less complex than MMSE(Minimum Mean Square Error) or LMS(Least Mean Square) but at the same time less accurate. But MMSE produces the signal to noise ratio more accurate compared to the LS estimator. Pilot symbols are used with sharp spheroidal nature than the normal rectangular shape pulses to gather knowledge about the channel and try to estimate it with better bandwidth efficiency.

Project modules

The Figure 4.4 show the block diagram of orthogonal frequency division multiplexing

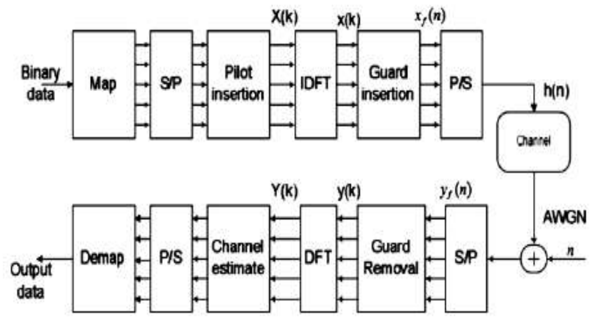

Fig.4.4 OFDM Basic block diagram

The above block diagram gives the detail information about the OFDM data transmission. Here the high data rate is achieved with modulating data on subcarriers. Pilots are inserted which provide channel estimation. To avoid ICI guard (CP/UW) are inserted.

Due to multipath fading, fast fading, highly mobile equipment, the channel changes within the symbol. Thus it is necessary to estimate the channel characteristics.

There are various techniques to estimate the channel.

1. Before FFT
   1.1 based on input (CP)
   1.2 non input based(educational symbols)
2. After FFT
   2.1 pilot insertion
   2.2 direct decision

In this paper replacing the channel estimation by State of Art approach where the complexity is $O(N)^3$, a two dimensional Prolate function is used which reduces the complexity to $O(N)^2$.This technique depends only upon maximum delay spread and maximum Doppler spread. This technique is independent of particular channel scattering function. The Basic expansion model (BEM) is used for channel estimation. In this paper we have used LS method as it is less complex than MMSE.

To equalize the effect of intersymbol Along with the prolate function we have also used the Slepian pulses which are highly bandwidth limited. Thus can estimate the channel perfectly using chirp as pilot and using Doppler frequency shift and actual time delay.

Discrete spheroidal sequences are pulses having highly concentrated in the Bandwidth. Thus use of DPSS provides spectral efficiency.

In this paper we are going to use discrete prolate spheroidal sequences to reduce the no of calculations also to reduce the bandwidth requirement thus comparison with rectangular pulses with DPSS.

V. CONCLUSION

An enhanced channel estimation based on basis expansion using slepian sequences for time varying OFDM systems is proposed. It can be shown that with less SNR requirement

MMSE performs better but at the same time very less performance difference with LS. To reduce the complexity slepian Basis expansion model is used for estimation of fast as well as slow time varying channel. Also the comparison between LS and MMSE estimation techniques with and without prolate function is proposed. By using sharp discrete slepian pulses replacing rectangular pulse we can extract all the information from uniformly spaced samples and effectively use the bandwidth.

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