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WAVELET BASED OFDM: A LITERATURE REVIEW

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ABSTRACT

Orthogonal Frequency Division Multiplexing (OFDM) is very efficient technique used for high data rate digital communication system. It is a special type of multicarrier modulation. Conventionally Fourier Transform (FFT) is used in OFDM to generate orthogonal subcarriers. The orthogonality is destroyed if the transmitted signal is exposed to multipath environment. To maintain orthogonality cyclic prefix is added to each symbol before transmission. But this addition reduces the spectral efficiency of the system. In this paper a comparison is done between conventional OFDM and recently proposed wavelet based OFDM. Wavelet has been emerged as replacement of Fourier Transform. The wavelet Transform has several advantages over Fourier Transform because it can provide time and frequency resolution simultaneously. Many modulation schemes are implemented to compare both the systems. After comparisons and discussion based on their performance in simulation it is concluded that wavelet transform is better choice for OFDM systems.

Keywords- *DWT-OFDM, FFT-OFDM, Fourier Transform, Wavelet Transform.*

I. INTRODUCTION

Multicarrier modulation is an optimum modulation technique for band limited distortion channel. In multicarrier modulation technique the high data rate bit stream is divided into several low rate bit streams. This reduces the Inter Symbol Interference (ISI) because the symbol time in each sub-stream is much greater than the channel delay spread.

But for wideband channels, the channel delay spread is much larger than the symbol time, which causes severe ISI. To avoid this the symbol time should be greater than the channel delay spread. The low rate sub-streams must be orthogonal to each other also. To achieve the orthogonality Fourier Transform is used, this type of multicarrier modulation technique is called OFDM.

II. EVOLUTION OF FOURIER TRANSFORM

Before advent of FFT or Fourier Transform diagnosis of signals were done by examining the time waveform of the signal. But by this method complex signals cannot be accurately analyzed.

Several techniques were developed to solve this problem such as time synchronous averaging and auto-correlation of the signal. The time synchronous averaging uses the average of the signal over a large number of cycles. This filters the effect of noise or non-synchronous frequencies presented in signal.

The auto-correlation function is the average of the product of x(t)andx(t+r). The auto-correlation function of a time series allows us to indirectly get the information about the frequencies present in the signal.

However these techniques provide only a limited amount of information about the signal, because they cannot distinguish between orthogonal signals of similar frequency. The advent of Fourier series brings revolution in modern signal processing. Fourier introduced the concept that any arbitrary function could be represented by a single analytical expression even if the function exhibits discontinuities. For a continuous function of Period 2P the Fourier series is given by,

} (1)

Where,

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The Fourier Transform decomposes any periodic signal into a set of orthonormal basis functions of sines and cosines. The coefficients of these orthonormal basis functions represent the contribution of sine and cosine components of the signal at all frequencies. Thus the signal can be analyzed in terms of frequency components.

The main advancement in signal processing occurs when a faster computational method of computing Fourier Transform was developed called Fast Fourier Transform (FFT) by Cooley and Tukey in 1965. The FFT increases the computational efficiency of Fourier Transform from an order of to arithmetic operations.

III. OFDM SYSTEM USING FOURIER

The OFDM system is a high rate data communication technique in which the high rate serial data stream is broken into several parallel low rate data streams using orthogonal subcarriers and transmitted simultaneously. Generation and modulation of subcarriers is achieved by applying FFT operation on each of the sequence block of a data stream. Figure 2.1 shows basic building block of OFDM.In Fourier-based OFDM, the input serial data is converted into lower rate sequence via serial to parallel conversion. These lower rate sequences are encoded to generate corresponding channel symbols, which are then frequency division multiplexed via an IFFT. The parallel outputs of the IFFT are converted back to serial to transmit.

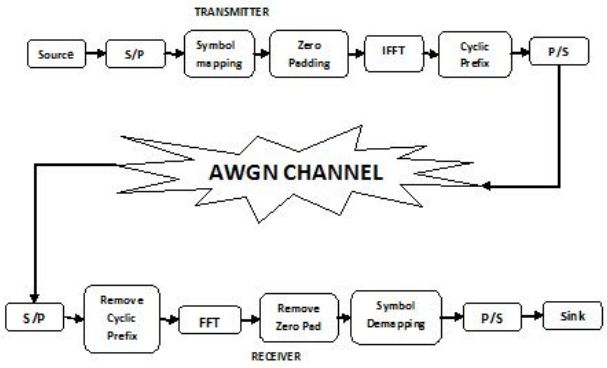

Figure 2.1 OFDM system

OFDM signal with N subcarriers can be expressed as

(2)

Where:

= Input data symbol carried by k^{th}subcarrier.
(t)=

T=Symbol duration
Although the Fourier Transform provides good functionality in obtaining spectral analysis of a signal but there are several shortcomings of this technique.

The first limitation is that, the FT cannot accurately represent functions that have non-periodic components localized in time or space.

Another deficiency is its inability to provide any information about the non-stationary signals. This makes the signal poorly affected by some situations such as multipath environment, High PAPR, synchronization error, and carrier frequency offset. There are several techniques to combat these problems. Cyclic prefix is added to transmitting signal to minimize the effect of multipath or ISI at the expense of reduced spectral efficiency. To avoid High PAPR several techniques are introduced such as Amplitude clipping, clipping and filtering, coding, tone reservation, tone injection, active constellation extension (ACE), and multiple signal representation techniques such as partial

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transmit sequence(PTS), selected mapping (SLM), and interleaving. These techniques reduce PAPR but at the cost of transmit signal power increase, bit error rate (BER)increase, data rate loss, computational complexity increase etc.

IV. ALTERNATIVE APPROACHES FOR OFDM

To improve the description of non-stationary signals several alternative approaches has been developed. These techniques involves mathematical modelling of signal to convert the non-stationary signal to pseudo-stationary signal through angular sampling and time-frequency analysis is done.

There are two basic approaches of time frequency analysis.

In first approach, the signal is divided into small time slices and then analysis of each slice is done to examine their frequency contents. This approach is used in Short Time Fourier Transform (STFT) and Wigner-Ville Transform.

In second approach, at first the signal is filtered in different frequency bands and then cut these bands into slices of time and their energy content is analyzed. This process is used in Wavelet Transform which is focus of this paper.

V. DESIGN AND APPLICATION OF WAVELET BASED SYSTEMS

In paper [1] design of Wavelet based OFDM is discussed. Paper [2] compares Wavelet based UWB system with Fourier based UWB. Paper [3] describes various multicarrier systems such as OFDM, MC-CDMA and MC-DS-CDMA. It also compares these systems with wavelet based OFDM. In paper [4] Discrete Wavelet Transform based OFDM is designed and various performance criterion such as BER and PAPR are discussed. Paper [5] compares wavelet based OFDM with conventional OFDM in presence of multipath channel conditions.

In Paper [1] a new technique has been demonstrated that couldprovide a more flexible replacement for conventional OFDM with lower complexity while still maintaining the same thechannel capacity and SNR characteristics as OFDM.

This system has advantage that it is possible to dynamically allocate the bandwidth for each of the sub-bandsdepending on the application and changing the modulation techniques of each subband to suit the channel. This paper compares the technology in terms of SNR and throughput.

The main advantage of using OWDM is that it is a veryflexible and simple system, only low order filters are needed instead ofcomplex FFT processors.In addition, the filter type canbe dynamically chosen (and thus the wavelet type)depending on the condition of the channel or the data.

In Paper [2] the concept of wavelet transformas an alternative to the conventional Fouriertransform-based multicarrier UWB system is introduced and analysed. Unlike Fouriertransform-based multicarrier UWB systems wavelet transform-based multicarrierUWB systems do not require a cyclic prefix for transmission. This increases the spectral efficiency of the system.

Therefore DWT could be considered as attractive technique in future multicarrier UWB systems and other high data rate systems.

The objective of the paper [3] is to provide a survey on multi-carrier transmission techniques i.e. OFDMand the combination of OFDM with Code Division Multiple Access (CDMA). And this survey alsoexplains how to use Discrete Wavelet Transform based OFDM (DWT-OFDM) instead of using Fast Fourier Transform based OFDM Fast Fourier Transform based OFDM (FFT-OFDM).

This paper analyses and review ofOFDM and CDMA techniques as well as thecombination of both. The combination of OFDMand CDMA schemes offers great advantage whichcan lower the symbol rate in each subcarrier. Thelonger symbol duration makes it easier tosynchronize the transmission.

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In this paper [4], an efficient technique for the OFDMsystem using wavelet transform is proposed. This system shows a superiorperformance when compared with traditional OFDM-FFT systemsthrough an Additive White Gaussian Noise (AWGN) channel. The systemperformance is described in Bit Error Rate (BER) as a function ofSignal to Noise Ratio (SNR) and the peak-to-average ratio (PAR).

In this paper [5], the performance of wavelet based OFDM is analysed and compared to thatof conventional Fourier OFDM over multipath Rayleigh fading channels with exponential power delay profile.Results show that Wavelet based OFDM has better bit error rate (BER) performance than conventional OFDM withoutcyclic prefix (CP) for all signal-to-noise ratios (SNRs) and also outperforms OFDM with CP for low SNRvalues in indoor and outdoor environments. Therefore, Wavelet based OFDM might be an alternative to conventionalOFDM since it also has better spectral efficiency.

VI. CONCLUSION

By study of several papers and analysing them we get that the Wavelet Transform is a better replacement of Fourier Transform. It is also proved when applied to different multicarrier system and tested. The study also suggests that use of Wavelet transform instead of Fourier Transform in OFDM systems is also simpler and economical as it does not require cyclic prefix to mitigate the effect of multipath. Different schemes and channel conditions are also applied to test the system based on wavelet. Thus we can conclude that Wavelet based OFDM may be superior choice than conventional OFDM. Thus it can be concluded that wavelet transform can be a potential area of research.

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