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Reduction of Paper in OFDM System Using Haar Wavelet Based Approach

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Abstract:- Communication is one of the important aspects of life. With the advancement in age and its growing demands, there has been rapid growth in the field of communications. Signals, which were initially sent in the Analog domain, are being sent more and more in the Digital domain these days. For better transmission, even single – carrier waves are being replaced by Multi – carrier systems like CDMA and OFDM are now – a – days being implemented commonly. Orthogonal frequency-division multiplexing (OFDM) is a method of digital modulation in which a signal is split into several narrowband channels at different frequencies. Priority is given to minimizing the interference, or crosstalk, among the channels and symbols comprising the data stream. OFDM is essentially identical to coded OFDM (COFDM) and discrete multi-tone modulation (DMT), and is a frequency-division multiplexing (FDM) scheme used as a digital multi-carrier modulation method. A large number of closely spaced orthogonal sub-carrier signals are used to carry data on several parallel data streams or channels. The primary advantage of OFDM over single-carrier schemes is its ability to cope with severe channel conditions without complex equalization filters. But the large Peak – to – Average Power Ratio of these signal have some undesirable effects on the system. In this thesis we have focused on learning the basics of an OFDM System and have undertaken HAAR WAVELET transformation method to reduce the PAPR in the system. Finally we compare BER performance of our proposed OFDM with the conventional OFDM over different channels to show the excellent performance of our proposed OFDM model.

Keywords **COFDM, PAPR, BER, CCDF, Multicarrier, IFFT, Wavelet Transform.**

I. INTRODUCTION

Frequency division multiplexing (FDM) involves the allocation of each channel to a unique frequency range. This frequency range prescribes both the center frequency and channel width (bandwidth). Because these channels are non-overlapping, multiple users can operate concurrently simply by using different channels of the frequency domain.OFDM is essentially identical to **coded OFDM** (**COFDM**) and **discrete multi-tone modulation** (**DMT**), and is a frequency-division multiplexing (FDM) scheme used as a digital multi-carrier modulation method. The word "coded" comes from the use of forward error correction (FEC). A large number of closely spaced orthogonal sub-carrier signals are used to carry data[2] on several parallel data streams or channels. Each sub-carrier is modulated with a conventional modulation scheme (such as quadrature amplitude modulation or phase-shift keying) at a low symbol rate, maintaining total data rates similar to conventional *single-carrier* modulation schemes in the same bandwidth.

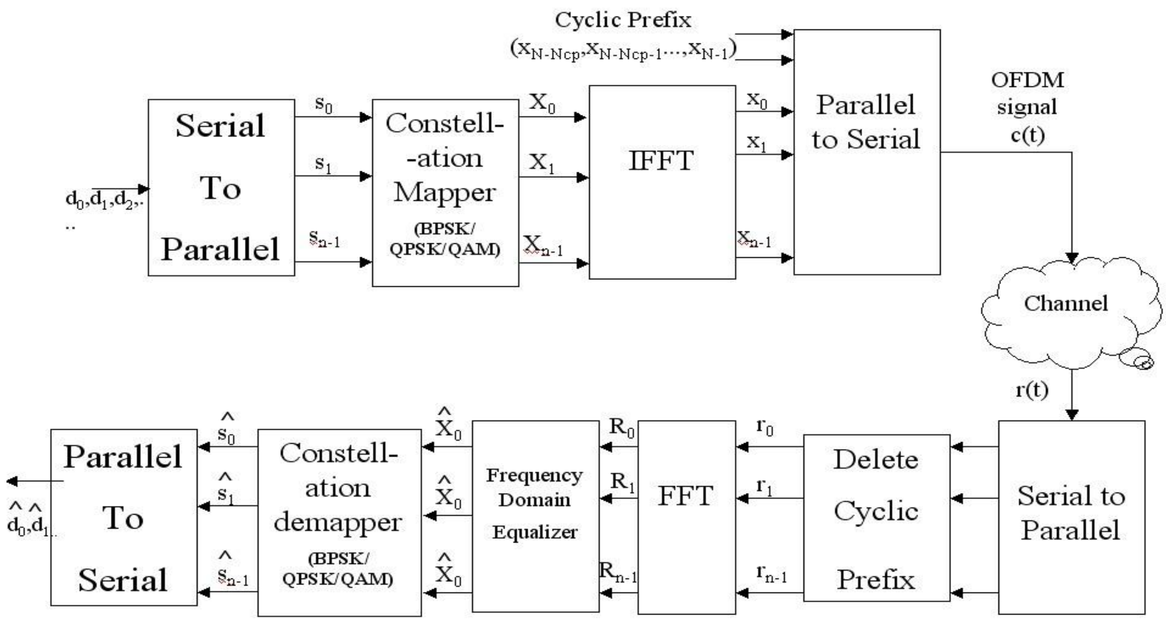

FIG. (1) Block diagram of OFDM Conventional model

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II. DEVELOPMENT OF OFDM

The development of OFDM systems can be divided into three parts. This comprises of Frequency Division Multiplexing, Multicarrier Communication and Orthogonal Frequency Division Multiplexing.

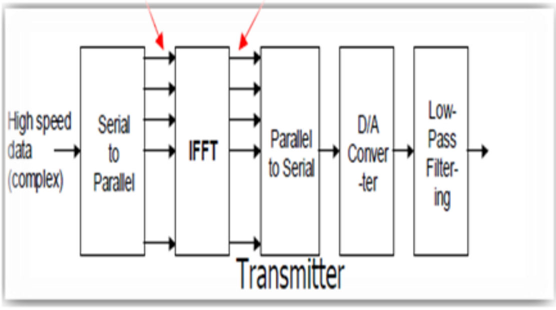


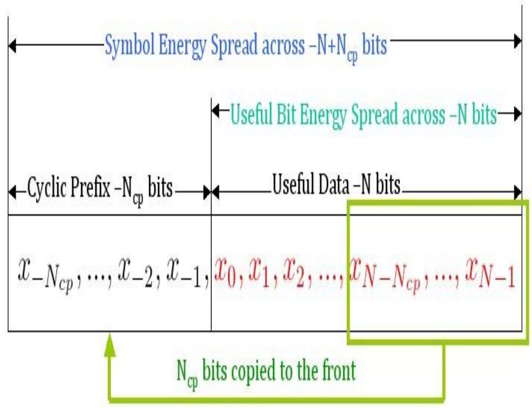
FIG 2 OFDM Transmitters with IFFT block

A. Serial to Parallel Conversion

In an OFDM system, each channel can be broken into various sub-carriers. The use of sub-carriers makes optimal use out of the frequency spectrum but also requires additional processing by the transmitter and receiver. This additional processing is necessary to convert a serial bit stream into several parallel bit streams to be divided among the individual carriers. Once the bit stream has been divided among the individual sub-carriers, each sub-carrier is modulated as if it was an individual channel before all channels are combined back together and transmitted as a whole. The receiver performs the reverse process to divide the incoming signal into appropriate sub-carriers and then demodulating these individually before reconstructing the original bit stream.

B. *Modulation with the Inverse FFT*

The modulation of data into a complex waveform occurs at the Inverse Fast Fourier Transform (IFFT) stage of the transmitter. Here, the modulation scheme can be chosen completely independently of the specific channel being used and can be chosen based on the channel requirements. In fact, it is possible for each individual sub-carrier to use a different modulation scheme. The role of the IFFT is to modulate each sub-channel onto the appropriate carrier. Lets say, without cyclic prefix we transmit the following N values (N=Nfft=length of FFT/IFFT) for a single OFDM symbol. $X_0,X_1,X_2,X_3\dots\dots\dots X_{n-1}$ .Lets consider a cyclic prefix of length Ncp, (where Ncp<N), is formed by copying the last Ncp values from the above vector of X and adding those Ncp values to the front part of the same X vector.With a cyclic prefix length Ncp, (where Ncp<N), the following values constitute a single OFDM symbol



If T is the duration of the an OFDM symbol in secs, due to the addition of cyclic prefix of length Ncp, the total duration of an OFDM symbol becomes T+Tcp, where Tcp=Ncp*T/N. Therefore, the number of samples allocated for cyclic prefix can be calculated as Ncp=Tcp*N/T, where N is the FFT/IFFT length, T is the IFFT/FFT period and Tcp is the duration of cyclic prefix.

III. EFFECT OF PAPR IN OFDM MODEL

However, OFDM also has its shortcoming. The major drawback of OFDM signal is its large peak-to-average power ratio (PAPR), which causes poor power efficiency or serious performance degradation to transmit power amplifier. The peak-to-average power ratio (PAPR) is a related measure that is defined as the peak amplitude squared (giving the peak power) divided by the RMS value squared (giving the average power)

$$PAPR = \frac{\max\left|x(t)\right|^2}{E[\left|x(t)\right|^2]}$$

In general papr is defined as the ratio period between the maximum instaneous power and its average power during an ofdm symbol. Reducing the max | x (t) | is the principle goal of PAPR reduction techniques. We can evaluate the performance of PAPR using the cumulative distribution of PAPR of OFDM signal. The cumulative distribution function (CDF) is one of the most regularly used parameters, which is used to measure the efficiency of and PAPR technique. However, the complementary CDF (CCDF) is used instead of CDF, which helps us to measure the probability that the PAPR of a certain data block exceeds the given threshold. The CCDF of the PAPR of the data block is desired is our case to compare outputs of various reduction techniques .The reason is that in time domain, multi carrier signal is the sum of many narrow bandsignals.at some instances, this sum is large and other time it is small, which means that the peak value of the signal is substantially larger than the average value. The high PAPR is one of the most important

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implementation challenges that face MC-CDMA because it reduces the efficiency and hence increases the cost of the RF power amplifier, which is one of the most expensive components in radio. In past we have different PAPR reduction techniques like selective mapping, DCT, partial transmit sequence, companding etc….. In this paper we projected a HAAR wavelet based approach to reduce the PAPR efficiently.

IV. HAAR WAVELET TRANSFORMS

The Haar wavelet is the simplest possible wavelet. The technical disadvantage of the Haarwavelet is that it is not continuous, and therefore not differentiable. The oldest and most basic wavelet system is named Haar wavelet that is a group of square waves with magnitude of ±1 in the interval [0 to1].Haar wavelet has two functions namely Haar scaling equation and wavelet function they are represented as

$$\varphi_0(t) = \begin{cases} 1, & \text{for } 0 \le t < 1 \\ 0, & \text{otherwise} \end{cases}$$

$$\varphi_1(t) = \begin{cases} 1, & \text{for } 0 \le t < \frac{1}{2} \\ -1, & \text{for } \frac{1}{2} \le t < 1 \\ 0, & \text{otherwise} \end{cases}$$

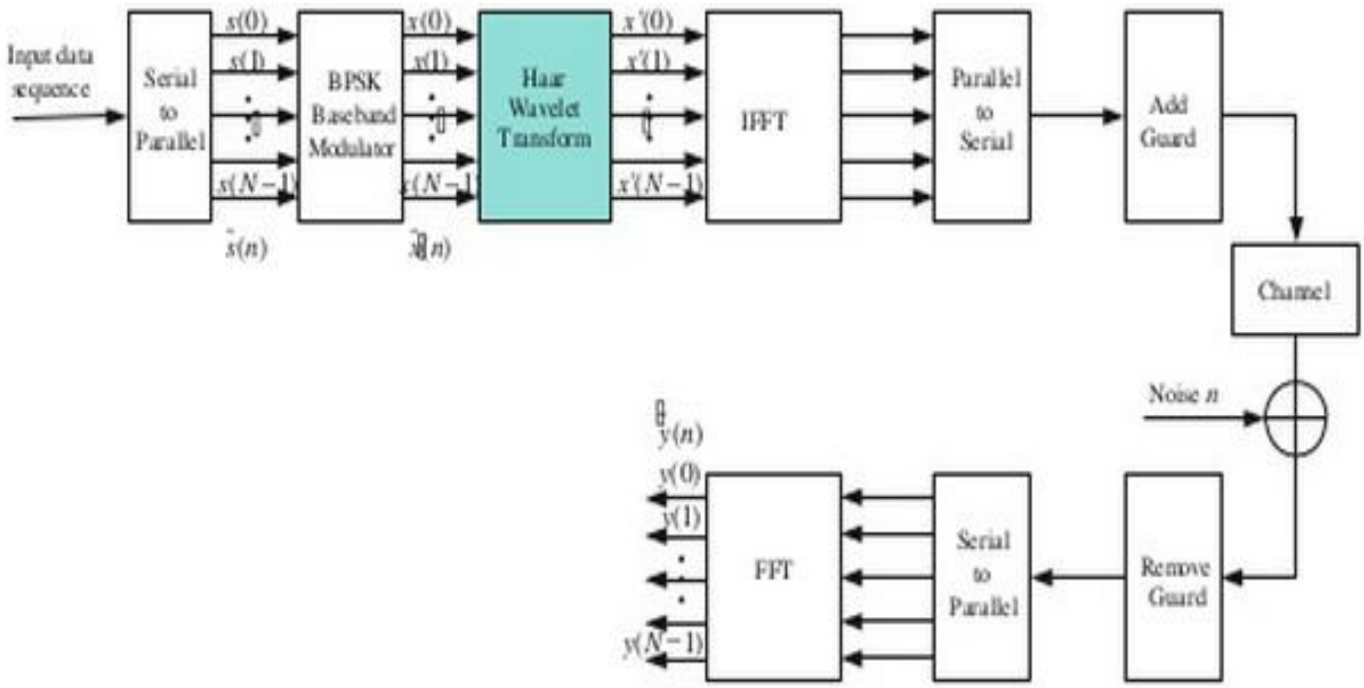
All other subsequent functions are generated from Ψ_1 (t), which means the scale equation and vector equation are obtained as follows

$$\varphi(t) = \sqrt{2}\left(\frac{1}{\sqrt{2}}\varphi(2t) + \frac{1}{\sqrt{2}}\varphi(2t-1)\right)$$

$$\psi(t) = \sqrt{2}\left(-\frac{1}{\sqrt{2}}\varphi(2t) + \frac{1}{\sqrt{2}}\varphi(2t-1)\right)$$

A. PROJECTED OFDM MODEL

The proposed |HAAR wavelet based BPSK OFDM system structure is shown in fig below.. We can see from the figure that the proposed system only increases HAAR wavelet transformation at the transmitter compared with the conventional OFDM system.



Fig; 3. proposed OFDM model

Some of the past techniques uses Fourier transform unit to process the signal information, but here we substitute a discrete wavelet transform technique which is very simple to process the signal information.

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$$\begin{pmatrix} C(j) \\ D(j) \end{pmatrix} = T \cdot C(j+1), \text{ and}$$

$$T = \begin{bmatrix} \frac{1}{\sqrt{2}} & \frac{1}{\sqrt{2}} & 0 & 0 & 0 & \cdots & 0 & 0 \\ 0 & 0 & \frac{1}{\sqrt{2}} & \frac{1}{\sqrt{2}} & 0 & \cdots & 0 & 0 \\ & & & \vdots & & & & \\ 0 & 0 & 0 & 0 & 0 & \cdots & \frac{1}{\sqrt{2}} & \frac{1}{\sqrt{2}} \\ -\frac{1}{\sqrt{2}} & \frac{1}{\sqrt{2}} & 0 & 0 & 0 & \cdots & 0 & 0 \\ 0 & 0 & -\frac{1}{\sqrt{2}} & \frac{1}{\sqrt{2}} & 0 & \cdots & 0 & 0 \\ & & & \vdots & & & & \\ 0 & 0 & 0 & 0 & 0 & 0 & -\frac{1}{\sqrt{2}} & \frac{1}{\sqrt{2}} \end{bmatrix}_{N \times N}$$

B. *PRINCIPLE OF THE PROPOSED OFDM SYSTEM*

The Haar wavelet transform unit in fig. operates decomposition over the input data symbol sequence. we denote the input data sequence as $x(n)=[x(0),x(1),\ldots\ldots x(N-1)]^T$. And the decomposition result as $x'(n)= [x'(0), x'(1)\ldots. x'(N-1)]^T$ since the input N by 1 data sequence is generated by BPSK modulator, each component of x(n) is either 1 or -1. The detail process of Haar wavelet decomposition over input vector sequence x(n) is

$$\begin{bmatrix} x'(0) \\ x'(1) \\ \vdots \\ x'\left(\frac{N}{2}-1\right) \\ x'\left(\frac{N}{2}\right) \\ x'\left(\frac{N}{2}+1\right) \\ \vdots \\ x'(N-1) \end{bmatrix} = \begin{bmatrix} \frac{1}{\sqrt{2}} & \frac{1}{\sqrt{2}} & 0 & 0 & 0 & \cdots & 0 & 0 \\ 0 & 0 & \frac{1}{\sqrt{2}} & \frac{1}{\sqrt{2}} & 0 & \cdots & 0 & 0 \\ & & & \vdots & & & & \\ 0 & 0 & 0 & 0 & 0 & \cdots & \frac{1}{\sqrt{2}} & \frac{1}{\sqrt{2}} \\ -\frac{1}{\sqrt{2}} & \frac{1}{\sqrt{2}} & 0 & 0 & 0 & \cdots & 0 & 0 \\ 0 & 0 & -\frac{1}{\sqrt{2}} & \frac{1}{\sqrt{2}} & 0 & \cdots & 0 & 0 \\ & & & \vdots & & & & \\ 0 & 0 & 0 & 0 & 0 & 0 & -\frac{1}{\sqrt{2}} & \frac{1}{\sqrt{2}} \end{bmatrix}_{N \times N} \begin{bmatrix} x(0) \\ x(1) \\ \vdots \\ x(N-1) \end{bmatrix}$$

After Haar wavelet transform, half of the coefficients $x(n)=[\ x'(0),\ x'(1),\ldots\ldots\ x'(N-1)[]^T$ are zeros, and the remaining coefficients are either √2 or -√2. Since the Haar wavelet transformation is added in conventional OFDM system, the computational complexity will increase.However the Haar wavelet transformation is simply to operate at the transmitter as follows

$$\begin{bmatrix} x'(0) \\ x'(1) \\ \vdots \\ x'\left(\frac{N}{2}-1\right) \\ x'\left(\frac{N}{2}\right) \\ x'\left(\frac{N}{2}+1\right) \\ \vdots \\ x'(N-1) \end{bmatrix} = \begin{bmatrix} \frac{1}{\sqrt{2}}[x(0)+x(1)] \\ \frac{1}{\sqrt{2}}[x(2)+x(3)] \\ \vdots \\ \frac{1}{\sqrt{2}}[x(N-2)+x(N-1)] \\ \frac{1}{\sqrt{2}}[-x(0)+x(1)] \\ \frac{1}{\sqrt{2}}[-x(2)+x(3)] \\ \vdots \\ \frac{1}{\sqrt{2}}[-x(N-2)+x(N-1)] \end{bmatrix}$$

From above equation, we can see that the proposed OFDM system don't increase too much computational complexity, compared with the conventional OFDM system.

V. SIMULATION RESULTS

In this section, we provide the simulation results of the cumulative distribution functions for the proposed OFDM versus conventional OFDM, simulation results of the BER versus SNR for conventional OFDM system versus proposed OFDM system. We assume 256 subcarriers, i.e., N=256, and assume BPSK modulation is used in conventional and proposed OFDM systems. For simplicity, we assume that the maximum likelihood estimation method is used at the recievr.one can clearly see that the BER performance of proposed OFDM system is better than the conventional system.

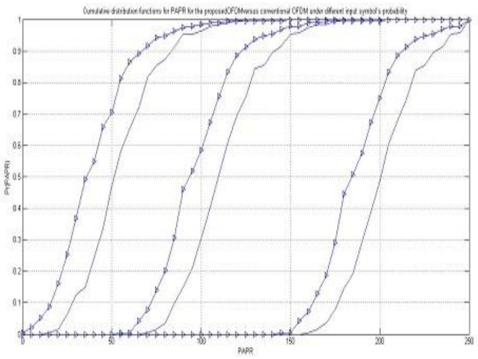

Fig: 4.cumulative distribution Functions

We are mainly Concentrating on PAPR Reduction, so in Fig. a cumulative distribution Functions cumulative distribution Functions, Vs PAPR.

Before ⟹ Haar Wavelet Approach

Haar ——Wavelet Approach

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VI. CONCLUSION

In this paper, technique for PAPR reduction of OFDM signals has been proposed. This is very efficient and simple technique, when compared to the previous techniques. Since the Haar wavelet transformation is used in our proposed OFDM system, half of the information symbols are zeros and the rest are either √2 or -√2 in each OFDM symbol. The simulation results and theory analysis illustrate the proposed system has two advantages when compared with OFDM system (1) Reduces PAPR by 3dB almost (2) Shows robustness to spectral null channels, improving BER performance 3db atmost. Analysis also shows that our proposed OFDM system does not increase too much computational complexity at the transmitter. Since our proposed OFDM system is only suitable for BPSK modulation which is better than the others.

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