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PAPR REDUCTION TECHNIQUE USING COMBINED DCT AND LDPC BASED OFDM SYSTEM FOR UNDERWATER ACOUSTIC COMMUNICATION

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ABSTRACT

Underwater acoustic sensor networking (UWASN) system are playing an imperative role to establish the communication in underwater for various of the ocean applications, such as surveillance, ocean pollution monitoring, oceanographic data collection, assisted - navigation, natural exploration and resource managements etc. The environment of underwater is much different from terrestrial environment. The Radio frequency (RF) signals used by Terrestrial sensor networks (TSN's) can only propagate a few meters in the ocean due to the high dense salty in water. Some of the main challenges in under water communication are low date rate, propagation delay, high bit error rate and limited bandwidth. In our system, combined discrete cosine transform (DCT) and Low density parity check (LDPC) based orthogonal frequency division multiplexing (OFDM) is proposed for Underwater Acoustic Communication. In conventional of OFDM system, along with the orthogonality property the DCT structure is added which provide the advantages of improved computational speed and reduced size. LDPC can provide a reliability using less power than a OFDM system without LDPC. This proposed system, uses DCT along with LDPC, reduces the higher Peak to average power ratio (PAPR), better noise immunity and better Bit error rate (BER) performance than conventional OFDM system, with low implementation cost. The computer simulation results prove the improved performance than existing system.

Keywords: underwater acoustic sensor networks, orthogonal frequency division multiplexing, peak-to-average power ratio, low-density parity check, discrete cosine transform.

1. INTRODUCTION

The research of underwater acoustic sensor network (UWASN) is an essential one for various applications such as for emergency, military, and commercial purpose. The water covered one third of our earth. The underwater environment is much complicated than terrestrial environment. It uses acoustic communications, since radio wave does not work well in underwater environments due to large latency, low bandwidth, and high error rate [20]. The main issues that have to consider carefully when designing an acoustic based transmission system for underwater channels [1,2].

a) Low propagation speed of the sound, roughly around 1500 m/s,

b) Multi-path due to the reflection from the bottom and surface of sea, causing echoes and interference,

c) Noise in the ocean.

Multi-carrier modulation (MCM) has become popular in UWASNs for two reasons:

a. Signal can be processed in a receiver without the increase of noise or interference caused by linear equalization of a single carrier signal, and

b. Long symbol time used in MCM produces a much greater immunity to impulse noise and fast fades [3].

Orthogonal frequency division multiplexing (OFDM) as an MCM is particularly efficient when noise is spread over a large portion of the available bandwidth. It transmits signals over multiple orthogonal sub-carriers simultaneously and performs robustly in severe multi-path environments achieving high spectral efficiency. OFDM has been used in underwater communications as an alternative to single carrier broadband modulation to achieve high data rate transmission [4-7].

Recently, researchers have proposed various approaches to reduce the PAPR including clipping and companding [8], non linearcompanding transforms [10], Hadamard transforms [9].These techniques reduces the signal power but degrading bit error rate (BER) performance and causing non linear phenomena such as spectral spreading. Spectral spread causes degradation of spectral efficiency.

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2. UNDERWATER ACOUSTIC CHANNEL

2.1 Attenuation

Sound propagates in the underwater environment at approximate speed of c = 1500 m/s, which is 200000 times lower than the speed of electromagnetic waves in the air. This causes long propagation delays in underwater acoustic systems. But the transmission channel is affected by spreading loss as well as absorption loss that cause significant attenuation. For a distance *l* (km) from a source to a destination at a frequency f (kHz) and spreading coefficient k, then the attenuation A(*l*, f) can be calculated[11,12] as

$$A(l,f)=l^k a(f) \quad (1)$$

Where, k is the spreading factor (k = 1 is cylindrical, k = 2 is spherical, in practical spreading k = 1.5). Attenuation or path loss that occurs in an underwater acoustic channel over a distance in meters for a tone of frequency in kilohertz is given in decibels by

$$10\log_{10}\left(A(l,f)/A_O\right)=k\,10\log_{10} l+\frac{l}{10^3}10\log_{10} a(f) \quad (2)$$

Where A_O is a normalizing constant, k denotes the spreading factor, and a(f) is the absorption coefficient, it can be expressed by Thorp's formula [13] as

$$10\log a(f)=\frac{0.11f^2}{1+f^2}+\frac{44f^2}{4100+f^2}+\frac{2.75}{10^4}+0.003[dB/km] \quad (3)$$

This above formula is generally valid for frequencies above a few hundred hertz. The absorption coefficient increases rapidly with frequency, thus imposing a limit on the maximum usable frequency for an acoustic link of a given distance.

3. PAPR IN OFDM SYSTEMS

In an OFDM systems, the entire system bandwidth is divided into many orthogonal sub-channels with narrow bandwidth and the data symbols typically modulated by PSK (Phase shift keying) or QAM (Quadrature amplitude modulation) are transmitted independently on the sub carriers. An OFDM signal consists of N symbols $X=\{X_k, k=0,1,2,.........N-1\}$ and each symbol is modulated by one of a set of sub carriers $\{f_k, k=0,1,2........N-1\}$, where N is the total number of sub carriers used. The 'N' sub carriers are chosen to be orthogonal, that is $f_k = k\Delta f$, where $\Delta f=\frac{1}{NT}$ (Hz) and T is the original symbol period. Therefore, the complex envelope of the transmitted OFDM signals can be written as,

$$x(t)=\frac{1}{\sqrt{N}}\sum_{k=0}^{N-1} X_k e^{j2\pi f_k t}, \quad 0\le t\le NT \quad (4)$$

The PAPR of OFDM signals x(t) is defined as the ratio between the maximum instantaneous power and its average power during its OFDM symbol.

$$PAPR[x(t)]=\frac{\max_{0\le t\le NT}\left[|x(t)|^2\right]}{P_{avg}} \quad (5)$$

where, P_{avg} is the average power of x(t) and it can be computed in the frequency domain because Inverse fast fourier transform (IFFT) is a (scaled) unitary transformation.

$$P_{avg}=\frac{1}{NT}\int_0^{NT}|x(t)|^2\,dt \quad (6)$$

In equation (6), the PAPR reduction of OFDM signals is mainly achieved by minimizing the maximum instantaneous signal power $\max_{0\le t\le NT}|x(t)|^2$. For better approximation, the continuous time OFDM signal x(t) samples over sampled by a factor of L at frequency f_s= L/T, where L is the over sampling factor. This is extended from original signal x(t) by using the zero-padding scheme .i.e., by inserting (L-1)N zeros in the middle of the x(t). The over sample IFFT output with operation length NL can be expressed as

$$x(n)=\frac{1}{\sqrt{N}}\sum_{k=0}^{N-1} X(k)e^{j\frac{2\pi nk}{LN}} \quad 0\le n\le LN-1 \quad (7)$$

The PAPR computed from the 'L' times over sampled time domain OFDM signal sample can be defined as

$$PAPR\{x[n]\}=\frac{\max_{0\le n\le NL}\left[|x(n)|^2\right]}{E\left[|x(n)|^2\right]} \quad (8)$$

Where, E[.] – denotes the expectation operator and it will be taken over all OFDM symbols.

4. LOW DENSITY PARITY CHECK CODE (LDPC)

LDPC codes were discovered by Gallager in 1962 and have recently been rediscovered. LDPC codes

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exhibit a performance extremely close to the Shannon capacity formula. Using error control coding increases the reliability and it decreases the transmit power required. LDPC codes are a class of linear block codes. The name comes from the characteristics of their parity –check matrix which contains only a few 1's in comparison to the amount of 0's. Basically there are two different possibilities to represent LDPC codes. They can be described via matrices (or) graphical representation. Turbo code has also been recommended to apply to underwater digital speech communication system and simulation results in underwater digital speech system discussed in have shown that LDPC has a better performance than the turbo coder. The researcher results show that LDPC code system has a better error correct performance and can achieve a better BER under the relative lower SNR.[14-16].

When LDPC coder used as channel coder for Zero- padding orthogonal frequency division multiplexing (ZP- OFDM) multi-carrier modulation the spectral efficiency η and the data rate *R* are [17,18].

$$\eta = \frac{T_{ZO}}{T_{ZO}+T_G}\frac{|N_D|}{N}.r.\log_2 S \ \ bps/Hz \quad (9)$$

$$R = \eta B \ \ Kbps \quad (10)$$

Where T_{ZO} is the ZP-OFDM symbol duration, *TG* is the guard interval, *N* is number of all sub carrier, $N_D$is total number of data sub carrier required, *S* is the Quadrature amplitude modulation symbol, and B is the channel bandwidth.

5. DISCRETE COSINE TRANSFORM (DCT)

DCT based OFDM is a better technology for under- water acoustic communication, because the bandwidth required for DCT is half of that required for DFT when both systems have same number of subcarriers which will be matched with underwater channel limited bandwidth. It was also shown that the speed of calculation of orthogonal components is increased three folds while the implementation size reduces to half as compared to fast Fourier transform (FFT) based design. A precise BER analysis of DCT-OFDM in the presence of carrier frequency offset on AWGN channels was done. The peak value of the auto correlation is the average power of input sequence. If the side lobe of an autocorrelation functions of an input sequence has larger value than other input sequences. The former has high correlation property. To reduce the PAPR in an OFDM signal, DCT is applied to reduce the autocorrelation of the input sequence before the IFFT operation. The one-dimensional DCT with length N is expressed as,

$$X[k] = \alpha(t)\sum_{n=0}^{N-1} x(n)\cos\left\{\frac{(2n+1)\pi k}{2N}\right\} \quad 0 \le k \le N-1 \quad (11)$$

$$\alpha(k) = \sqrt{\frac{1}{N}} \qquad if \ \ k = 0$$

$$\alpha(k) = \sqrt{\frac{2}{N}} \qquad if \ \ k \neq 0$$

The output of an IDCT is expressed as

$$x[n] = \alpha(t)\sum_{k=0}^{N-1} X[k]\cos\left[\frac{(2n+1)\pi k}{2N}\right] \ ,0 \le n \le N-1 \quad (12)$$

The DCTbasis have excellent spectral compaction and energy concentration properties which in turn lead to improved performance with suitable channel estimation.

6. PROPOSED SYSTEM

The proposed system contains combined LDPC encoder and IDCT. The serial input data stream is first processed by LDPC encoder, after Quadrature amplitude modulation (QAM) then with DCT.Consider $\left\{x_i(0), x_i(1), x_i(3)............x_i\left(N/2-1\right)\right\}$ are the LDPC encoded input data vector of OFDM symbol i. Then it is applied to DCT block, due to symmetric extension property of DCT, it will add N/2 symbols to form $\left\{xc_i(0), xc_i(1), x_i(3)............xc_i(N-1)\right\}$ which is the actual entire OFDM symbol to be transmitted. x(t) is the information transmitted after addition of the cyclic prefix to avoid interference between symbols and parallel to serial conversion.

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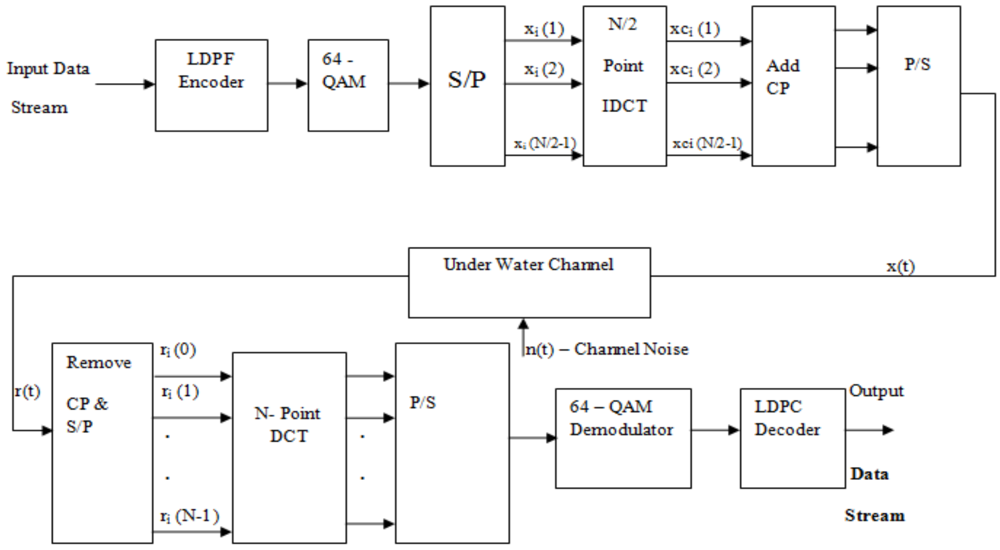

Figure-1. Proposed system

The received signal r(t) is the combination of transmitted signal x(t) and the channel noise n(t). After eliminating the guard interval we are getting the received vector $\{r_i(0), r_i(1), \ldots\ldots r_i(N-1)\}$. N point DCT is performed over this set to obtain $\{rc_i(0), rc_i(1), \ldots\ldots rc_i(N-1)\}$. Finally we obtain the demodulated information vector $\{R_i(0), R_i(1), R_i(3) \ldots\ldots R_i(N/2 - 1)\}$. Symmetric extension of the input vector to a DCT operation results in half of the subcarriers being equivalent to zero. The one-dimensional DCT with length N is expressed as,

$$X[k] = \alpha(t)\sum_{n=0}^{N-1} x(n)\cos\left\{\frac{(2n+1)\pi k}{2N}\right\} \quad 0 \le k \le N-1 \quad (13)$$

$$\alpha(k) = \sqrt{\frac{1}{N}} \qquad if \quad k = 0$$

$$\alpha(k) = \sqrt{\frac{2}{N}} \qquad if \quad k \ne 0$$

The IDCT is expressed as

$$x[n] = \alpha(t)\sum_{k=0}^{N-1} X[k]\cos\left[\frac{(2n+1)\pi k}{2N}\right], 0 \le n \le N-1 \quad (14)$$

PAPR of OFDM signal can be defined as

$$PAPR[x(t)] = \frac{\max_{0\le t\le NT_s}\left[|x(t)|^2\right]}{E\left[|x(t)|^2\right]} \quad (15)$$

Each sub-carrier power is 1 after normalized, then $E\left[|x(t)|^2\right] = 1$, and we get

$$PAPR[x(t)] = \max_{0\le t\le NT_s}\left[|x(t)|^2\right]$$

$$= \max_{0\le t\le NT_s}\left|\frac{1}{\sqrt{N}}\sum_{k=0}^{N-1} X_k e^{j2\pi k\Delta f t}\right|^2$$

$$= \frac{1}{N}\left|\sum_{k=0}^{N-1} X_k e^{j2\pi k\Delta f t}\right|^2$$

$$= \frac{1}{N}.N^2 = N \quad (16)$$

Therefore, the maximum PAPR of a baseband signal can be expressed as

$$\mathrm{MaxPAPR}[x(t)] = N \quad (17)$$

S_{DCT} is the most of peak power of OFDM after DCT [19] and expressed as

$$\lim_{N\to\infty}|S_{DCT}| \le 2.2825 + \frac{2}{\pi}\ln N \quad (18)$$

Therefore, DCT can improve the performance of OFDM, After DCT many data values are very small and even some zero elements appear in the transformed sequence.

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7. SIMULATION RESULTS

To show the overall effect of the PAPR reduction, randomly generated data are modulated into 64 -QAM. From the equation(17), it is clear the PAPR value is mainly depends upon the number of sub-carriers used but it reduced by half by using the symmetric extension property DCT that will maximum reduces the PAPR value along with LDPC. We can evaluate the performance of the PAPR reduction scheme using complementary cumulative distribution (CCDF) of the PAPR of the OFDM system.

7.1CCDF Performance

Complementary cumulative distribution function (CCDF = 1-CDF) is used to evaluate the performance in PAPR reduction which denotes the probability that the PAPR exceeds a certain threshold. CCDF values are obtained by checking how often PAPR exceeds the threshold values.

CCDF = P (PAPR> threshold) = 1- P(PAPR< threshold)

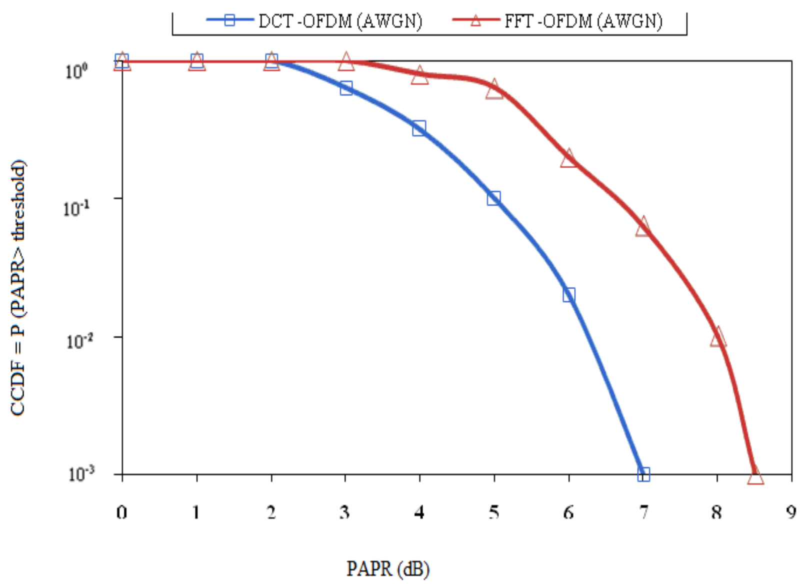

Figure-2. Comparison of PAPR reduction in OFDM by FFT and DCT for AWGN channel.

Figure-2 clearly shows the comparison of PAPR reduction by both FFT and DCT for general OFDM system using AWGN channel. Here DCT performance is better than FFT. Figure-3 represents the comparison of PAPR reduction by both FFT and DCT for general OFDM system using underwater acoustic (UWA) channel. Here DCT performance is better than FFT.

Figure-4 represents the comparison of PAPR reduction by both FFT and DCT for OFDM system using LDPC and turbo codes in Under Water Acoustic (UWA) channel. Here DCT performance is better than FFT.

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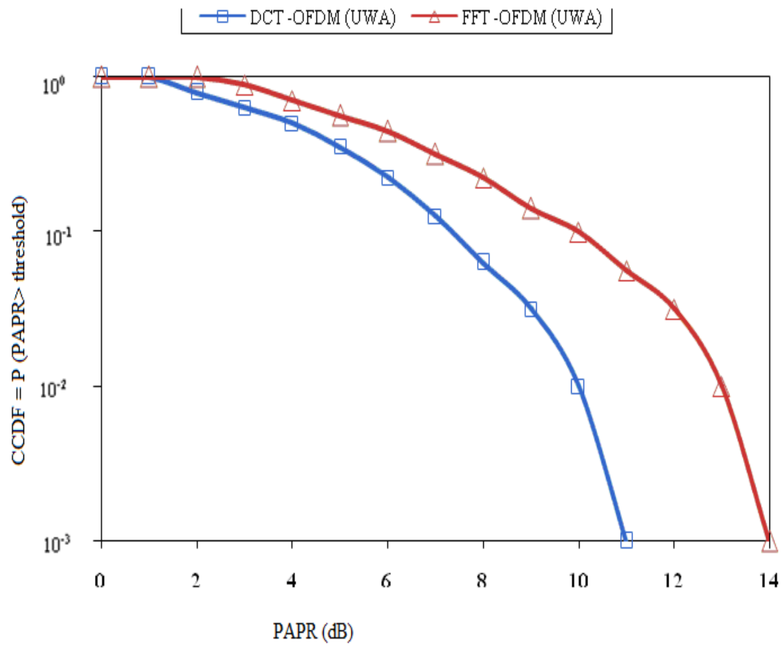

Figure-3. Comparison of PAPR reduction in OFDM by FFT and DCT for UWA channel.

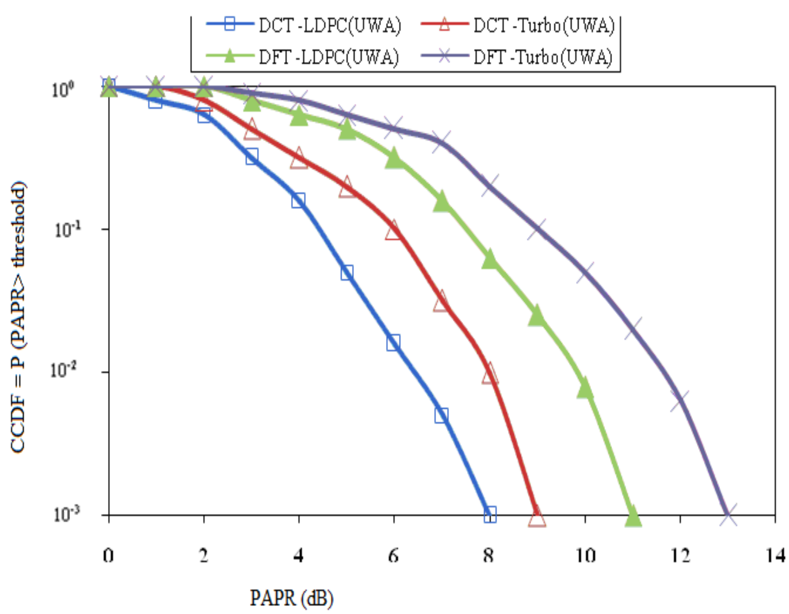

Figure-4. Comparison of PAPR reduction in OFDM by FFT and DCT using different codes for UWA channel.

8. CONCLUSIONS

In this paper, while considering PAPR performance, the proposed scheme using combined DCT and LDPC for the reduction of the PAPR of OFDM system for underwater acoustic system. Here number of required sub-carrier was reduced to less than half by the combination of this. The DCT-LDPC OFDM system has the advantage of low hardware complexity and no side information. The simulation results show that the PAPR reduction is improved when compared with other techniques.

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