LOW-PAPR ASYMMETRICALLY CLIPPED OPTICAL OFDM FOR INTENSITY-MODULATION/DIRECT DETECTION SYSTEMS

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Abstract

DHT- based clipped optical orthogonal frequency division multiplexing (ACO-OFDM) system is proposed in this work to yield better results than traditional state-of-art methods. OFDM is growing with immense pace due to its high level advantages but on other side it frequently suffers from PAPR which declines the system performance. In literature high level research is carried on to reduce the impact of PAPR but none can meet the desired requirements. DHT based PAPR reduction with DHT-spreading techniques is proposed in this paper which yields better results than DHT based PAPR reduction without DHT-spreading technique. Effective equalization and better transmission performance are the resultant of proposed work and achieved low PAPR over traditional PAPR reduction schemes.

Keywords: PAPR, ACO-OFDM, DHT, intensity-modulated/direct-detection (IM/DD) systems.

1. INTRODUCTION

As the requirement of higher data rate is increased in number of applications in optical wireless communication which are described in the LTE (long term evolution). The use of multicarrier system is developed, named as orthogonal frequency division multiplexing (OFDM) in optical wireless communication. This OFDM system is used mainly due to its advantages like high spectral efficiency as well as resistant to inter symbol interference (ISI).Among all the OFDM systems the best is IM/DD (intensity modulation and direct detection) because of following parameters as compare to other system are better in this IM/DD OFDM like range of system, cost and high speed in optical wireless communications like discrete multi-tone (DMT) systems and passive optical networks (PONs).

ACO(asymmetrically clipped optical) OFDM is then extensively studied and recognized that this system having good power efficiency as compare to other optical wireless schemes and design of the any system for any constellation are same so computations for different constellation is easily checked. This is mainly due to nonuse of the DC-bias in this system. Recently DHT (Discrete Hartley Transform) is developed which is real trigonometric transform better than DFT (Discrete Fourier Transform) based ACO-OFDM.

DHT based OFDM system does not require Hermitian Symmetry (HS) so again complexity is very less because the same model algorithm of DHT based OFDM system is used for both multiplexing and de-multiplexing processing. When the DHT based ACO OFDM model having same size as compare to DFT based ACO OFDM model the but the 2-PAM (pulse amplitude modulation) in DHT based ACO OFDM transmit same number of bits as the DFT based ACO OFDM system using QPSK system and also having BER performance same in both the system.

In OFDM system we have so many drawbacks but we are going to consider the PAPR which mainly degrades the performance the OFDM system because of nonlinear distortion in electronic as well as optical domain. As ACO OFDM having more PAPR than as compare to simple OFDM because the peak power will be the same but average power in the ACO OFDM is reduced, so research is required to reduce the PAPR in ACO OFDM. Researcher researched between this two techniques but they got that the results for DHT based ACO OFDM are better.

So in this paper DHT spread is applied to reduce the PAPR in DHT based ACO OFDM and performance of the system is checked by both simulation and experimental results. Different from DFT-spread technique, DHT-spread technique has the real output, which make simpler DHT-based ACO-OFDM system. At the complementary cumulative distribution function (CCDF) of10^{-3}, the PAPR values of our proposed scheme are about 9.7 dB and 6.2 dB lower than those of conventional DHT-based ACO-OFDM without DHT-spread technique for 2-PAM and 4-PAM, respectively. The proposed system has better performance of equalization as well as the nonlinear distortion removal as compare to the existing techniques.

2. OPTICAL WIRELESS COMMUNICATION

Light is a resource used to perceive content by human visual system in well defined manner. Light plays a vital role in human civilization from hundreds of years and previously light acts as medium to communicate in various applications. Lot of historical evidences proves that light acts as source of medium for communication especially in warships and history of evidences are from biblical times to modern times. In biblical times, fire acts as medium for communication to give signals about information about enemies and other related matters.

The predominant use of optical technology is as very fast “electric wire”. Optical fibres replace electric wire in communications systems and nothing much else changes. Perhaps this is not quite fair. The very speed and quality of optical communications systems has itself predicated the development of a new type of electronic communications itself designed to be run on optical connections. ATM and SDH technologies are good examples of the new type of systems.

It is important to realize that optical communications is not like electronic communications. While it seems that light travels in a fibre much like electricity does in a wire this is very misleading. Light is an electromagnetic wave and optical fibre is a waveguide. Everything to do with transport of the signal even to simple things like coupling (joining) two fibres into one is very different from what happens in the electronic world. The two fields (electronics and optics) while closely related employ different principles in different ways.

3. LITERATURE SURVEY

Nowadays, increase in bandwidth-hungry applications, including sharing of video and music along with new emerging applications like video on demand, video surveillance have motivated the investigation of high capacity optical communication technologies. Internet traffic has been growing at alarming rate and this would attain to zeta-byte level by ending 2015. There is necessity to explore spectrally efficient, cost effective transmission solution for next generation optical networks to meet the increased demand of internet traffic. New communication trends expect cost effective, flexible high performance transmission, which can be achieved by using DSP. Literature survey shows increase in interest for using DSP at receiver by researchers in recent years for providing flexibility, cost efficiency and improvement in transmission performance for next generation photonic networks. OOFDM has been considered as most probable solution for next generation photonics networks with high spectral efficiency and flexibility in bandwidth allocation.

The idea of orthogonal frequency-division multiplexing (OFDM), can be traced back to 1966 through a patent as a multi-carrier transmission using closely spaced 9 overlapping subcarriers, which was modified using Discrete Fourier transform (DFT) to obtain less complex system by Weinstein in 1971. OFDM has been widely accepted and extensively explored for wireless transmission due to various advantages offered by it and capability of dealing with inter symbol interference (ISI) for practical wireless applications in mid-1980s [30-31]. The applicability of OFDM has been first introduced for wired transmission in digital subscriber line in 1991 whereas now it has been base for various practical areas including local area networks, broadcasting of radio and television globally. In addition, it exists as standard to various wireless application like wireless Local area network (LAN) IEEE 802.11a, IEEE 802.11g, IEEE802.11n, wireless personal area networks (PAN) IEEE 802.15.3a, wireless metropolitan area networks (MAN) 802.16e (WiMax), and the 4G mobile communication, long-term evolution (LTE).

Further two alternatives including DD-OOFDM for simple low cost solution and CO-OOFDM for achieving high spectral efficiency has been proposed in literature. Conventionally OFDM signals are bipolar and information is propagated with electrical signals whereas OOFDM signal needs to be uni-polar as information is carried by intensity modulation of optical signals. In order to build non-negative OOFDM various forms of uni-polar OFDM including Direct current-biased optical OFDM (DCO-OFDM) and asymmetrically clipped optical OFDM (ACO-OFDM) has been explored. DCO-OFDM is based on adding DC bias to reduce and clip negative venture of signal, where as alternative solution ACO-OFDM avoids the use of DC bias with reduced clipping noise. This is based on asymmetrically clipping of negative half of OFDM symbol. Another technique based on single sideband modulation OFDM (SSB-OFDM) has been experimented on OOFDM system [52]. An experiment on multi gigabit CO-OOFDM has been proposed in 2009 over 1000 km SSMF fiber employing two Quadrature phase shift keying polarization division multiplexing (QPSKPDM) subcarriers. Transmission using CO-OOFDM achieving spectral efficiency of 3.3 bit/s/Hz with sub wavelength bandwidth access has been explored over 600 km long Single mode fiber (SMF).

Subcarrier allocation can be applied to improve transmission performance robustness. Although some Bit loading (BL), power loading (PL), Bit and power loading (BPL) has been experimented for performance improvement but adaptive subcarrier allocation using instantaneous channel information at transmitter side can be utilized for BER reduction. Different subcarriers are associated with different SNR. There is motivation to use these subcarriers effectively and allocate them according to channel state information that needs to be known at transmitter. Such effective utilization of adaptive subcarrier allocation is yet unexplored in literature. Consequently, an adaptive subcarrier allocation technique is required to be explored which can efficiently utilize spectrum as per user requirement using channel state information for performance improvement.

4. PROPOSED METHODOLOGY

The multiplexing and de-multiplexing process of the proposed ACO-OFDM for IM/DD system using DHT algorithm is explained in detailed way in following process. The N point DHT and inverse DHT is defined as follows

$$X_n = \frac{1}{\sqrt{N}} \sum_{k=0}^{N-1} X_k cas\left(\frac{2\pi kn}{N}\right) \qquad X_k$$

$$= \frac{1}{\sqrt{N}} \sum_{n=0}^{N-1} X_n \, cas\left(\frac{2\pi kn}{N}\right) \quad (1)$$

Where $cas(\cdot) = \cos(\cdot) + \sin(\cdot)$, n and k ranges from 0 to $N-1$,

X_n represents time-domain OFDM sample,

X_k represents frequency-domain input sample,

In DFT-based IM/DD OFDM, HS is needed to generate real signals. But in DHT-based IM/DD OFDM, DHT is a real trigonometric transform with a self-inverse property, it automatically generates real signal and the multiplexing and de-multiplexing processes employ the same algorithm.

The diagram of DHT-spread ACO-OFDM (DHT-S-ACO-OFDM) for IM/DD system is shown in Fig. 1. In contrast to typical ACO-OFDM, DHT-S-ACO-OFDM adds 2 L-point DHT modules within the transmitter and receiver because the red boxes show. At transmitter, the information sequences square measure sent to the real constellation plotter [PAM mapper] after serial-to-parallel operation. Then the generated M-PAM signals square measure sent to the L-point DHT to comprehend the DHT-spread operation. The output of L-point DHT x is outlined as

$$X_m = \frac{1}{\sqrt{L}} \sum_{l=0}^{L-1} X_l \, cas\left(\frac{2\pi lm}{L}\right) \quad (2)$$

where m is from 0 to $L-1$. X_m is assigned to odd positions of N-point DHT operation (i.e., N ¼ 2L)

Y=[0,X_0,0, X_1, ……, X_{L-1}] (3)

After N-point DHT operation, the generated OFDM, Y can be defined as

$$Y_i = \frac{1}{\sqrt{2L}} \sum_{h=0}^{2L-1} y_h cas\left(\frac{2\pi hi}{2L}\right) = \frac{1}{\sqrt{2L}} \sum_{j=0}^{L-1} y_{2j+1} \, cas\left(\frac{2\pi(2j+1)\, i}{2L}\right) \quad (4)$$

where i is from 0 to $N-1$.

As shown in (3), $y_{2j+1} = X_j$

$$Y_i = \frac{1}{\sqrt{2L}} \sum_{j=0}^{L-1} X_j \, cas\left(\frac{2\pi(2j+1)\, i}{2L}\right)$$

$$= \frac{1}{\sqrt{2L}} \sum_{j=0}^{L-1} \frac{1}{\sqrt{L}} \sum_{l=0}^{L-1} X_l cas\left(\frac{2\pi lj}{L}\right) * cas\left(\frac{2\pi(2j+1)\,i}{2L}\right)$$

$$= \frac{1}{\sqrt{2L}} \sum_{j=0}^{L-1} \sum_{l=0}^{L-1} X_l [cos\left(\frac{2\pi(i-l)j-\pi i}{L}\right) + \sin\left(\frac{2\pi(i+l)j+\pi i}{L}\right) \quad (5)$$

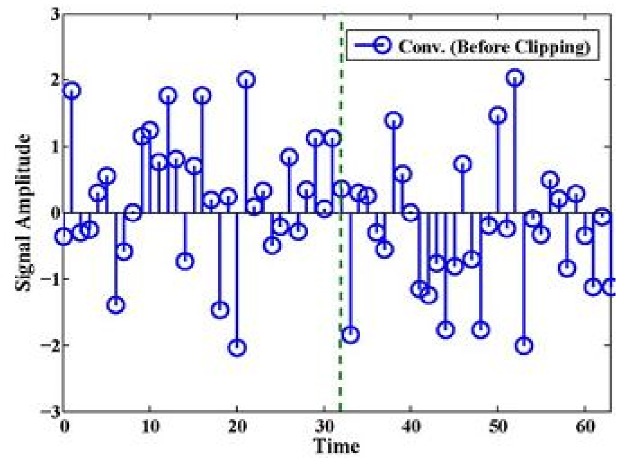
Therefore, we can get the output of N-point DHT Y

$$Y_i = \begin{cases} \frac{1}{\sqrt{2}}[X_i \cos\left(\frac{\pi i}{L}\right) + X_{L-i} \sin\left(\frac{\pi i}{L}\right)] & 0 \le i \le L-1 \\ \frac{1}{\sqrt{2}}\left[X_{i-L} \cos\left(\frac{\pi i}{L}\right) + X_{2L-i} \sin\left(\frac{\pi i}{L}\right)\right], & L \le i \le 2L-1 \end{cases} \quad (6)$$

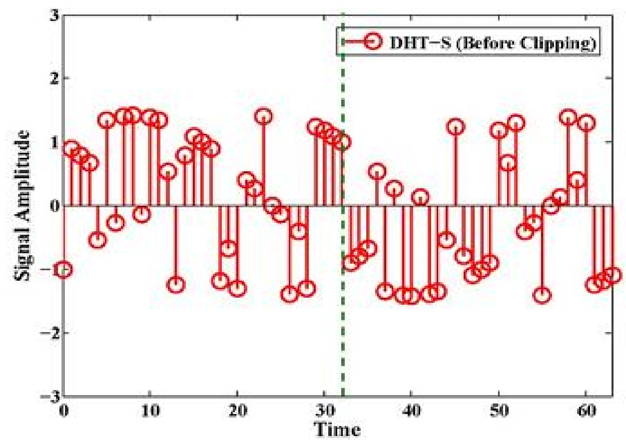
Y has the anti-symmetrical property. The negative samples of Y can be forced to zero without any loss of information [7]. The DHT-S-ACO-OFDM, C, can be obtained from Y by clipping operation,

$$C_i = \begin{cases} Y_i, & Y_i > 0 \\ 0, & Y_i \le 0 \end{cases} \quad (7)$$

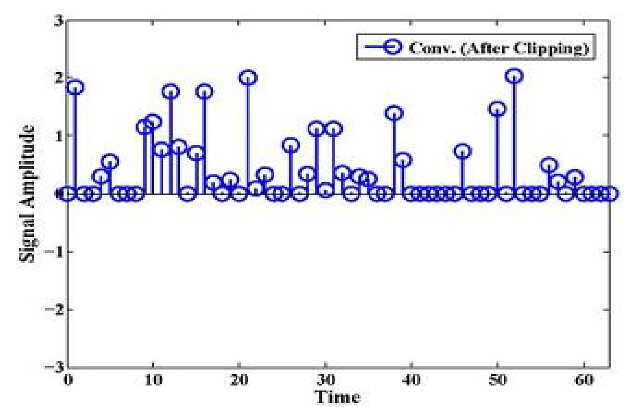
After addition of cyclic prefix (CP), digital-to-analog conversion (DAC) and low-pass filter (LPF) modules, the transmitted signal is generated. At receiver, the inverse operations of transmitter square measure accomplished to recover the data sequences, chiefly together with analog-to-digital conversion (ADC), removal of CP, N-point DHT, channel estimation, L-point DHT and PAM de-mapper.



(a)



(b)



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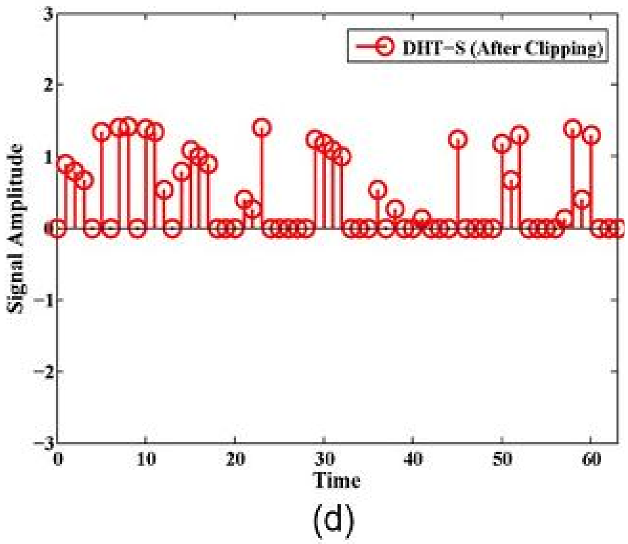
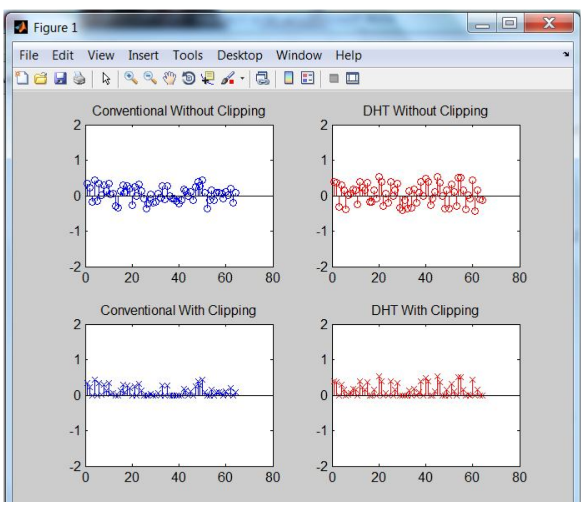


Fig.1: (a) Anti-symmetry conventional OFDM symbol. (b) Anti-symmetry DHT-S-OFDM symbol. (c) Conventional ACO-OFDM symbol. (d) DHT-S-ACO-OFDM symbol. The N is equal to 64

5. RESULTS



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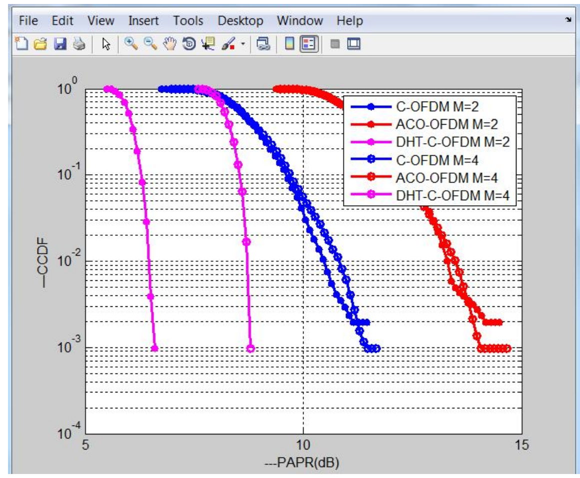

Fig.2. Complementary cumulative distribution function (CCDF) curves of w/o clipping OFDM, conventional ACO-OFDM, and DHT-S-ACO-OFDM.

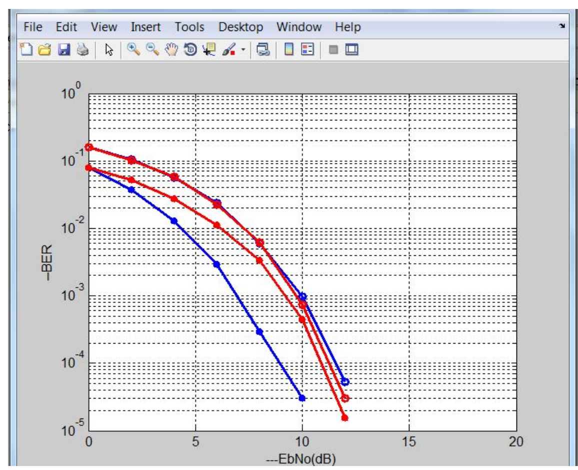

Fig.3. Comparison of BER performance between conventional ACO-OFDM and DHT-S-ACOOFDM in AWGN channel.

6. CONCLUSION

We used DHT based algorithm in DHT ACO OFDM to reduce the PAPR in OFDM system. At the CCDF $=10^{-3}$, we checked the PAPR values which are 9.7 dB and 6.2 dB less than that of conventional algorithm for 2-PAM and 4-PAM respectively. This proposed scheme registers good performance over previous algorithms because of its effective equalization as well as low PAPR values. Hence finally we concluded that the proposed scheme performance is best for IM/DD due to its low PAPR and excellent transmission performance through channel.

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