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Low-PAPR Analysis of OFDM-Based and OWDM-Based Radio-Over-Fiber Systems

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Abstract: **Orthogonal Frequency Division Multiplexing (OFDM) is used in many wired and wireless communication systems because of the ability to combat with intersymbol interference (ISI) and multipath distortion. Recently, OFDM has been focused on in optical communication systems. But the High Peak-to-Average Power Ratio (PAPR) is one of the main obstacles to limit the application. Because of the non-linear of the power amplifiers, the modulator and optical fiber, the high PAPR cause the distorted signal and reduce the efficiency of the optical Orthogonal Frequency Division Multiplexing systems. In this paper the impact of a Radio-over- Fiber (RoF) optical subsystem on the sensitivity to the phase noise of an Orthogonal Frequency Division Multiplexing (OFDM) system using Discrete Fourier Transform (DFT) and Discrete Wavelet Transform (DWT) are evaluated and compared by computer simulation. The study investigates the effect of phase jitter on the system Bit Error Rate (BER) of the DFT/DWT-based OFDM for different modulation schemes in the presence of optical sub-system's nonlinearities in AWGN channel.**

Keywords: **Optical Orthogonal Frequency Division Multiplexing; Peak-to-Average Power Ratio; Asymmetrically Clipping Technique; Filtering Technique RoF; OWDM; AWGN.**

I. INTRODUCTION

Radio-over-Fiber (RoF) is a technology by which information bearing signals using RF carries are delivered by means of optical components and techniques. Better coverage and increased capacity, centralized upgrading and adaptation, higher reliability and lower maintenance costs, support for future broadband applications, and economic access to mobile broadband are among the most important advantages of RoF [1], [2]. However, RoF systems are vulnerable to nonlinearities in the optical subsystem that cause degradation of the system BER performance. Normally, these effects are expressed as AM-AM and AM-PM characteristics; the former is an amplitude transfer function while the latter is a phase transfer function. One area of interest in modern communications is OFDM which is becoming widely used in wireless communication systems due to its high data rate transmission capability with high bandwidth efficiency and also its robustness to multi-path fading without requiring complex equalization techniques [3], [4], [5].OFDM has been adopted in a number of wireless applications including Digital Audio Broadcast (DAB), Digital Video Broadcast (DVB), Wireless Local Area Network (WLAN) standards such as IEEE802.11g and Long Term Evolution (LTE) [6].To mitigate Inter-Symbol Interference (ISI), a cyclic prefix (CP) is used which in turn leads to spectral inefficiency. In comparison to single carrier systems, more vulnerability to frequency offset and phase noise are OFDM disadvantages. In recent years, wavelet transform has been suggested to replace DFT in OFDM systems. While signals in DFT-OFDM systems overlap in the frequency domain only, DWTOFDM signals overlap in the time domain as well, so there is no need for the CP as in the DFT-OFDM case [7],[8]. Hence, some savings in bandwidth can be achieved. Hereafter DFTOFDM and DWT-OFDM are referred as OFDM and OWDM (Orthogonal Wavelet Division Multiplexing), respectively.

However, one of the main disadvantages of OFDM is its high Peak-to-Average Power Ratio (PAPR). When N signals are added with the same phase, they produce a peak power that is N times the average power. A high PAPR implies that many of devices for high performance, such as the power amplifier, modulator and the A/D converter must have an inefficiently large linear range. Therefore, the high PAPR problem must be solved. Many solutions have been proposed for PAPR reduction in wired and wireless OFDM communication systems. But the fundamental differences are existed between the radio communication systems and the optical communication systems. Therefore, the scheme for PAPR reduction in optical communications may be combined with the characters of the optical fiber system. In this paper, a new scheme of asymmetrically clipping and filtering technique for PAPR reduction is proposed in the optical OFDM system. The main algorithm of this new scheme is discussed, and some performances including the PAPR, power spectral density and bit error rates are achieved by Monte Carlo simulations.

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II. SYSTEM DESIGN MODEL

A. *Definition of the PAPR*

In OFDM systems, the baseband time domain signal consisting of *N* subcarriers may be written

as:

$$x(t) = \frac{1}{\sqrt{N}} \sum_{n=0}^{N-1} X_n e^{j2n\pi\triangle ft}$$

Where $\varDelta f$ is the subcarrier spacing, and *Xn* are the modulating symbols. The PAPR of the transmit signal can be defined as:

$$PAPR = \frac{max[|x_n|^2]}{E[|x_n|^2]}$$

Where *xn* is the samples of *x*(*t*) , and *E*() denotes statistical expectation. In particular, a baseband OFDM signal with *N* subcarriers has

$$PAPR_{max} = 10log_{10}N(dB)$$

From the central limit theorem, it follows that for large values of *N* ($N \geq 64$), the real and imaginary values of *x*(*t*) become Gaussian distributed. Therefore the amplitude of the OFDM signal has a Rayleigh distribution, with a cumulative distribution given by $F(z) = 1 - e{-}z$ .The

probability that the PAPR is below some threshold level can be written as $P(PAPR \leq z) = (1 - e{-}z)N$. In fact, the complementary cumulative distribution function (CCDF) of PAPR is usually used, and can be expressed as:

$$P(PAPR > z) = 1 - (1 - e^{-z})^N$$

The theoretical CCDFs of OFDM signals with *N* = 32, 64, 128, 256 are shown in figure 1. With increasing the number *N* of subcarriers, there was a corresponding increasing in CCDFs under a certain PAPR threshold.

B. *Solutions of the PAPR reduction*

In order to reduce the PAPR of an OFDM signal, many techniques are proposed in the literature.

These techniques can be organized into three classes: signal distortion, signal scrambling, and block coding. Signal distortion is the simplest class of techniques, including clipping and peak windows [3], peak cancellation, weighted multicarrier transmission, companding and filtering, etc. These techniques reduce high peaks directly by distorting the signal prior to amplification [4] [5]. To clip the signal, the peak amplitude is limited to some desired maximum level. It can give a good PAPR, but at the expense of some performance degradation, including in-band and out-of-band interference. To remedy the out-of-band interference problem, the suitable window functions may be applied, including the cosine, Kaiser, and Hamming windows.

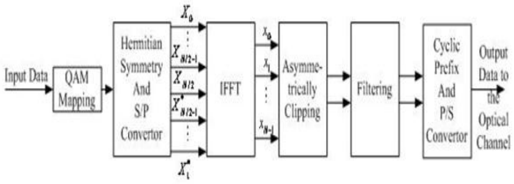


Fig 1:Block Diagram Of ACO OFDM

The basic idea of signal scrambling is to introduce some limited redundancy, and to send the OFDM signal with the minimum PAPR. The goal is not to eliminate the peaks, but only to make them less frequency. These techniques include the selective mapping (SLM) approach [6] and the partial transmit sequences (PTS) approach [7]. These related schemes are effective and flexible to reduce the PAPR without nonlinear distortion.

A number of forms of optical OFDM systems have been proposed recently. Coherent optical OFDM (CO-OFDM) is one form of optical systems. It requires coherent reception, and very narrow line-width lasers are required at the transmitter and receiver because of the sensitivity of OFDM signal to frequency offset and phase noise. Direct-detection optical OFDM (DDOOFDM) improves on these disadvantages, and has been demonstrated experimentally to provide a simple and effective solution to chromatic dispersion for long-haul fibre applications.

C. *Radio-over-Fiber (RoF)*

Radio-over-Fiber (RoF) is a technology by which information bearing signals using RF carries are delivered by means of optical components and techniques. Better coverage and increased capacity, centralized upgrading and adaptation, higher reliability and lower maintenance costs, support for future broadband applications, and economic access to mobile broadband are among the most important advantages of RoF [1], [2]. However, RoF systems are vulnerable to nonlinearities in the optical subsystem that cause degradation of the system BER performance. Normally, these effects are expressed as AM-AM and AM-PM characteristics; the former is an amplitude transfer function while the latter is a phase transfer function.

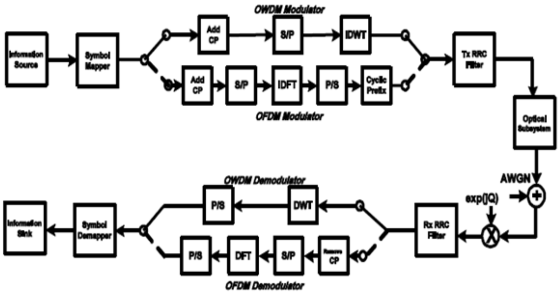
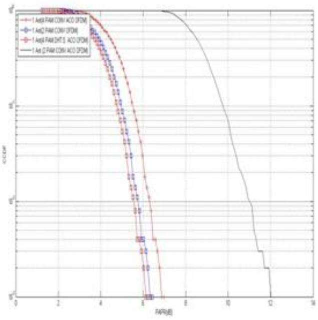
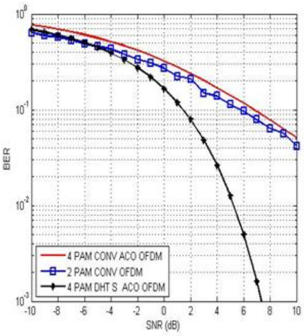


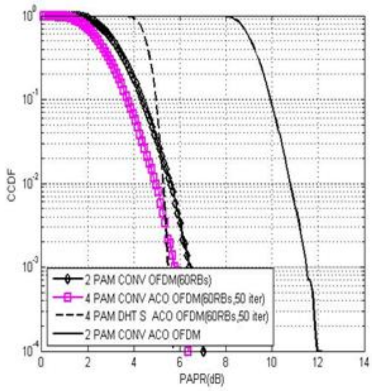
Fig. 2 Block Diagram of MC RoF.

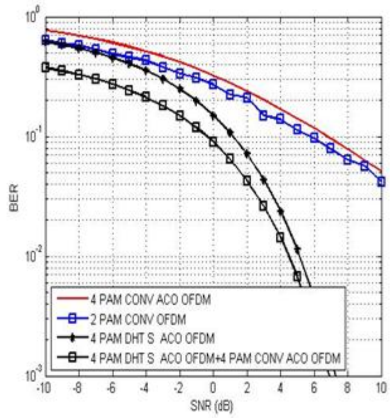
In order to evaluate the system performance, computer simulations were carried out based on the system model presented in Fig. 2. The data source transmits 1,000,000 bits. For the sake of simplicity and focusing on the phase distortion itself, operations such as coding and interleaving are not considered. Then, the data are mapped using a QPSK/16PSK/16QAM modulator. To produce OFDM symbols, first the resultant signal is converted from serial to parallel. Then, either an Inverse Discrete Fourier Transform (IDFT) or an Inverse Discrete Wavelet Transform (IDWT) is taken. The resultant signal in the OFDM case is converted to serial , and in order to mitigate ISI, a CP with a length of 25% of the whole OFDM symbol period is added. Then the resultant signal is filtered by the receive RRC filter followed by the CP removal from the OFDM signal, and thereafter it is converted to parallel symbols. Subsequently, a DFT /DWT is taken followed by a conversion to serial data. For a fair comparison of the effect of carrier phase noise, no channel estimation is performed. After being demodulated, the received data are compared with those transmitted.

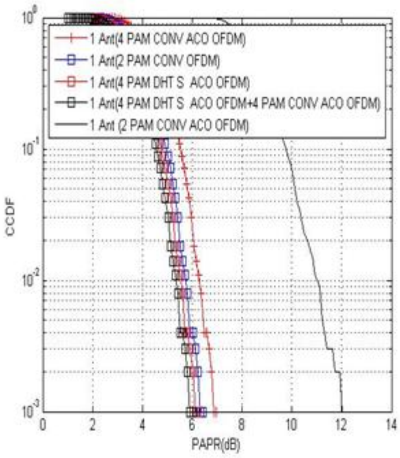
III. SIMULATION RESULTS

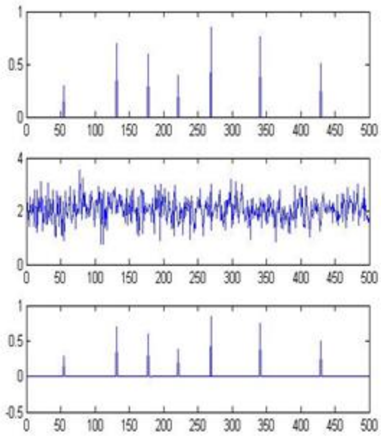


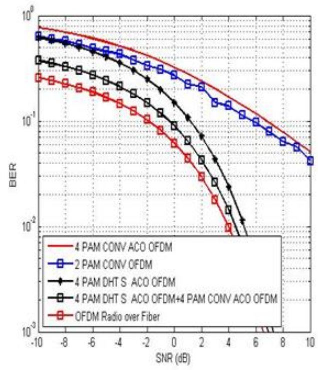












Here number of subcarriers per optical OFDM symbol is 128 and oversampling ratio is 4 in all the simulations. And a constellation size of 16QAM was used for mapping. To introduce oversampling, a number of zeros can be added to the input data. And the zeros should be added in the middle of the input data rather than appending them at the end. To investigate the effect of RoF nonlinearity, additional simulations were performed. Figure shows BER versus for different wavelets along with that of OFDM for the MC RoF-QPSK at OBO=1 dB. The behaviors of the BER plots follow approximately the same trend as in the linear scenario. One can observe that while wavelet sym2, from Group I, achieves poor performance, OFDM and the other wavelets have comparable BER performance for low values.

IV. CONCLUSION

PAPR problem is one of the most important issues to be considered in developing the optical OFDM systems. Several techniques have been proposed for PAPR reduction in wireless and wired communications, not for optical communication system. A new scheme of asymmetrically Clipping and filtering technique for PAPR reduction is proposed combined with the characters of the IM/DD optical OFDM system. Analytical and simulation results have been presented that this scheme can not only reduce the PAPR for optical OFDM signals, but also offer good BER performance. The scheme of asymmetrically clipping and filtering is a very promising technique for PAPR reduction of optical OFDM signals.

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