Enhancing Performance of Optical Link using Integrated DWDM and Flip- OFDM for High Speed Optical Communication Systems

T. Beni Steena, P. Indira, M. Geethalakshmi

Abstract: ***The main advantages of the optical transmission media such as wide bandwidth, high bit rate with large channel capacity made it most favorable delivering transmission media. In this paper we consider flip-OFDM along with DWDM. Both techniques have different hardware complexities. The Dense Wavelength Division Multiplexing (DWDM) network is reshaping the landscape of communication networks. To compensate dispersion effects in optical wireless communication we use OFDM. We convert bipolar OFDM signals to unipolar OFDM symbol is to add a DC bias. This is known as DC offset OFDM. DC bias depends on the value of PAPR, which is large for OFDM. To lower DC bias values we use clipped negative time samples. Which results in Inter-carrier Interference and out of band optical power. DC bias is avoided by Asymmetric clipped optical OFDM. Only positive (odd) subcarriers carry information and negative values are clipped at the transmitter. The performance were still improved by Flip-OFDM, the positive and negative parts are extracted from bipolar OFDM real time domain signal and transmitted in two consecutive OFDM symbols. Both frames are positive samples since negative part is flipped before transmission. Thus Flip OFDM is a unipolar technique that can be used in optical wireless communication. In this paper we review and analyse Flip-OFDM and suggests further improvements. The future based DWDM based integrated services are also discussed. It is clear that the proposed system can provide tremendous improvement in BER performance and high data rate which is well suited for future applications. The simulations are performed by MATLAB.***

Keywords: Flip-OFDM, DWDM, PAPR.

I. INTRODUCTION

Block diagram is a typical IM/DD wireless communication system [4]. An infrared emitter is used as optical transmitter to generate optical signal. This signal represents the intensity of optical carrier transmitted over optical wireless channels.

At the receiver the photodetector collects the optical signals and coverts it into electrical current. Optical wireless link is operated in two modes: Directed and non-directed. In directed mode, Line of sight dominates and an additive white gaussian noise is appropriate. In diffused mode there is no strong LOS.

System Model

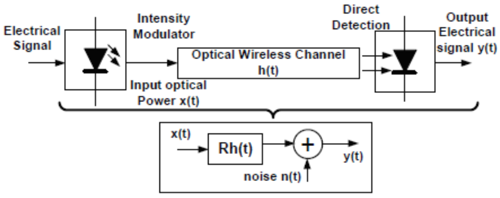

Fig.1: Equivalent base band channel model for IM/DD optical wireless channels

Optical wireless channel is modelled as linear baseband system. The channel impulse response and noise component h(t) and n(t) resp. The received electrical signal is given by, $y(t) = h(t) * x(t) + n(t)$

Where * denotes convolution

Diffused Optical wireless Channel model

In this case the optical power propagation along various path contributes to multipath propagation. As in [10], using delta Dirac functions, the impulse response of an optical wireless channel is given by,

$$h(t) = \sum_{n=0}^{N_D} h_n \delta(t - n\Delta\tau) \qquad (1)$$

The exponential decay model are widely used to model both two multiple and single optical reflections. The channel response due to multiple reflections is modeled as

$$h_e(t) = \frac{1}{D} e^{-\frac{t}{D}} u(t) \qquad (2)$$

Where D represents RMS delay spread of multiple reflections, u(t) represents unit step functions resp.

Noise Model

In Optical communication system, the two dominant noise components are photon noise and receiver circuit thermal noise[8],[10]. The photon arrivals mainly due to background light sources leads to photon noise. Optical filtering reduces background light. But even with well designed photo detector, it creates shot noise. The shot noise is independent of transmitted signal and is modelled as white Gaussian. The power spectral density of shot noise and thermal noise are given in [8].

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II. FLIP-OFDM

OFDM is an efficient multi-carrier modulation technique which can provide high data rate and bearable inter symbol interference [2], [3], [9].

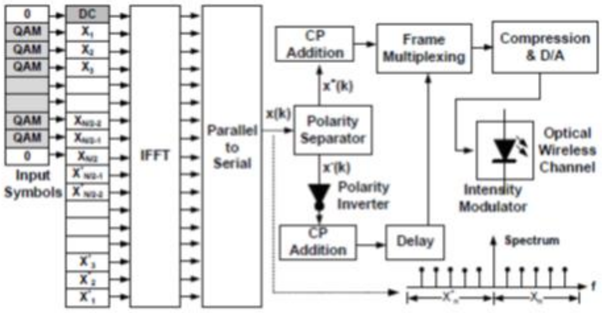

Fig.2: Block Diagram of Flip OFDM Transmitter

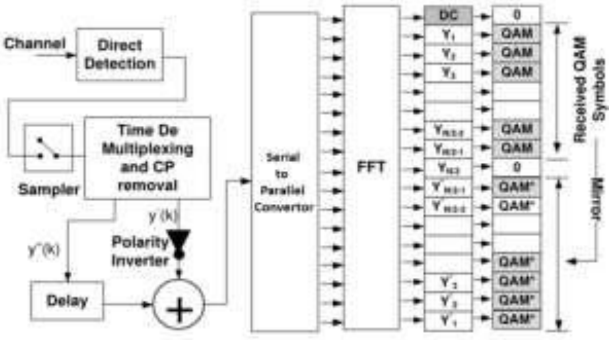

Fig.3: Block Diagram of Flip OFDM Receiver

Let x(n) be the transmitted QAM symbol in then-th OFDM subcarrier. The output of IFFT-Inverse Fast Fourier Transform operation at the k-th time instant is given by,

$$x(k) = \sum_{n=0}^{N-1} X_n \exp\left(\frac{j2\pi nk}{N}\right) \quad (3)$$

N is the size of IFFT, the time domain signal x(k) produced by the IFFT operation is complex. This can be avoided by Hermitian symmetry property, ie.

$$X_n = X^*_{N-n} \quad n=0,1,2\ N/2-1; \quad (4)$$

Flip-OFDM uses half of the total OFDM subcarriers to carry information so that the output of IFFT block is a real bipolar signal.

$$x(k)=x^+(k)+x^-(k) \quad (5)$$

Positive and negative parts are defined as

$$x^+(k) = \begin{cases} x(k) & \text{if } x(k) \geq 0 \\ 0 & \text{otherwise} \end{cases}$$
$$x^-(k) = \begin{cases} x(k) & \text{if } x(k) < 0 \\ 0 & \text{otherwise} \end{cases} \quad (6)$$

The positive signal $x^+(k)$ is transmitted in the first OFDM subframe, while the flipped (inverted polarity) signal $x^-(k)$ is transmitted in the second OFDM subframe. Cyclic prefix are added to both OFDM subframes. The cyclic prefix associated with each OFDM subframe are first removed and the original bipolar signals are regenerated,

$$y(k) = y^+(k) - y^-(k) \quad (7)$$

Fast Fourier Transform(FFT) operations are performed to recreate the bipolar signal to order to detect the transmitted information symbols at the receiver.

III. COMPARISON OF OFDM WITH FLIP-OFDM

Both have same bandwidth, data rate and cyclic prefix length. We compare some special key parameters.
(i)SNR (ii)Spectral efficiency (iii)BER performance

Modification of Flip-OFDM

Flip OFDM [7] performs compression of time samples. Compression doubles the bandwidth and data rate and it reduces the length of cyclic prefix by half when compared with OFDM.

Comparison of key parameters

1.Spectral efficiency

The number of information bits per unit bandwidth is defined as spectral efficiency and is measured in bits/Hz.

Flip-OFDM uses both odd and even subcarriers, it needs two subframes to reconstruct the bipolar signal and to extract the information. Flip-OFDM uses twice the number of samples to transmit twice as many information symbols. So the spectral efficiencies of both are same.

2. Expected BER and electrical domain SNR:

Expected BER performance is directly related electrical domain SNR defined as E[xt2(k)]/2, where E[xt2(k)]/2 gives the energy of the transmitted signal xt(k) and 2 represents variance of the electronic noise.SNR depends on i) equivalent electrical energy per symbol and ii) noise power.

IV. MAJOR COMPONENTS OF DWDM

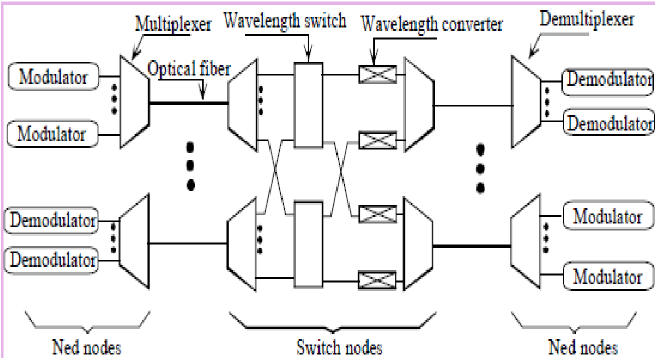

Fig.4: Components of DWDM

DWDM is the most important phenomena which is utilized to enhance the capacity of optical fiber communication system. The information of multiple channels can be launched into SMF using DWDM [1]. While working with DWDM system, it is assumed that different channels propagate along fiber without interfering with one another. This assumption fails when power level is increased due to non linear and linear effects (chromatic dispersion) [5].Due to suppression of non-linear distortion leads to enhancement of high data rates and large bandwidth.

Applying intensity modulation in direct-detection systems is one technique that has been used to increase network capacity. This technique utilizes DWDM system and optical amplification to achieve very high capacity network [8]. The ideal modulation format for long haul high speed DWDM optical link is one that has narrow spectral width, low susceptibility to fiber non-linearity, large dispersion tolerance, good transmission performance, simple design and cost effective configuration for generation [9][6].

V. FWM EFFECT

FWM in fiber is related to self phase and cross phase modulation. In DWDM system, it occurs when two ormore different frequency components propagate simultaneously in optical fiber. The interference produced between two propagating wavelengths produce new groups of spectral components at different frequencies. This FWM products are mixed with channel signals and produce higher order FWM products and produce cross talk. FWM can be eliminated and suppressed by increasing equal or unequal spacing between channels. The four-wave mixing effect is minimum at 100 GHz channel spacing between input channels. The number of FWM components increases with increase in the number of channels.

$$N = M^2(M-1)/2 \qquad (8)$$

Where N is the number of channels

M is the Four Wave mixing components

VI. SIMULATION AND RESULTS

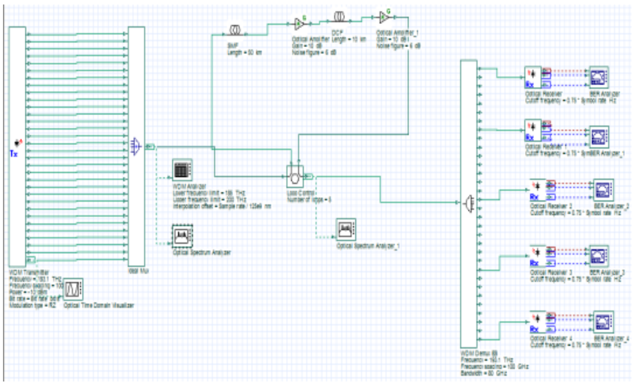

Fig.5. Simulation set up for DWDM optical link

Table 1: Comparative study of performance parameter at 100GHz channel spacing excluding NL effect.

Performance Parameters	*Channel (1)*	*Channel (8)*	*Channel (16)*
Q-factor (NRZ)	*13.15*	*11.04*	*9.34*
Q-factor (RZ)	*10.94*	*11.03*	*9.25*
Eye height(NRZ)	*0.022*	*0.021*	*0.020*
Eye height (RZ)	*0.016*	*0.016*	*0.012*
Min BER (NRZ)	*7.62e-040*	*1.07e-028*	*4.52e-021*
Min BER (RZ)	*3.40e-028*	*1.29e-028*	*1.05e-019*
SNR dB (NRZ)	*33.14*	*30.11*	*30.25*
SNR dB (RZ)	*26.00*	*21.36*	*21.95*

By comparing the performance parameters for NRZ and RZ modulation format, It is observed that Q-factor,Eye height, Min BER, SNR are superior for NRZ modulation format. Therefore NRZ shows better performance, with the non linear effect infiber model.

In simulation by excluding and including non linear effect

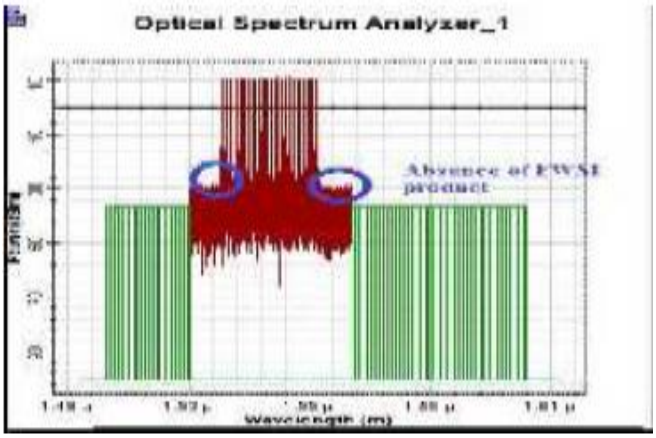

Fig.6: Result after 300km for NRZ (excluding NLE for channel space of 100GHz)

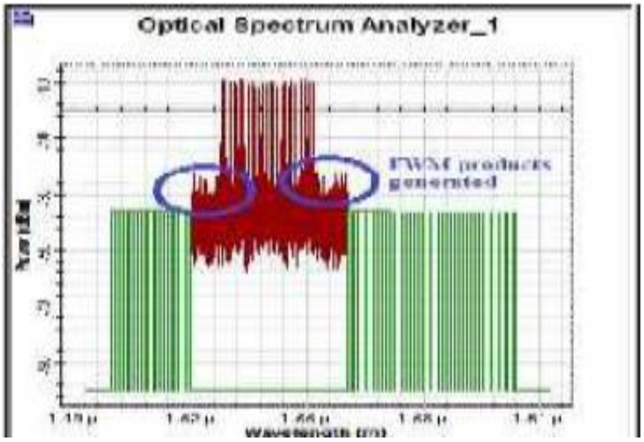

Fig.7: Result after 300km for NRZ (including NLE for channel space of 100GHz)

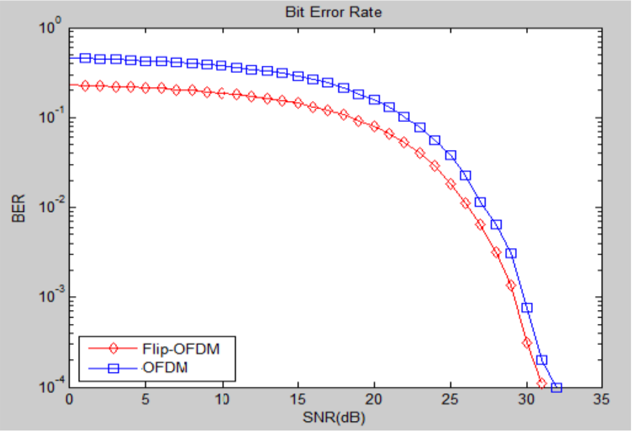

Fig.8: BER comparison of Flip-OFDM optical wireless system with conventional OFDM system

VII. CONCLUSION

Flip-OFDM is an efficient unipolar version of OFDM for high speed optical wireless communication system. Flip-OFDM scheme is the best transmission scheme which can be used for 5G applications. In DWDM optical link

it was also observed that by increasing channel spacing from 100 to 200 GHz for NRZ modulation formats, mitigation of non-linear effects, especially Four wave mixing. Thus DWDM-Flip-OFDM shows a better performance.

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