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Select the Best Cyclic Prefix for Various Effective Area in an O-OFDM System

Abstract- *In the past few years, the Optical Orthogonal Frequency Division Multiplexing (O-OFDM) has been deliberated as a promising future in high data transmission technology. OFDM is a special case of FDM technology, which is a multi-carrier-modulation (MCM). OFDM has been developed in the wireless as well as wireline systems, for that reason it is popularly used in optical transmission systems. O-OFDM system is simulated with Optisystem V14.0 program from @Optiwave company. This paper provides an examination of O-OFDM system using different cyclic prefix length to eliminate the effect of ICI and ISI, on the other hand using different values of effective area of the optical fiber and observe its effect on the bit error rate of the system. The best transmission performance (best BER) at a length of 1000Km of optical fiber of the system is at a cyclic prefix of 1/16 (6.25%) at the effective area of 150 μm^2.*

Keywords- *O-OFDM, Cyclic prefix, Effective area, BER, Optisystem.*

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1. Introduction

The claim for ultra-high capacity transmission networks resulted from profound development and inquiry on Tera-bits/s (Tb/s) transmission over long distance. Optical Orthogonal Frequency Division Multiplexing (OFDM) is a mixture of multiplexing and modulation format for high capacity transference systems .This system works by separating the data signal into liberated subsets then switching it with liberated subcarriers, then OFDM signals are produced by multiplexing the sub-channels. OFDM is regarded as an exceptional type of FDM that includes a mixture of several tiny streams in one pack instead of one particular stream [1]. Chang discovered the first OFDM system as he published his revolutionary work on the formation of band-limited orthogonal signals for multi-channel data transference [2]. He revealed a recent plan for conveying signals all together over a band-limited channel without ISI and ICI. An early OFDM application was AN/GSC-10 (KATHRYN), it was a changeable data rate modem synthesized for the high-frequency radio [3]. A basic block diagram for an O-OFDM system is shown in Figure 1. This type of subcarrier modulation is only one of its kinds because all of the subcarrier frequencies are orthogonal. OFDM signal is mapped into N_d constellation symbols $\{X(K)\}_{k=0}^{Nd-1}$ using different types of modulation techniques. Before N_p pilots are changed into the time domain signal, they are put into the data symbols by means of an IFFT given as [4]:

$$m_x[n]=\frac{1}{\sqrt{N}}\sum_{k=0}^{N-1} X[k]e^{\frac{j2\pi nk}{N}},\ n=0\ldots,N-1 \qquad (1)$$

A duplication of the end of the symbol and inserting it at the beginning of it is called the cyclic prefix, this operation is added to the system to eliminate the effect of Intersymbol interference. The output of the IFFT block feeds straightforward into a Digital to Analogue Converter (DAC), which interprets the distinct IFFT model points into nonstop time-varying signal, which is then used to make the strength of the optical source-starting place [4].

The optical signal field during the duration of the one-bit period is given by:

$$E_s(t)=E_p(t)\ a(t)\cos[\omega(t)t+\theta(t)]\ \ for\ 0\le t\le T \qquad (2)$$

Where $E_s(t)$, $E_P(t)$, $a(t)$, $\omega(t)$, and $\theta(t)$ are the signal optical field, the polarized field coefficients as a function of time, the amplitude variation, the optical frequency change with respect to time, and the phase variation with

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respect to time depending on the modulation of the carrier by amplitude, frequency, or phase [1].

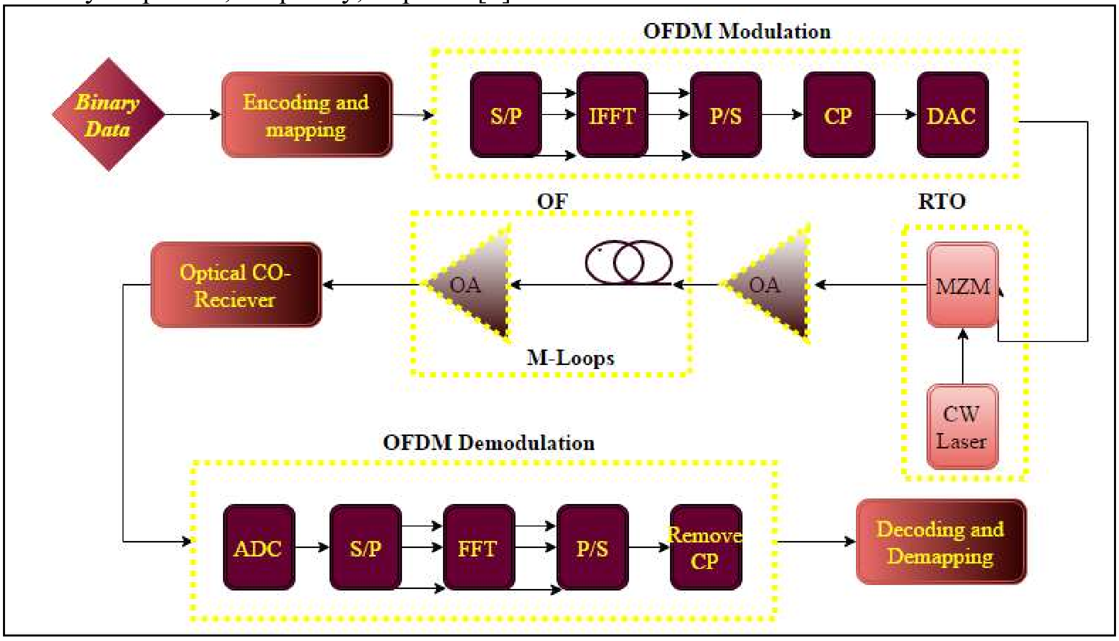


Figure 1: Optical OFDM block diagram

After the cyclic prefix is taken off, a signal is applied to the FFT at the receiver. The cyclic prefix linear convolution between the transmitted signal and the channel results in a circular convolution. Optical signal suffers from nonlinear and linear effects as it transmitted over an optical fiber [5,6], Increasing the effective area of the fiber leads to decrease the nonlinear effects.

2. Cyclic Prefix

In telecommunication, the word Cyclic Prefix (CP) refers to copying the end of the symbol and sending it at the beginning as shown in Figure 2.
At the receiver this added part will be removed, the cyclic prefix length must be greater than the maximum delay spread produced by dispersion, t_{max}, the main purpose of using CP is to provide robustness to the OFDM signal and to reduce the effect of ISI, The Inter-symbol-interference free OFDM transmission condition [7] is given by:

$$t_{max} < \Delta_G \quad (3)$$

where Δ_G is a guard interval insertion. The disadvantage of adding the cyclic prefix is the information loss from the reduction of SNR due to bits lost in the location of the added part of the symbol, where

$$SNR_{loss} = -10 log(1 - \frac{T_{cp}}{T}) \quad (4)$$

Where T_{cp} is the cyclic prefix and T data symbol length, the CP should not be larger than needed to minimize the SNR loss. Reduced Guard Interval (RGI) in Coherent-OFDM systems achieve less ICI because shorter symbol durations are utilized [8,9] , as in [10] if the CP length is high it

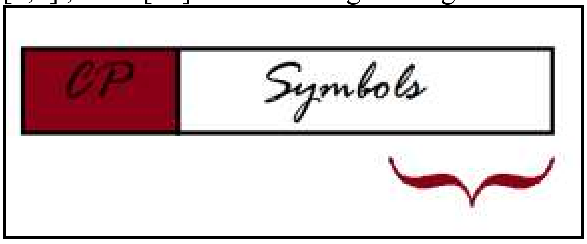


Figure 2: Illustration of the Cyclic Prefix.

takes higher energy for transmission but it don't carry any data and this leads to a degradation in the performance of the system, on the other hand if the CP length is undersized it cannot compensate dispersion effects.

3. Proposed Optical OFDM System Design

O-OFDM system design is done by using @Optisystem 14.0 [11] system software platform; this software is used to provide the optical fiber channel and its effect on the communication system. The proposed Optical OFDM system consists of the O-OFDM transmitter, which comprises of the BER test set to calculate the system performance and to provide a bit sequence generator inside it, a Quardrature amplitude modulation sequence generator which encode and modulate a binary signal to an electrical signal using 16-QAM, an OFDM modulation block is located in this place to generate an OFDM signal a in Figure 3. The OFDM signal need to be converted from a RF signal to an optical signal through the RF to optical converter system which consist of two mach-zehender modulator and a CW laser source as in Figure 4. The optical link consists of 1000Km single mode fiber, at every 50Km there is an optical amplifier of gain 10dB as in Figure 5. The receiver part contain also a coherent detection where the optical signal is detected and converted into an electrical signal, an OFDM demodulation is used to demodulate the waveform using the inverse transform of that used in the transmitter, a QAM decoder which is used to change the samples into bits, as in Figure 6.

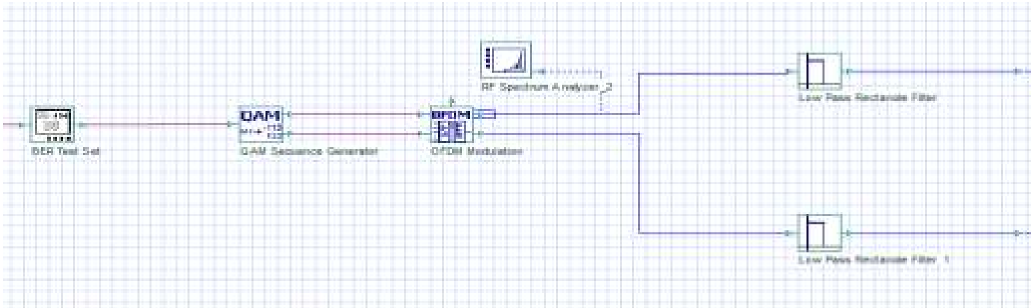


Figure 3: O-OFDM transmitter part.

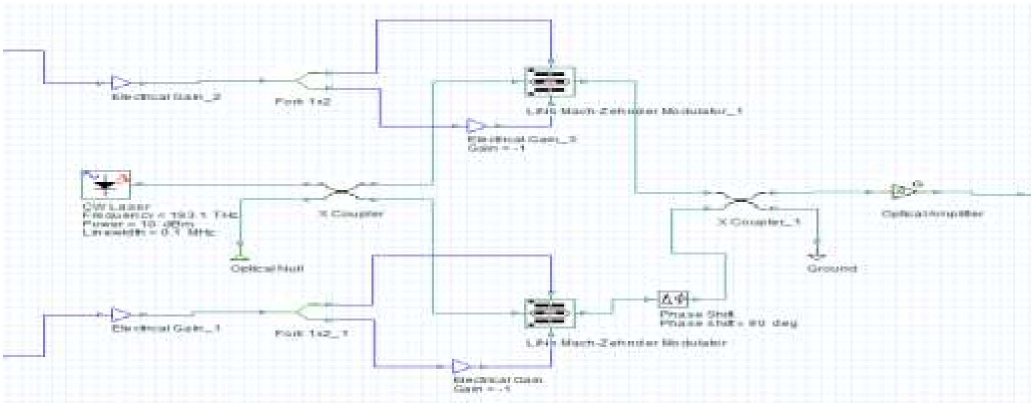


Figure 4: RF to optical Upconverter part.

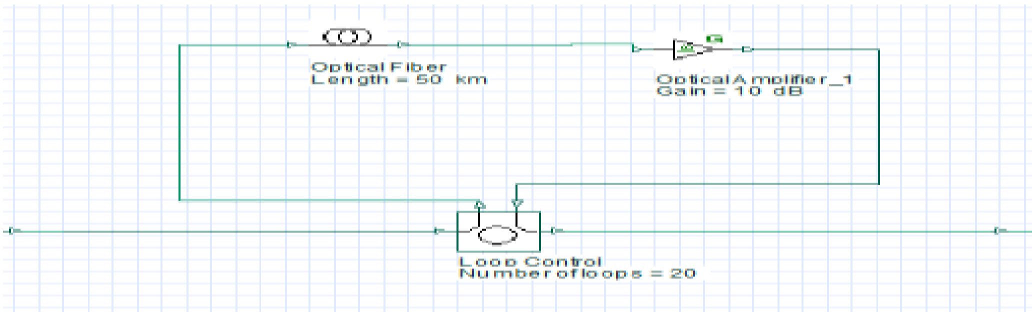


Figure 5: 1000Km SMF (optical channel part).

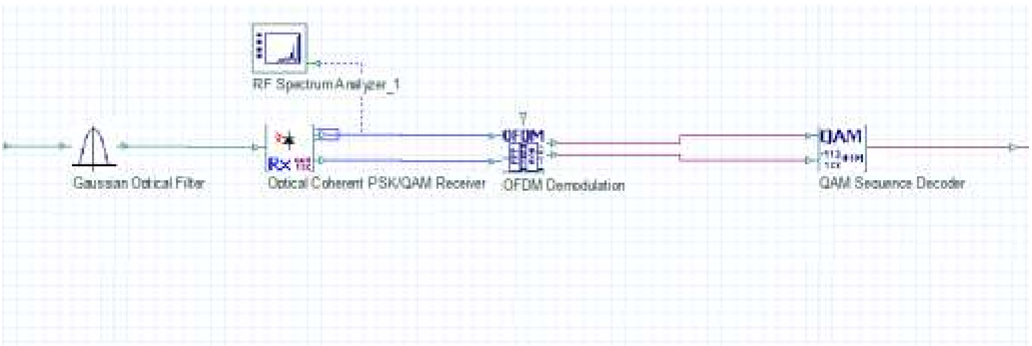


Figure 6: Coherent detection with O-OFDM receiver part.

The proposed system parameters is shown in Table 1 a 16QAM O-OFDM system was used, the selected optical link is a standard SMF consist of 20 loops of 50Km, each loop has an optical amplifier of gain 10 dB, the dispersion coefficient 16.75 ps/nm*km. the system with variable cyclic prefix length has been used, at each cyclic prefix the effective area of the optical fiber is varied from 60-150 µm2 in steps of 10.

4. Results and Discussion

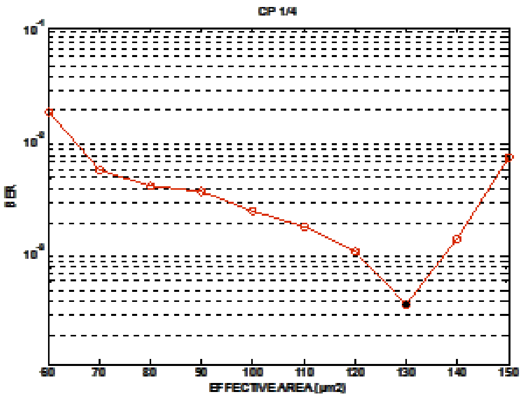
The system is studying the performance of the O-OFDM system and checking with different values of effective area and different percentage of cyclic prefix (25%, 12.5%, 6.25%, 3.125%, 1.56%, 0.78%, and 0.39%). The best value of bit error rate is examined. In [12-14] an effective area of 80 μm^2 was used, in this work and at the cyclic prefix of 1/4 the effective area are chosen from 60-150 μm^2 the best effective area is 130 μm^2 as it has the lower value of BER, at the cyclic prefix of 1/8 the best value of E.A. is 130 μm^2, at 1/16 the best value is 150 μm^2 and at 1/32 is 150 μm^2, as shown in Figure 7. The same process is repeated for the values of cyclic prefix of 1/64, 1/128, 1/256 where the best values are150 µm2, as in Figure 8. All these results are shown in Table 2 with their BER values.

Table 1: Proposed O-OFDM System Parameters

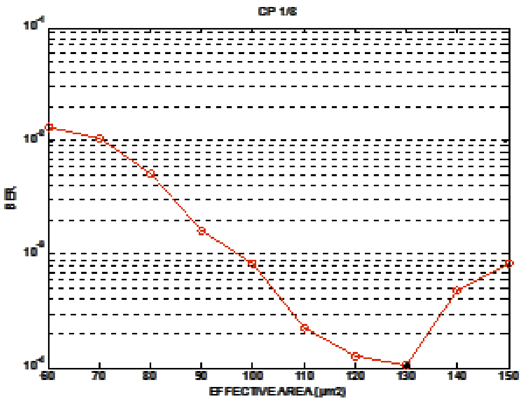
Bit Rate	40 Gbit/s
Bits per symbol (b/sym)	4
Maximum possible subcarriers	128
Number of prefix points	20
Cyclic prefix	1/4,1/8,1/16,1/32, 1/64,1/128,1/256
Average OFDM power	15 dBm
Subcarrier locations	25-104
Sequence length	20480 Bits
Channel wavelength	1550

Table 2: Comparison of results.

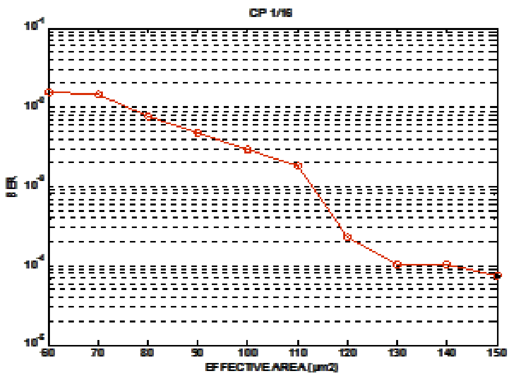
Cyclic prefix	Best Effective area (μm^2)	Best BER (dB)
1/4 (25%)	130	$37*10^{-5}$
1/8 (12.5%)	130	$10.4*10^{-5}$
1/16 (6.25%)	150	$7.5*10^{-5}$
1/32 (3.125%)	150	$15*10^{-5}$
1/64 (1.56%)	150	$30*10^{-5}$
1/128 (0.78%)	150	$20*10^{-5}$
1/256 (0.39%)	150	$22*10^{-5}$



(a)



(b)



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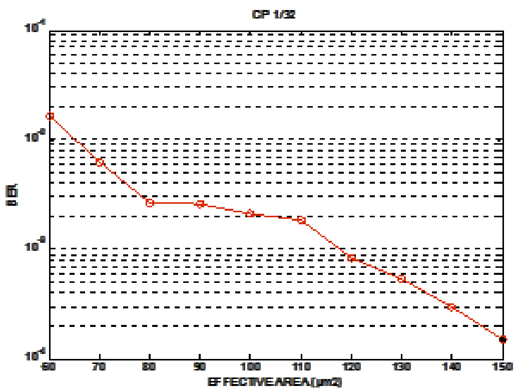
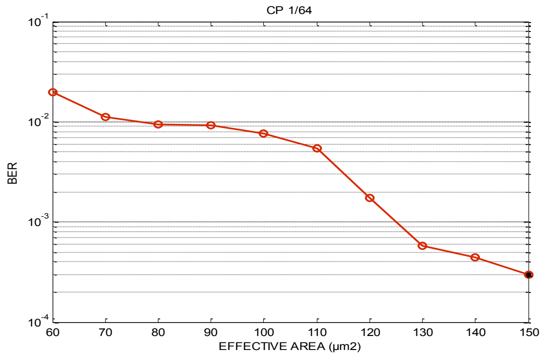
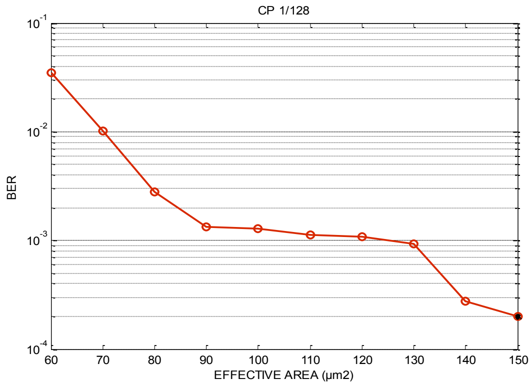


(d)

Figure 7: Cyclic prefix vs Effective area of optical fiber (E.A.), where: (a): cp 1/4. (b): cp 1/8. (c): cp 1/16. (d): cp 1/32.



(a)



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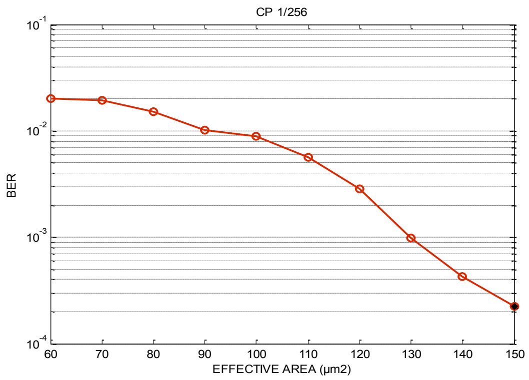

(c)

Figure 8: Cyclic prefix vs Effective area of optical fiber (E.A.), where: (a): cp 1/64. (b): cp 1/128. (c): cp 1/256.

5. Conclusion

The improvement of the O-OFDM system by using the cyclic prefix length and the effective area is used in terms of BER, as the effective area increased the system achieves the best BER. For the 16 QAM O-OFDM system the optimum value for the cp is 1/16 (6.25%) at E.A. of 150 μm^2 where its BER is $^{7.5}*10^{-5}$.

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