Long Reach Coherent Optical OFDM System using Multiple Mid Link Spectral Inversion Modules

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Abstract- *CO-OFDM is a very attractive modulation and multiplexing technique that is used in wideband optical systems as well as optical wireless systems. In this paper; performance of utilizing multiple optical phase conjugate (OPC) modules in CO-OFDM system as a midlink spectrum inverter has been analyzed in order to improve the performance of system in long-haul fiber-optic channel. Firstly, performance of CO-OFDM system investigated at 30Gb/s, 50Gb/s and 100Gb/s which successfully transmitted over 1800Km, 1440Km and 1080 Km link length respectively without using any optical phase conjugation module. Further multiple OPC modules used in order to compensate effects of Kerr non linearities.8400Km of long distance transmission has achieved with acceptable BER limits by incorporating 6 OPC modules each after 1200Km at 30Gb/s. Results are analyzed in terms of OSNR, Q-factor for varied launched power and results revealed that system performs best at 12dB input power and effects of SPM decreased by using multiple OPC modules.*

Index Terms *- optical phase conjugation, OSNR, error vector magnitude, self phase modulation, BER*

I INTRODUCTION

Optical OFDM technology plays a vital role in developing bandwidth flexible systems for providing the eventual way out for next generation optical networks [1]. Advanced modulation is a very attractive modulation and multiplexing technique that is used in wideband wireless and optical communication system due to its spectrum efficiency and channel robustness. Orthogonal frequency division multiplexing belongs to a broader class of multicarrier modulation (MCM) carrying the data information over many lower rate subcarriers. OFDM, a modulation as well as multiplexing technique is the origin of several telecommunications standards counting digital terrestrial television (DTT), wireless local area networks, and digital radio broadcasting.CO-OFDM systems have several advantages in overcoming transmission impairments such as CD (chromatic dispersion) and PMD (Polarization mode dispersion)[2].Main cause of degradation in performance of OFDM is due to non linear effects such as four wave mixing(FWM) and SPM (self phase modulation) in subcarriers at high launched power.

Kerr's effect is a major source of non linear impairments which cause phase shift in signals resulting into the generation of new signals [3].New generated signals mixed with the CD and degrades the signal quality. Till date many techniques has been proposed to compensate the effects of nonlinearities. However these proposed schemes have their different complexity trade-off's [4][5].In Long haul optical systems for the compensation of non linearity's and chromatic dispersion, optical phase conjugation is suggested in technical literature also called spectral inversion module. Placement of OPC in optical systems is very important and generally place in middle of transmission length in order to cancel the impairments generated in first part by next part of the channel. Firstly, OPC was used as pulse width reduction module [6].Logarithmic compensation impractical complexity shift attraction towards OPC. Recently, OPC is widely used in OFDM and phase modulated systems [7] [8].

In this work, multiple optical phase conjugation modules has been used for non linear compensation in CO-OFDM systems in order to increase reach of the transmission. Self phase modulation is investigated and compensated by using OPC in middle of the link. Further 6 OPC modules used to achieve 8400Km link distance with acceptable limits of BER. System performance analyzed in terms of OSNR at varied distance and launched power levels.

II SIMULATION SETUP

Figure.1(a). Represents the block diagram of OFDM Transmitter. Proposed System consisting of a CW laser source centered at frequency193.1THz.PRBS is used to generate random data and biased at 30 Gb/s followed by QAM modulation in order to convert serial bit stream into parallel bit stream. OFDM modulator with 512 subcarriers perform the operation of signal orthogonality in order to make a bandwidth flexible system. Two Linb MZM modulators are used to modulate OFDM signal into optical domain and combined by a power combiner. Output OFDM signal then fed to the loop consisting of SMF, DCF and EDFA.Figure.1(b) shows the transmission link consisting of 6 spectral inversion OPC modules. Effects of chromatic dispersion are compensated by Symmetric dispersion compensation module. Optical phase conjugation module incorporated in this system to mitigate non linear impairements.6 OPC modules are used each after 1200Km of link distance with WDM analyzer after each OPC to calculate OSNR. Local oscillator (LO) for phase matching with received signal placed at receiver and centered at freq. 193.1THz with power 8dBm-12dBm .O/E converted signal fed to OFDM demodulator and then m-array threshold detector is used to detect multilevel signal followed by QAM decoder as shown in Fig.1(c). A constellation visualizer evaluates error vector magnitude EVM i.e deviation of pulse from ideal point to another point of the system.BER analyzer is used to analyze the OFDM signal in terms of Q-factor and BER.

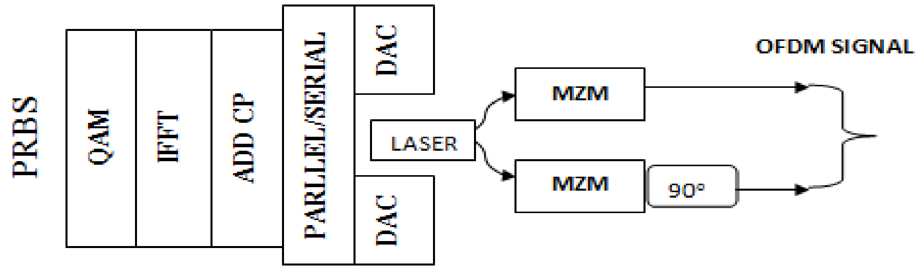


Figure.1 (a) CO-OFDM Transmitter at 30Gb/s

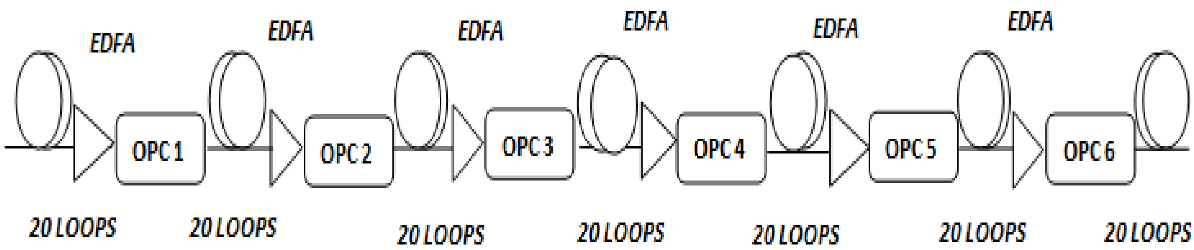


Figure.1(b) Transmission module consisting of 6 OPC after each 1200KZ

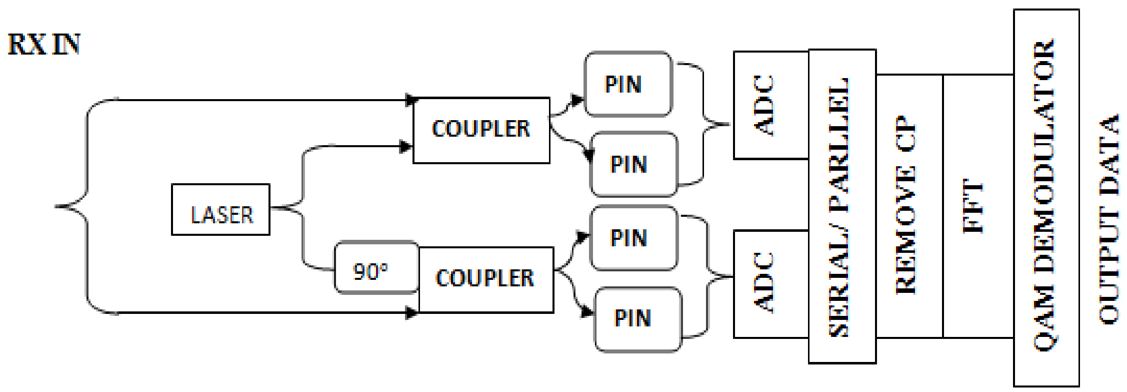


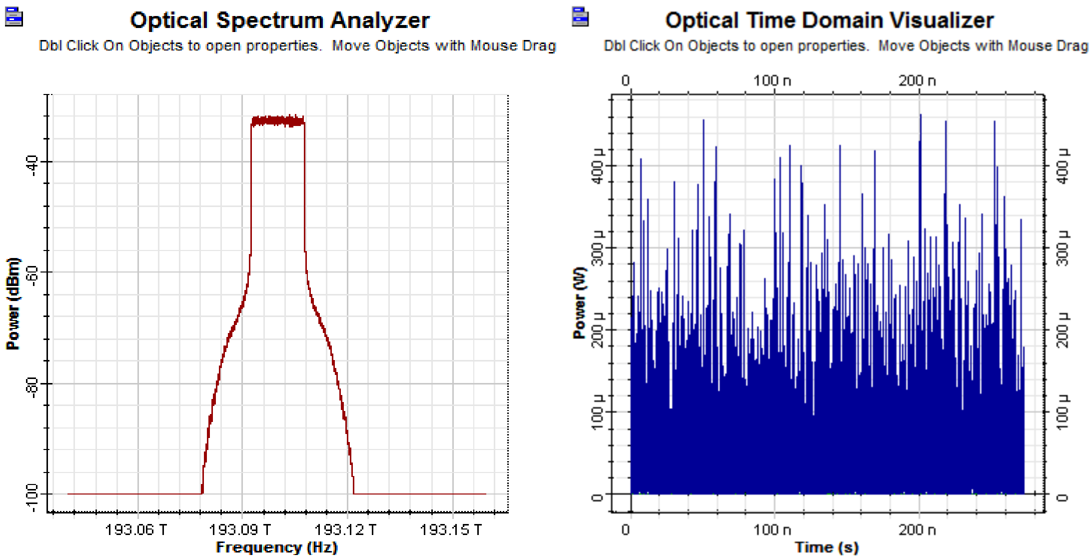
Figure.1(c) CO-OFDM Receiver

Table.1: Specification of long Haul system

Parameters	Values
Data Rate	30Gbps
Frequency	193.1THz
Laser Power	8dB-12dBm
LO Power	8dB-12dBm
QAM	4QAM
Total distance	8400Km
No. of Subcarrier	512
FFT Points	1024
No. of OPC	6
Each loop	1200Km
Seq. Length	8192

III RESULTS AND DISCUSSION

Figure.2 (a). represents the power spectrum of OFDM signal centered at 193.1THz.Encoded ofdm signal has been shown in fig.2(b) at OTDV visualizer. OFDM system has been analyzed for different data rates such as 30Gbps, 50Gbps and 100Gbps in terms of optical signal to noise ratio(OSNR).It has been observed that with the increase of data rate the output SNR of OFDM system decreases as shown in Fig.3.Maximum Reach of transmission successfully covered in case of 30Gb/s, 50 Gb/s and 100Gb/s is 1800Km, 1440Km and 1080 Km respectively without using any optical phase conjugation module.



• (b)

Figure.2.Diagram of (a) Optical spectrum at 193.1THz (b)Time domain representation of OFDM signal

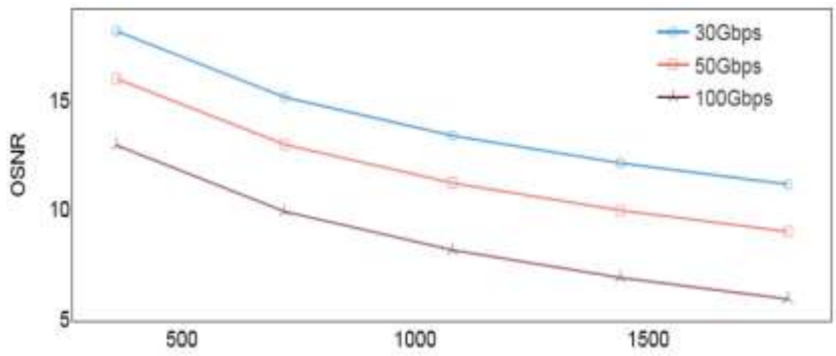


Figure.3.OSNR Vs Distance at different data rates

In this work, investigation has been done to compensate the effects of non linearities caused due to SMF and DCF. For mitigation the effects of SPM, optical phase conjugation is used after 1200Km.Total 6 optical phase conjugation modules used for successfully covering distance of 8400Km.Basic function here to use OPC is to provide negative wave front after 1200Km and it converted again to former phase after another non linear medium. Matlab component is used to make OPC component. Figure.3(a) shows the effects of increasing power on OSNR of proposed system.

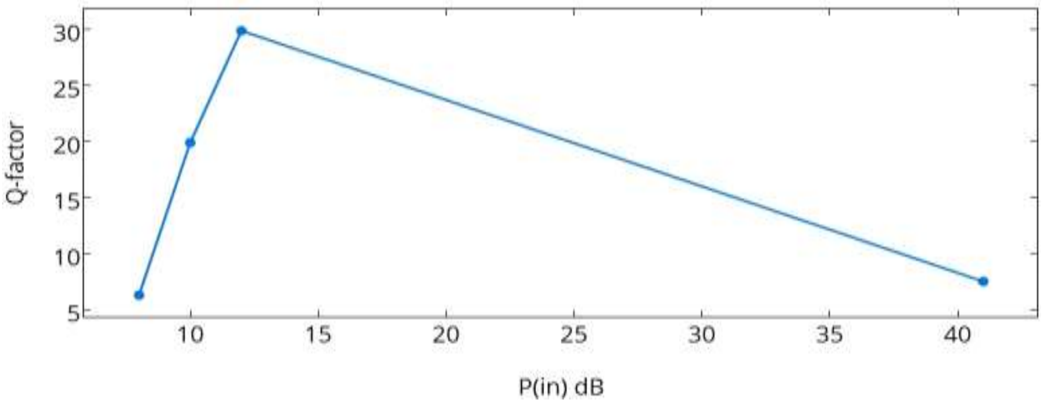


Figure.3 (a). Variation of Q-factor with input power

It is observed from the graphical representation that maximum quality factor has been reported at 10dB and 12dB and after tends to decreases power increased to 14dB. OSNR of the system tends to decrease from 1200Km to 8400 Km as shown in Fig.3(b).Table.2. Shows the values of OSNR after ach 1200Km.

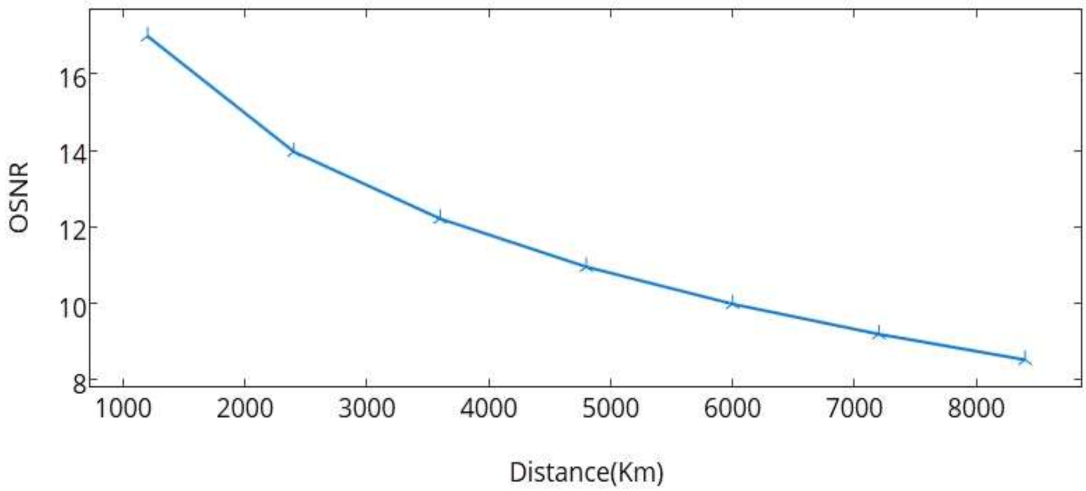


Figure.3(b). Graphical representation of Distance vs OSNR

Table..2: Values of OSNR after each OPC

Distance Km	OSNR
1200	16.99
2400	13.97
3600	12.22
4800	10.96
6000	9.99
7200	9.2
8400	8.53

Maximum OSNR reported at 1200Km after 1 OPC and minimum after 8400Km using 6 OPC modules.Figure.4. shows the combined OSNR curves after each 1200Km by using single OPC for every 1200Km.Total distance achieved 8400Km after 6 OPCs.

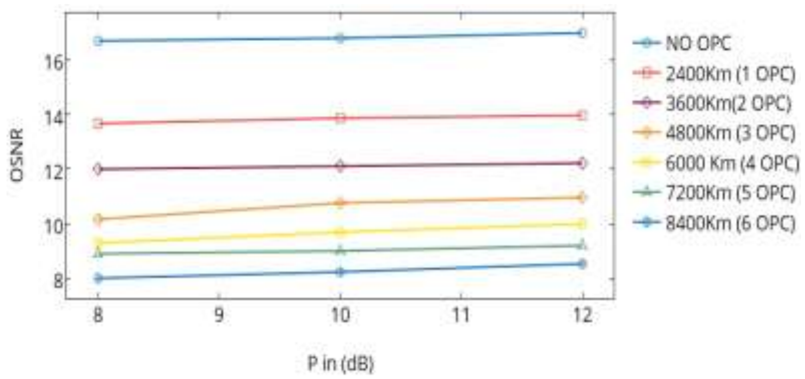
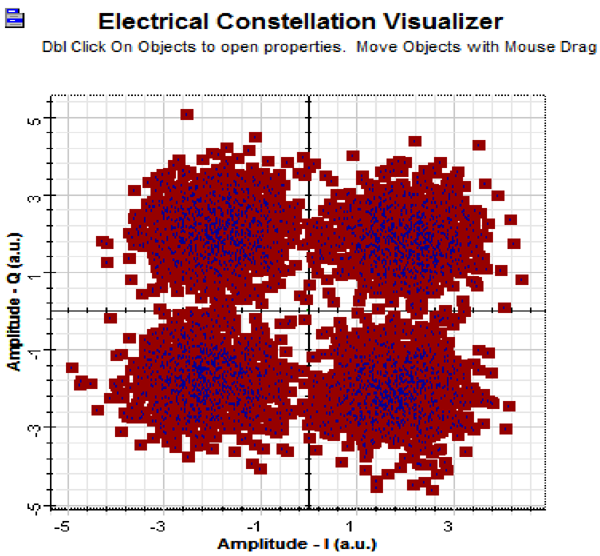
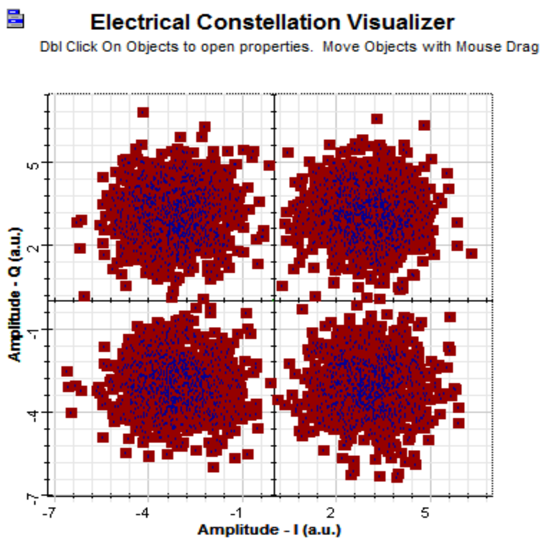


Figure.4: OSNR Vs pin after each OPC

Further constellation of received signal with respect to varied input has been studied at 8dB to 14 dB. Error vector magnitude decrease as power increase as shown in Fig.5.(a) and (b). In increasing the number of OPC modules used in the system from 5 OPCs to six, the enhancement of results is less. Another point in systems using WDM is that systems with even numbers of OPCs are preferable, since by using an odd number of OPCs, the order of WDM wavelengths after passing the cascaded OPCs is reversed. At the receiver, to obtain wavelengths with the same order, the input signal should be conjugated. However, in systems with an even number of OPCs, due to the functionality of OPCs, the order of wavelengths at the transmitter and the receiver are the same. Considering these facts, the use of 6 OPCs, in comparison with 5 or 7 OPCs, is preferred for a long-haul CO-OFDM link.



(a)



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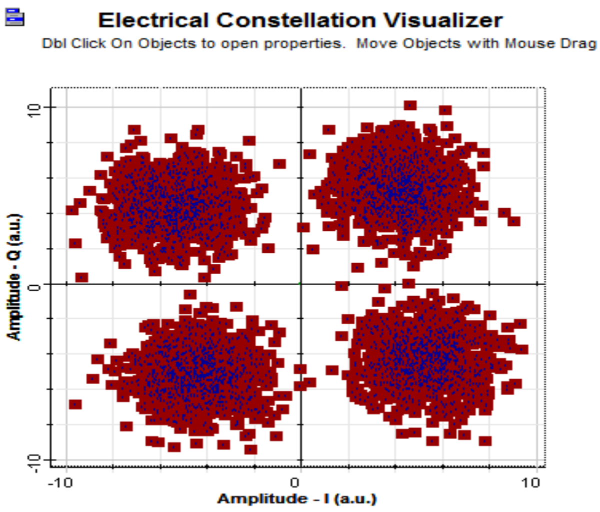
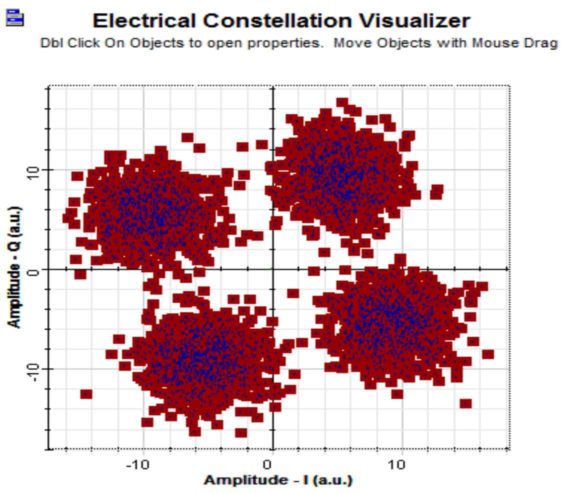


(c)



(d)

Figure.5: Constellation diagram for 8400Km OFDM system at (a) 8dB (b) 10dB (c) 12dB (d) 14dB

Minimum EVM observed in the case of 12dB input power. Further increase in power degreases the results. Worst results have been examined at 14 dB input power. Increasing the OPC modules enhance the total transmission link distance at higher launched powers which indicates that using multiple OPCs mitigate non linear penalty even at higher power levels. However, a small increase in the input optical power introduces a great penalty to optical signal to noise ratio.At lower values of optical signal to noise ratio, the phase noise effects are more and even strongest. Therefore use of optical phase conjugation is required for performance enhancement.

IV Conclusion

In order to enhance the performance of CO-OFDM communication systems in long-haul fiber-optic channels, investigation has been done utilizing multiple OPC modules along fiber spans. In this work, Performance of optical phase conjugation has been analyzed to enhance the system link length by mitigating the effects of non linearities.System performance in terms of Q-Factor and BER analyzed for different powers and distance. Maximum Q-factor observed at 12dBm input power. Minimum EVM observed in the case of 12dB input power. Further increase in power degreases the results. Worst results have been examined at 14 dB input power. Without using any OPC system works for 1800Km, 1440km and 1080Km at 30Gb/s, 50Gb/s and 100Gb/s respectively with error free communication and distance prolongs to 2400Km by using 1 another OPC at 30Gb/s. Maximum achievable distance with 10^-4 BER is 8400Km by using 6 OPC modules. Increasing distance more and more OPC modules completely provide errorous communication.

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