Eng. &Tech.Journal, Vol.34,Part (A), No.7,2016

Generation and Transmission of Optical Solitons in Ultrahigh Speed Long-Haul Systems

Dr. Ali Y. Fattah
Department of Electrical Engineering, University of Technology, Baghdad
Email: dralifattah@yahoo.com
Noor Q. Flaih
Department of Electrical Engineering, University of Technology, Baghdad, Iraq
Email: Noorqassem072@Gmail.com

Received on:29/9/2015 & Accepted on:21/4/2016

ABSTRACT

High bit rates optical communication systems pose the challenge of their tolerance to linear and nonlinear fiber impairments.The techniques processing of linear and nonlinear impairments involve which balance between linear and nonlinear impairments. Optical Solitons are the special breed of wave packets which can propagate over long distance without changing in their shape and velocity. Effective transmission distance could be increased by proper circuit designing and balancing Group velocity dispersion (GVD) with its counterpart Self phase modulation (SPM. The comparison between the results of single channel soliton source and CW laser 33% RZ_DPSK modulatiom formats shows that the soliton source has the better performance than the CW. Soliton source which has a Q factor of 98.4 at distance of 60Km, while the CW laser with 33% RZ-DPSK has 70.01 at distance at 60Km, when power lunch is (10) dBm. On other hand the BER is (-11.2) when SNR (5) dB at 60km, while CW laser with 33% RZ-DPSK has BER (-20) at SNR (5) dB at distance 60Km.The soliton system at multichannel (8x40Gb/s) with 50 GHz channel spacing has BER (-15) while 33%RZ-DPSK has BER (-9) at SNR (6.87) dB at 60Km distance.

INTRODUCTION

In the recent years, the optical Solitons are considered one of the remarkable techniques that are utilized in the long distance communication. Optical Solitons are the unique generation of the wave packets that are used to keep the power at a certain level and on account of its elemental property of keeping its velocity and shape phase without any changing during its spread over too long distance. The wonderful characteristic is complementing influence of the dispersion effect with the self-phase modulation cyclically [1-2].

To maintain its dispersion resilient nature in an optical link, a Soliton must keep its power between determined levels.

Therefore, the compensation process for the fiber loss becomes one of the essential issues that must be addressed periodically by using lumped **E**rbium-**d**oped **f**iber **a**mplifier (EDFA) repeaters [3].

As a result of a variety reasons, the capacity of optical fiber system is principally limited by linear and nonlinear degrading effects, the linear degrading characteristics in optical fiber consist of Chromatic Dispersion (CD) and attenuation while the nonlinear degrading effects were including Four-Wave Mixing (FWM), Self-Phase Modulation (SPM), Stimulated Raman Scattering (SRS), Cross-Phase Modulation (XPM) and Stimulated Brillouin Scattering (SBS) [4-6].

https://doi.org/10.30684/etj.34.7A.14
2412-0758/University of Technology-Iraq, Baghdad, Iraq

Because of the difficulty to remain the parameter of the group velocity dispersion (GVD) constant along the fiber length to obtain a lossless soliton and to increase the efficiency of the soliton fiber link, the dispersion compensated fiber is utilized for this important issue where these types of solitons are named dispersion-managed Solitons [7-9].

This paper presents the implementation, design, dispersion managed soliton transmission system.and the performance analysis of a lossless. A circulating loop comprises of three regular fiber spans, one dispersion compensating fiber (DCF) span, Bessel optical filter and EDFA, which is utilized for exciting the system. The date rate of the transmission process for data of this system is 40 Gbps for 540 km approximately. For this result as shown above, it is demonstrated that the pulse spectrum is expanding as a result of the high level soliton effect and the third order dispersion near the zero dispersion wavelength. At the termination of loop, Bessel optical filter constitute the spectrum and the undesirable

Spectral peak on the left hand side of the spectrum is removed by this filter permanently.

For the performance analysis, Optical spectrum Analyzer, Optical Time Domain Visualizer and Eye diagram Analyzer are utilized in this paper. For this simulation process, Optisystem Version 12.2 software has been utilized to obtain the required results.

I. Simulation of the Design System

1) For single channel :

The single channel transmission system which uses soliton source pulse at bit rate 40 Gb/s is shown in Figure (1).

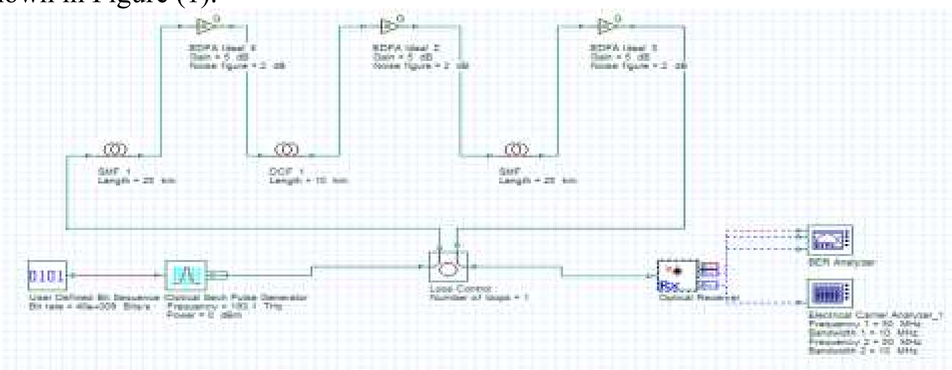


Figure (1): The simulated single channel transmission system with soliton source

i. Transmitter:

- **Pseudo Random Binary Sequence (PRBS)Generator**:

The module generates pseudo random binary sequences. These sequences are used to create an electrical bit stream (Random digital symbol streams) at the bit rate of 40 GB/s. Figure (2) shows the generating operation of these sequences by using shift register**.**

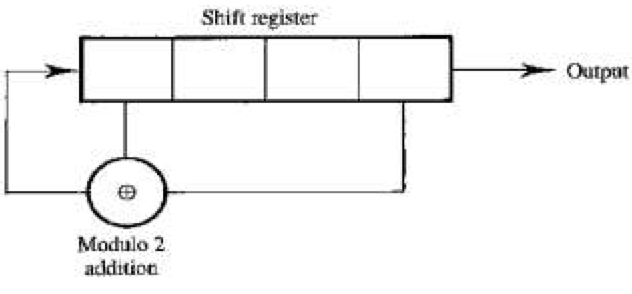


Figure (2): Sequence generation of pseudo-random

- **Soliton source:**

This generates a hyperbolic-secant pulsed optical at the input signal. This model generates optical pulses according to the bit sequence.

ii. Optical fiber channel:

The transmission is performed through a recirculating loop, which consists of five spans of (60Km SMF and 0.5Km DCF).

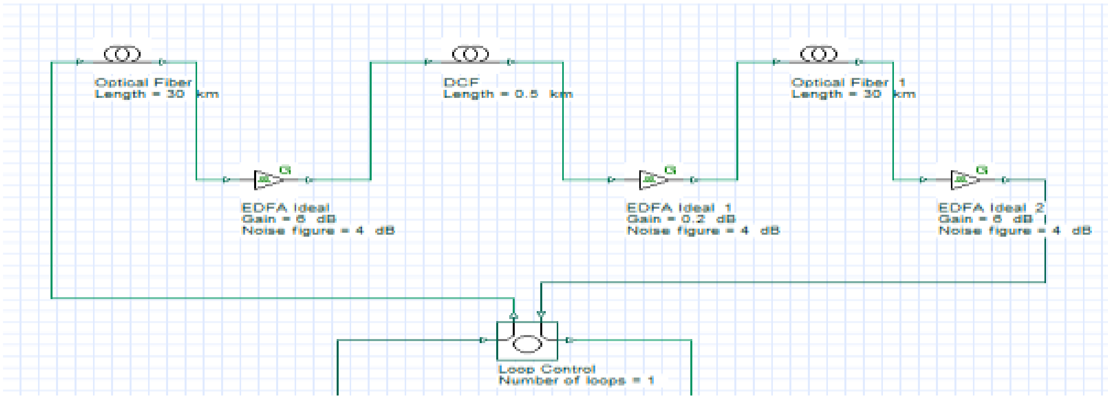


Figure (3): Symmetric dispersion compensation optical link channel

In the optical link channel show in fig (3) there are two of 30Km SMF (D=0.2 ps/km/nm) with attenuation of 0.2(dB/km) and two of 0.5Km Dispersion Compensation Fiber (DCF) are used to bring the accumulated dispersion to zero. Also Periodic optical amplifications are provided by inline Erbium-Doped Fiber Amplifier (EDFA) modules. The parameters of SMF, DCF are given in Table (1).

Table (1): Simulation parameters of the transmission link

Parameter	Value
SMF	
Attenuation (α)	0.2 dB/km
Dispersion parameter (D)	0.2 ps/nm-km
Dispersion slope (S)	0.075 ps/nm^2-km
Effective area	80 μm^2
DGD parameter	0.1 ps/$\sqrt{km}$
Nonlinear index of refraction (n_2)	$26 * 10^{-21}$ m^2/W
SBS Threshold	-28.84 dBm
SRS Threshold	20.89dBm
DCF	
Attenuation (α)	0.5 dB/km
Dispersion parameter (D)	-72 ps/nm-km
Dispersion slope (S)	-0.21 ps/nm^2-km
Effective area	30 μm^2
DGD parameter	0.1 ps/$\sqrt{km}$
Nonlinear index of refraction (n_2)	$26 * 10^{-21}$ m^2/W

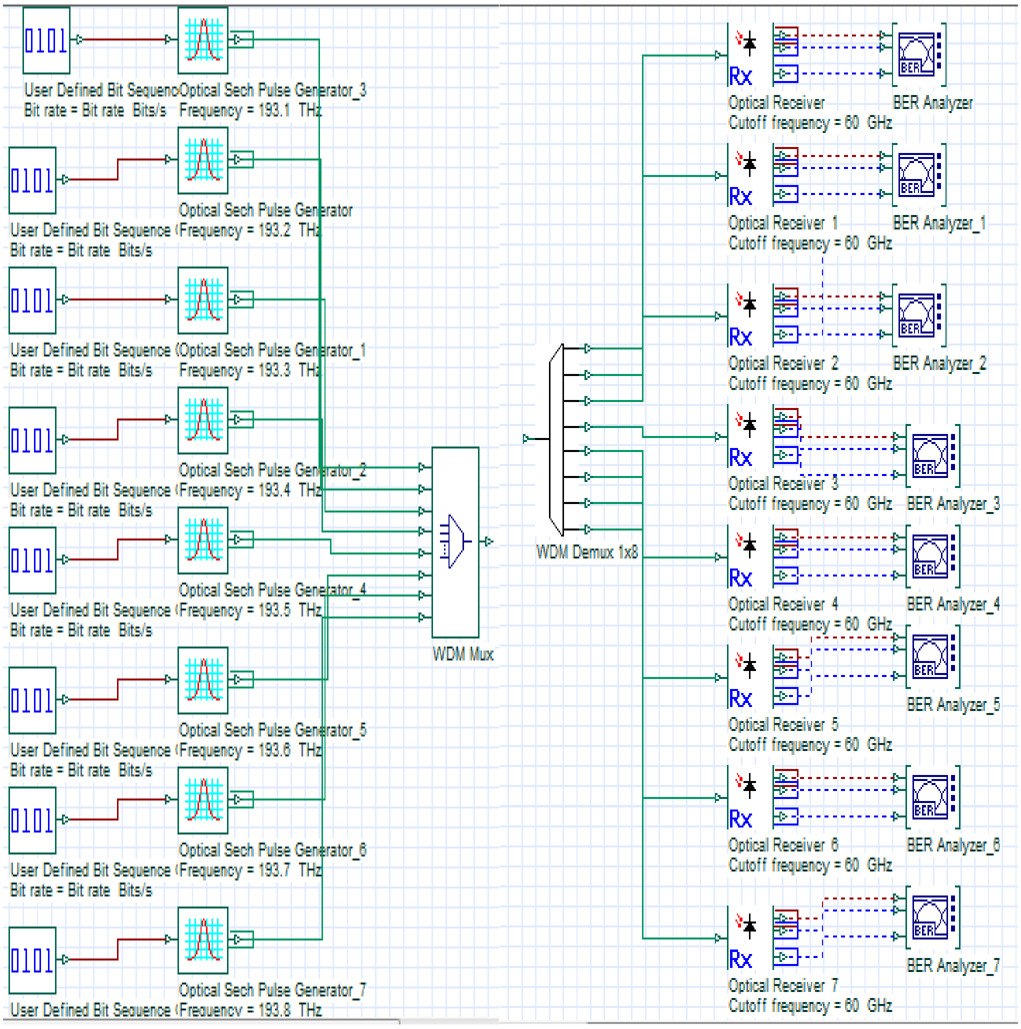
SBS Threshold	-28.9 dBm
SRS Threshold	-18.05dBm

iii. The receiver:

At the destination, the received signal is applied to detect and convert it into an electrical signal. The difference between the received currents from the two photodiodes is filtered by a 4th order Bessel filter of 30 GHz cutoff frequency.

2) For multichannel

The simulation of soliton source in the multi-channel WDM system employs 8 channels spaced 50 GHz apart with 40 Gb/s bit rates which are multiplexed onto the same optical fiber channel used in the single channel system shown in Figure (4).



(a)Structure of the transmitter (b) Structure of the receiver

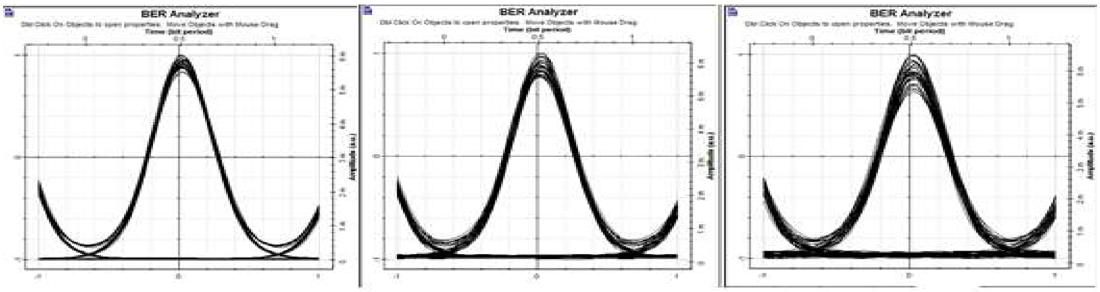
Figure (4): The receiver and transmitter sides of the simulated WDM system layout by using soliton source

The simulation parameters of multi soliton source, WDM Multiplexer, DWM Demultiplexer and the system losses are listed in Table (2).

Table (2): The simulation parameters of the CW array, Mux, Demux and the system losses.

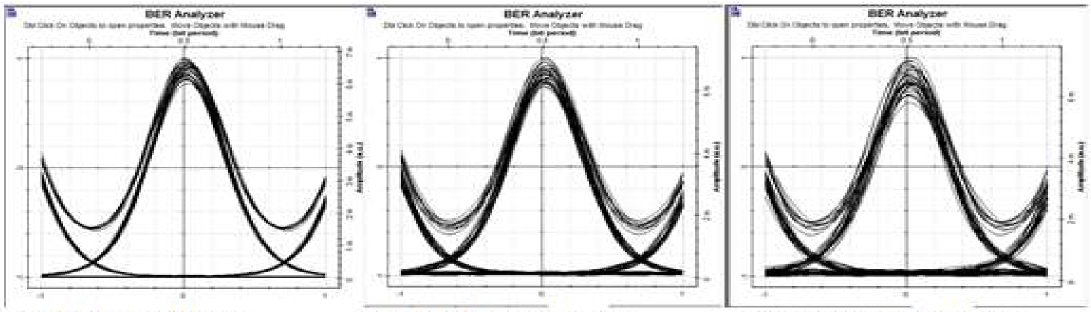
Parameter	Value
CW laser array	
Data rate	40G bit/sec
Center frequency	193.4 THz
Channel spacing	50 GHz
Power	-10 dBm to 10 dBm
Linewidth	10 MHz
Initial phase	0
Insertion loss(MUX & DMUX)	4 dB
Filter type	Bessel
Filter order	4
System losses	
Bandwidth of filter	30GHz
Fiber attenuation	0.2 dB/Km
Connecter loss	0.25 dB
Splicer loss	0.15 dB
Insertion loss	4 dB
Number of connectors	4
Number of splicers	15
Number of multiplexers	2
Source coupling loss	5 dB
Margin loss	6 dB
Total system loss	37.4dB
Sensitivity	more than -40 dB

Generally, the eye diagram for different width of pulse soliton that is related to the performance of the soliton source with various widths of pulse (w= 0.3, 0.4 and 0.5 bits) considered in the simulations in figure (1) at 40 GB/s is shown in Figure (5).



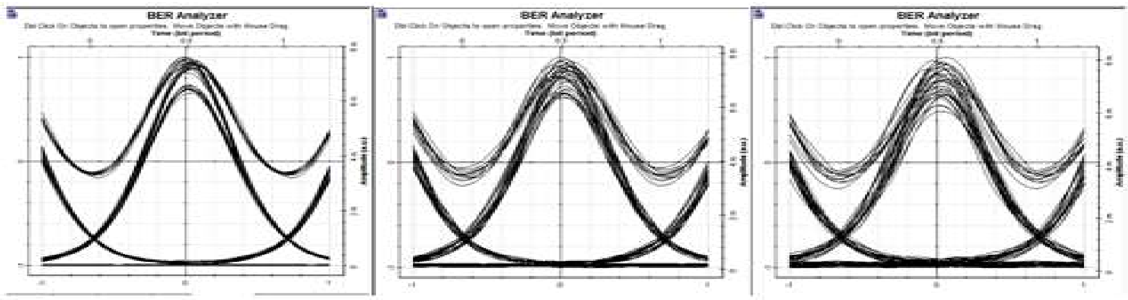
(a) At L=60Km (b) At L=300Km (c) At L=540Km

a. w =0.3 bit



(a) At L=60Km (b) At L=300Km (c) At L=540Km

b. w =0.4 bit

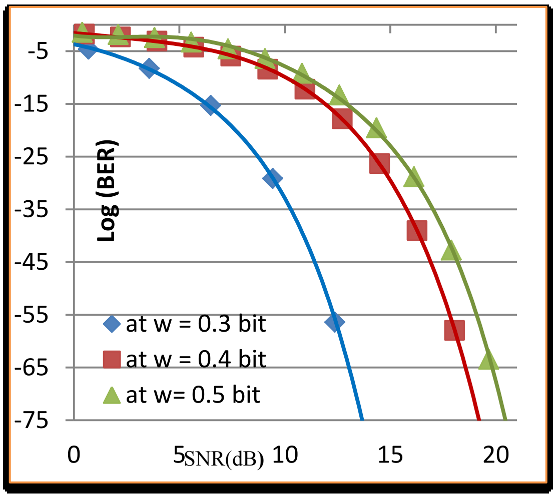


(a) At L=60Km (b) At L= 300Km (c) At L=540km

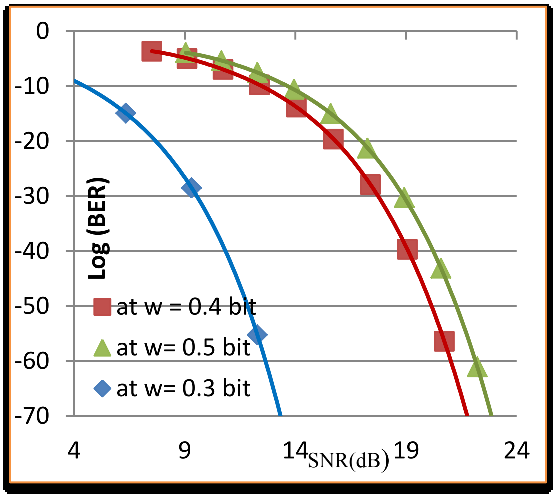
c. w = 0.5 bits

Figure (5) Eye diagrams for soliton system with different width at 40 GB/s.

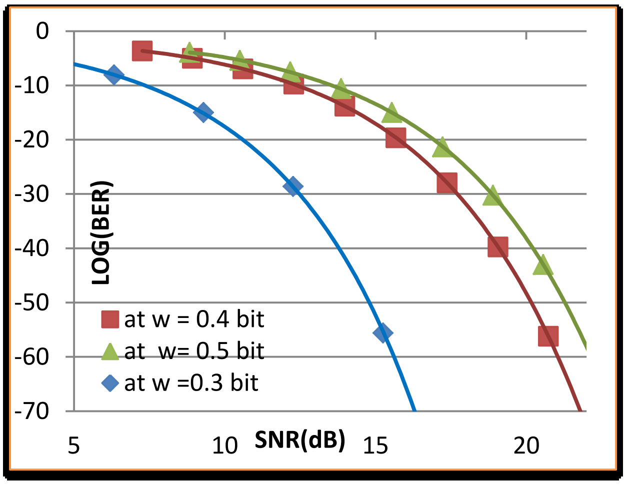
The relationship between SNR and BER for different width of soliton pulse with arranged differently is shown in Figure (6).



a. post channel



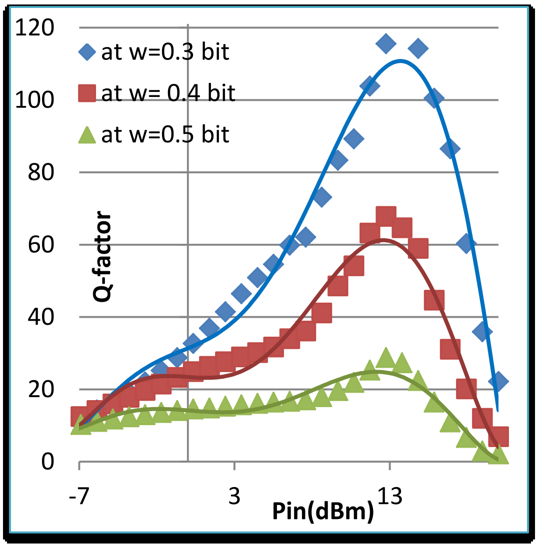
b. pre channel



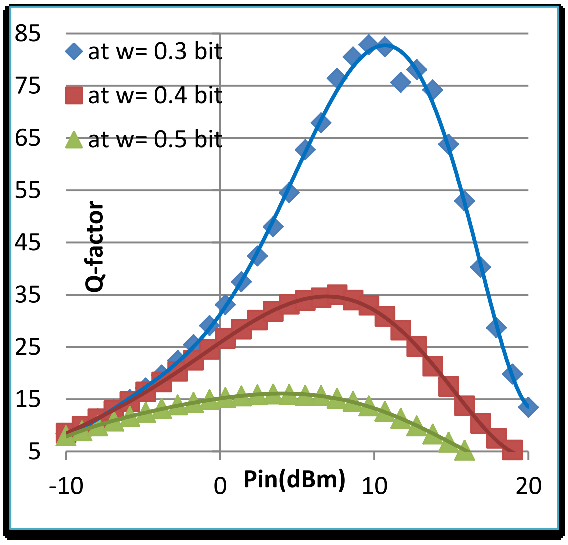
c. Symmetric channel

Figure (6) BER versus SNR for single channel with different width of pulse at 60Km.

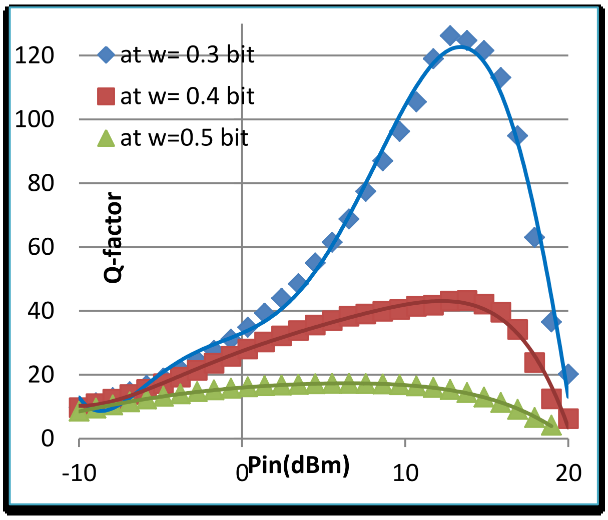
Figure (7) shows the relationship between powers injected versus Q-factor for different width of soliton pulse with Arranged differently channel.



a. post channel



b. pre channel



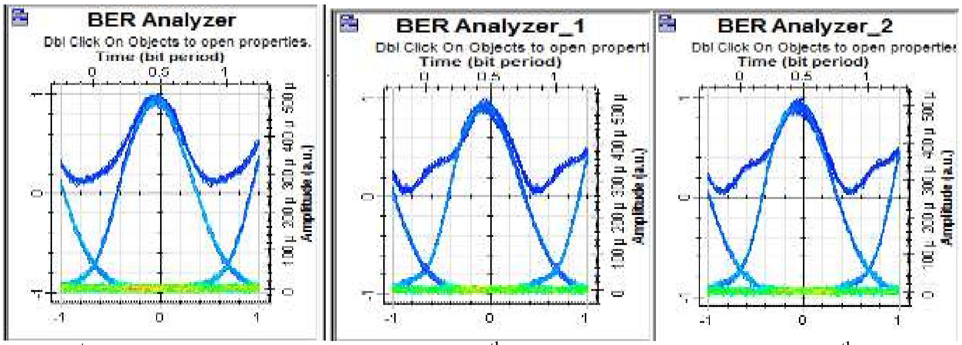
c. Symmetric channel

Figure (7) power launched versus Q-factor for single channel with different width of the pulse at 60Km.

It can be observed clearly from figures (5), (6)and (7) that the performance of the soliton system with a width of the pulse (0.3) bit is better than the system with width pulse (0.4 and 0.5) bit.

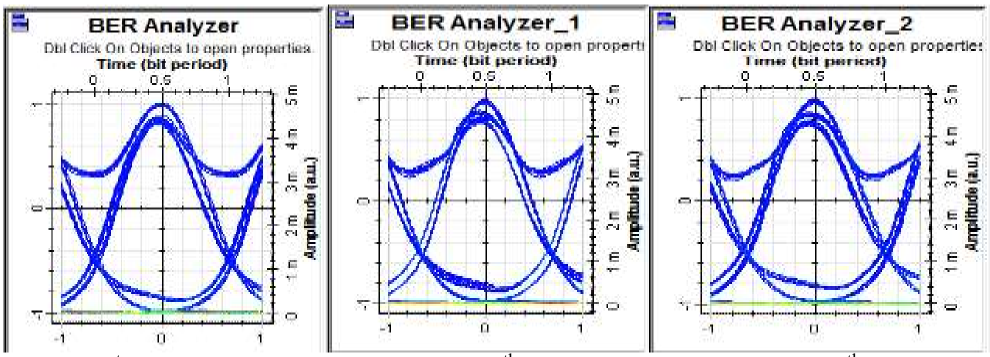
From figure (6) it can be noticed that width pulse 0.3 bits has Log(BER) (-20)dB at SNR (5) dB with symmetric channel while (-15)dB with post channel and (-16) dBwith pre channel and has Q-factor (42) with symmetric channel while (37) with post channel and (35) with pre channel when power launched equal to (0) dBm.

The eye diagrams of 1st channel, 4th channel and the 7th channel of 8 × 40 GB/s with a width of soliton pulse (0.3,0.4and 0.5)bits with 50 GHz as the channel spacing at the input power 0 dBm are shown in Figure (8), after 60Km long.



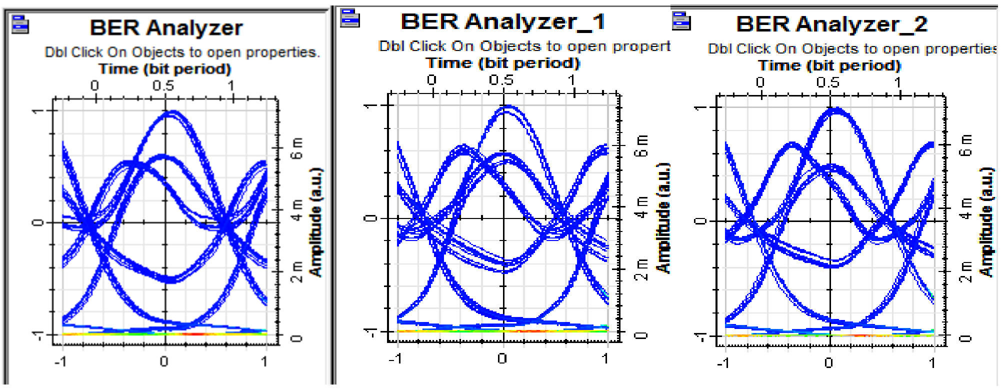
a) 1st channel (b) 4th channel (c) 7th channel

I. w=0.3 bit



(a) 1st channel (b) 4th channel (c) 7th channel

II. w=0.4bit

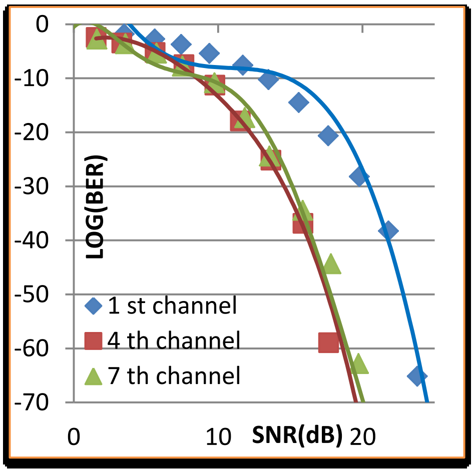


(a) 1st channel (b) 4th channel (c) 7th channel

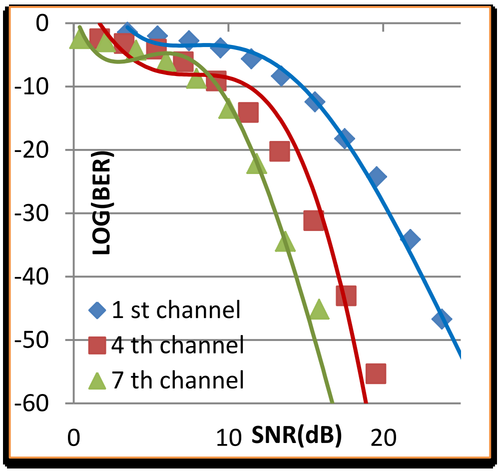
III. w=0.5 bit

Figure (8) Eye diagrams of the system with soliton source.

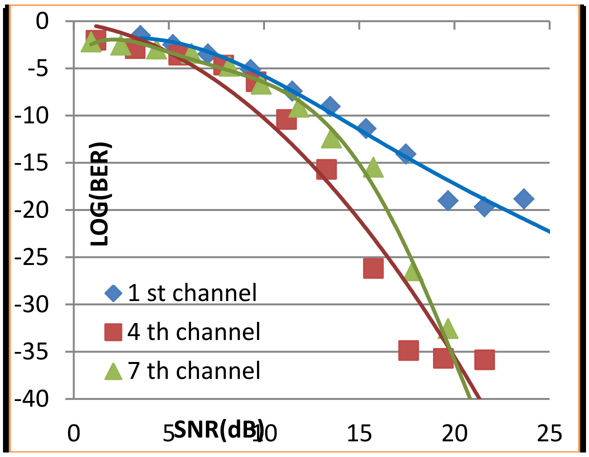
The comparison between the performance of three channels (1st, 4th and 7th) in term SNR vs. BER as shown in a Figure (9).



(a) Width of soliton pulse =0.3 bit



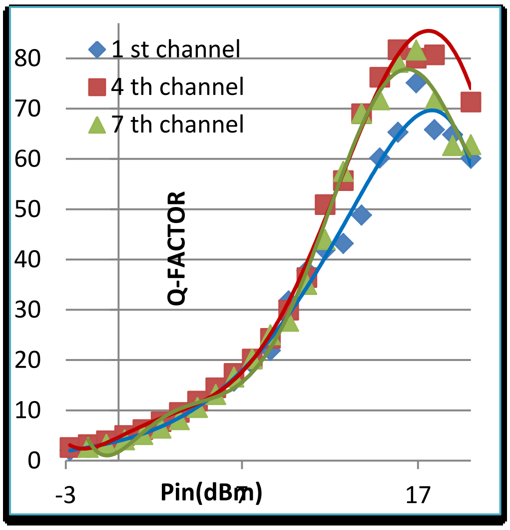
(b) Width of soliton pulse =0.4 bit



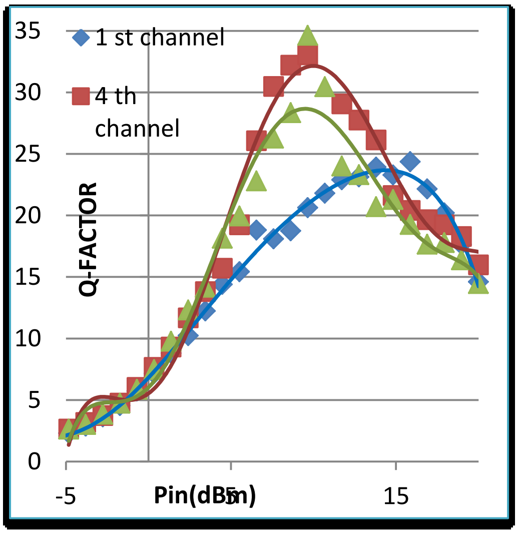
(c) Width of soliton pulse =0.5 bit

Figure (9) BER versus SNR for a symmetric channel with different width of soliton pulse

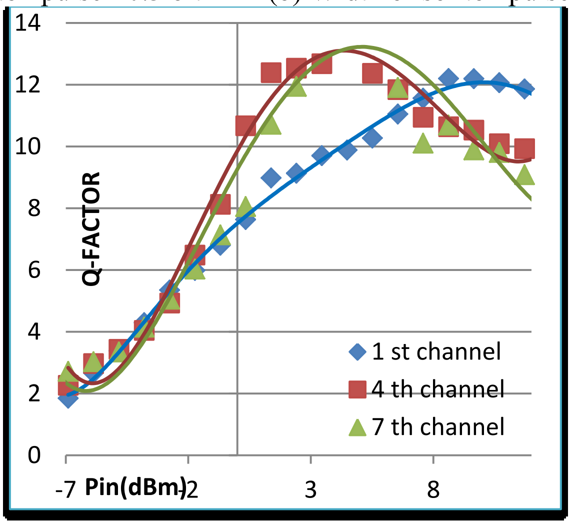
The comparison between the performance of three channels (1st, 4th and 7th) in term Q. Factor vs. power injected with different width of soliton pulse as shown in fig (10).



(a) Width of soliton pulse =0.3 bit



(b) Width of soliton pulse =0.4bit



c. Width of soliton pulse =0.5bit

Figure (10) Q.factor vs. power for symmetric channel with different width of soliton pulse.

In fig (9) shows that the seventh channel has BER (-10.21) dB While the fourth channel has (-8.51) dB and first channel (-7.34) dB when SNR is (5) dB.

Figure (10) shows that the seventh channel has Q.factor (83) while the Fourth channel has (77.54) dB and first channel (70.01) dB of power injected is (17) dBm and the width of soliton pulse is 0.3 bits. Also, it is observed that the seventh channel has Q.factor (35.06) while the fourth channel has (33.4) dB and first channel (21.9) dB power injected is (10) dBm when the Width of soliton pulse is 0.4 bits with also it is shown that the seventh channel has Q. Factor (13.9) while the fourth channel has (12.3) dB and first channel (10.3) dB of power injected is (5) dBm when the width of soliton pulse is 0.5 bits.

CONCLUSIONS

For single channel (60 Km) with soliton source system, 40Gb/s bit rate, it has been found that the performance of the system in case width pulse of soliton is 0.3 bit is the best among the width is 0.4 bit and 0.5 bit. For example the log of BER of width is 0.3 bit at SNR 10dB is -

18.94dB while in case 0.4 bit and 0.5 bit is -9.76 and -7.52 dB respectively. The value of Q-factor at 0dBm (input power) at 0.3 bit width pulse was 34.86while in case 0.4 and 0.5 bit width of pulse is 28.02and 16.16 respectively. The performance of the multichannel optical systems in case 0.3bit width pulse of soliton source is better than 0.4 bit and 0.5 bit for 60Km distance. For example, for 8 × 40 GB/s system, 50GHz channel spacing for channel No.7 it has been found that the log of BER was -15 for 0.3 bit while - 8.45, -5.19 for 0.4 bit and 0.5 bit respectively at SNR 10dB.

REFERENCES

[1] F. Kaertner ," Ultrafast Optical Physics II", 1st Edition ,2014.

[2] Shayan Mookherjea ," Coupled-resonator Optical Waveguides and Multiplexed Solitons", phd thesis , California Institute of Technology, June 2003.

[3] J. Adaikala Susai and S. Robinson ,"Analysing the transmission performance of the optical soliton system " , International Journal of Emerging Technology and Advanced Engineering, Volume 3, Issue 2, February 2013.

[4] M. Arora and G. Pandove ," Simulated Circuit for Generation of 40 GHz Soliton Train" , International Journal of Emerging Trends in Electrical and Electronics , Vol. 5, Issue. 2, July-2013.

[5]A.Fattah and S. Abdul-wahed ," Mitigation of Fiber Nonlinearity Effects in Ultra high-Dence WDM System", Eng.&Tch.Journal,Vol.34 part (A),No1,2016.

[6]A.Fattah and R.Abbas, '33% RZ-DPSK 10Gb/s WDM transmission", Eng.&Tch.Journal,Vol.29 ,No.11,2011.

[7] P. Dalotra ," Performance Analysis of Nonlinearities in Optical Fibers" , M.Sc. Thesis,Thapar university , July, 2013 .

[8] K. Hammani, "Soliton generation in a microstructured fiber by fourth order scalar modulation Instability", IEEE Photon. Journal, vol. 1, pp. 205-212, 2009.

[9] J. M. Dudley, "Modulation instability, Akhmediev Breathers and continuous wave super continuum generation", Opt. Express, vol. 17, pp. 21497-21508, 2009.

[10] B. Kibler,"The Peregrine soliton in nonlinear fiber optics ", Nature Physics, vol. 6, pp. 790-795, 2010.

[11] G. Keiser," Optical Fiber Communications", McGraw Hill, 3rdEdition, 2000