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Design of Ultra High Capacity DWDM System with Different Modulation Formats

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Abstract: ***Multi-channel optical communication systems are realized using wavelength division multiplexing to meet the challenge of increasing bandwidth demand. Dense Wavelength Division Multiplexing (DWDM) technique makes full use of the huge fiber bandwidth and hence it is the ideal means of network expansion and the convenient way to introduce new broadband services. The DWDM system designed in this paper have 64 channels each 20 Gbps data rate are multiplexed with various channel spacing to realize 1.28 Tbps as total transmission capacity. In this paper various combinations of EDFA and Raman amplifiers (Hybrid configuration) where used for a dense wavelength division multiplexed system with MDRZ modulation formats and investigates transmission capacity of the Hybrid configuration in terms of quality factor, bit error rate. Moreover, the role of laser line-width is also investigated to minimize the non linearity and four wave mixing effect.***

Keywords: DWDM, Hybrid configuration, EDFA, Raman amplifier, BER, Q factor, laser line-width

1. Introduction

The original optical fiber links that were installed in 1980 consisted of simple point to point connections. Since the spectral width of a typical laser source occupies only a narrow range of optical bandwidth, these simplex systems does not utilize the full bandwidth capacity of the optical fiber. The basic use of Wavelength Division Multiplexing is to upgrade the capacity of installed point to point transmission links [1].Dense Wavelength division multiplexer (DWDM) is the key feature of modern optical communication systems. This technology use to divide and combine different wavelength channels to increase the capacity of the existing optical network, each carrying an optical data signal. One of the key advantages of DWDM systems is its ability to cope with the current technologies such as SONET, ATM, SDH, Ethernet etc. The role of dispersion and nonlinearities produced in the optical fiber should be managed for the transmission systems in which data rate is higher than 10 Gbps. The optical amplification is a key technology for increasing the transmission capacity in an optical fiber network [2]. In recent years, dense wavelength division multiplexing (DWDM) transmission experiments utilizing different optical and hybrid optical amplifiers (HOAs) with a capacity of several terabits per second have been reported [5, 6].Three different modulation formats including NRZ, RZ, CS-RZ and its principles are also discussed. It is reported that the ability of anti-nonlinear and anti-PDM of RZ and CSRZ is stronger than NRZ under the complete dispersion compensation condition [3]. However, both RZ and NRZ formats are not suitable for DWDM systems due to presence of non linear effects and FWM. For conventional SMF, the advanced modulation formats such as Duo-binary modulation performs well as compared to the NRZ and RZ [5-7]. In this present paper, we have studied and simulated the performance of DWDM systems for different modulation formats; channel spacing; line widths of optical sources and different fiber lengths has been done.

2. Modulation Formats

Modulation formats are modulating the input signal amplitude and phase. Here three types of modulation formats are used.

2.1 Carrier Suppressed Return-To-Zero (CSRZ) format

The output signal is generated by passing the NRZ signal to the Mach Zender Modulator (MZM) and then applied to the phase modulator driven by a sine wave generator at the frequency equal to half the bit rate. A phase shift of π, between any two adjacent bits is introduced. As a result of this, the central peak at the carrier frequency is suppressed.

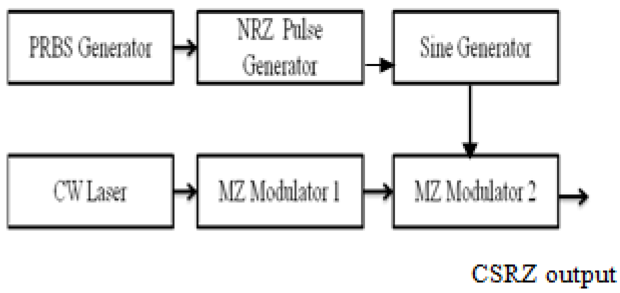

Figure 1: Carrier-Suppressed Return-To-Zero (CSRZ) format [8]

2.2Duo-Binary Return-To-Zero (DRZ) Format

The Duo binary was generated by first creating an NRZ duo binary signal using a precoder and a duo binary pulse generator. The generator drives the first MZM, and then concatenates this modulator with a second modulator that is driven by a sinusoidal electrical signal with the frequency of 20 GHz and phase −90◦. The duo binary precoder used here was composed of an exclusive-or gate with a delayed feedback Path. Fork 1*2 is used for Copies the input signal into two output signals. Duo binary generator is based on electrical delay and adder.

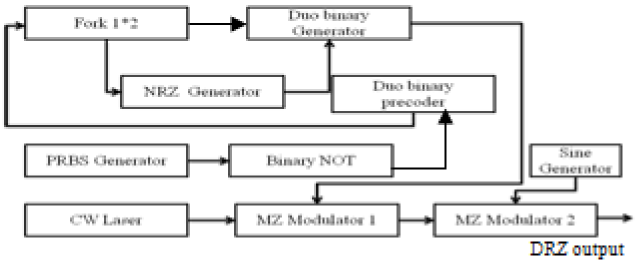

Figure 2: Duo-Binary Return-To-Zero (DRZ) format [8]

2.3 Modified Duo-Binary Return-To-Zero (MDRZ) Format

The MDRZ was generated by first creating an NRZ duo binary signal using a delay-and-subtract circuit that drives the first MZM [10], and then this modulator with a second modulator that is driven by a sinusoidal electrical signal with the frequency of 10 GHz and phase −90◦.

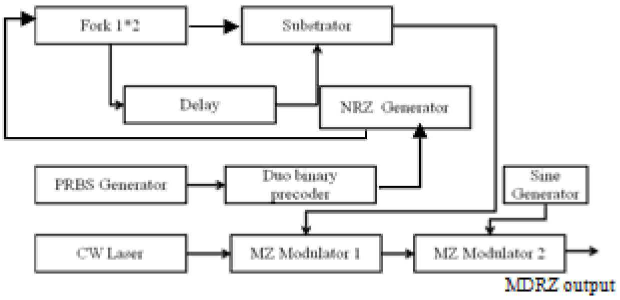

Figure 3: Modified Duo-Binary Return-To-Zero (MDRZ) format [8]

3. Design of Proposed DWDM System

The DWDM system analyzed here is a 64 Channel DWDM Optical Network. It has been divided into three sections, namely DWDM transmitter, DWDM Channel and DWDM receiver. DWDM transmitter section consist a transmitter of power 3dB with a CW Laser having a narrow line width; an ideal multiplexer (zero insertion loss) with 64 channel input ports and one output port and optical modulation formats like CSRZ, DRZ and MDRZ. In DWDM Channel, we used the medium having EDFA and Raman amplifier combined with single mode fiber (SMF) and dispersion compensating fiber (DCF) [8]. At the DWDM receiver section, optical pulses are detected and converted them into electrical bits. At the receiver end there is a demultiplexer, P Type Intrinsic N type (PIN) or Avalanche photodiode (APD), low pass filter which is connected to a BER analyzer. The demultiplexer has 64 outputs and single input.PIN photodiode has gain as 3 dB. Low pass filter has cut off frequency as 0.75*bit rate, which passes the low frequency signal and discard high frequency signal. The DWDM system shown in figure 4.

Figure 4: DWDM System

Hybrid optical amplifier configurations of EDFA-RAMAN, SMF + (EDFA-RAMAN), SMF + (EDFA-RAMAN)+DCF are used instead of fiber link shown in figure 5, 6, 7[12-14]. DCF is the dispersion compensating fiber and SMF is single mode fiber. The erbium doped fiber amplifier (EDFA) is used for compensating the linear loss and its noise figure is kept constant (6 dB) [15]. The signal is launched over N spans of fiber of 40.012 km (40 km-Raman + 12 m-EDFA) each.

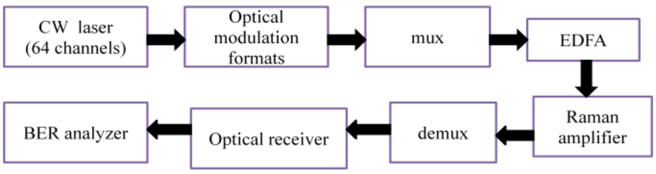

Figure 5: Hybrid configuration I

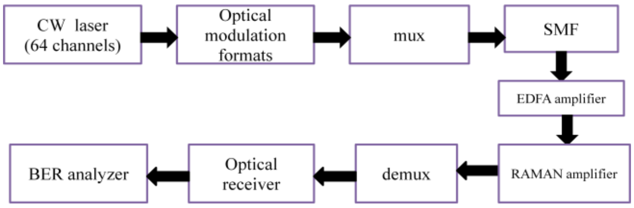

Figure 6: Hybrid configuration II

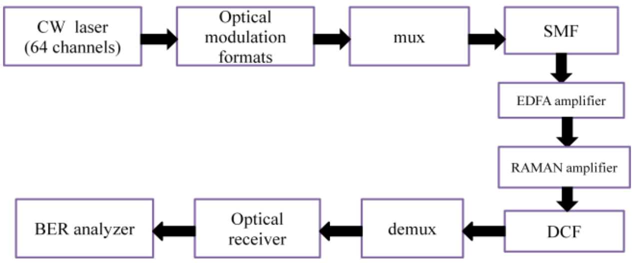

Figure 7: Hybrid configuration III

Table 1: Simulation parameters

Parameters	*Values*
No of channels	64
Bit rate	20Gbps
Laser power	3dBm
Channel spacing	50GHz
Raman amplifier frequency	980nm
EDFA frequency	1486nm
Raman Amplifier pump power (mw)	100-600
EDFA pump power(mw)	200-500
Raman length(Km)	30-40
EDFA length(m)	10-13

4. Result and Discussion

Simulation software Optisystem 7.0 is used in order to evaluate and compare the performance of the proposed DWDM system with the different Hybrid optical amplifier configuration. The parameters for the DWDM system and range of values for HOA are as given in Table 1.

4.1 Effect of modulation format on Q factor

The proposed setup is simulated for three different modulation formats for a distance of 50 km for varying input power. Figure.8 shows that the variation of Q factor with respect to input power for various modulation formats for centre channel (channel no. 32).Centre channel is considered for better comparison among the different modulation formats. It is observed that when the input power is too low or too high, the performance of the system deteriorates because, too low input power cannot be sufficient for driving the components; on the other hand too high input power causes more nonlinearity in the fiber. In order to address this trade-off, an input power level of 3 dBm is considered in our work. Then conclude that the use of MDRZ modulation format shows maximum Q factor, comparing to CSRZ and DRZ modulation format. Hence it is said as an optimized modulation format. In figure 8 the blue, green and red lines shows that MDRZ, DRZ and CSRZ.

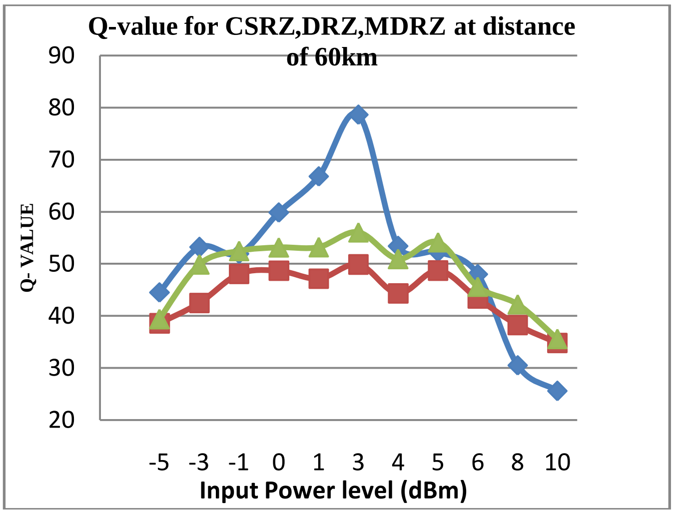

Figure 8: Variation of Q factor with respect to input power for various modulation formats for centre channel (Channel no. 32).

4.2 Effect of Raman amplifier and EDFA on Q factor

The Raman amplifier is used instead of fiber link [16]. Calculated the Q factor for various Raman pump powers and Raman length in Km at Raman frequency1489nm shown in figure 9.Its states that Q factor and Raman length is increased when Raman pump powers increased. At 600mw Raman pump power covering large distance (120Km) compared to other Raman pump power (100mw, 200mw, 300mw, 400mw, 500mw).

The EDFA is used instead of fiber link [16]. Calculated the Q factor for various EDFA pump powers and EDFA length in m at EDFA frequency980nm shown in figure 10.Its states that Q factor and EDFA length is increased when EDFA pump powers increased. At 486 mw EDFA pump power covering large distance (55Km) compared to other EDFA pump power (300mw, 400mw, 350mw).

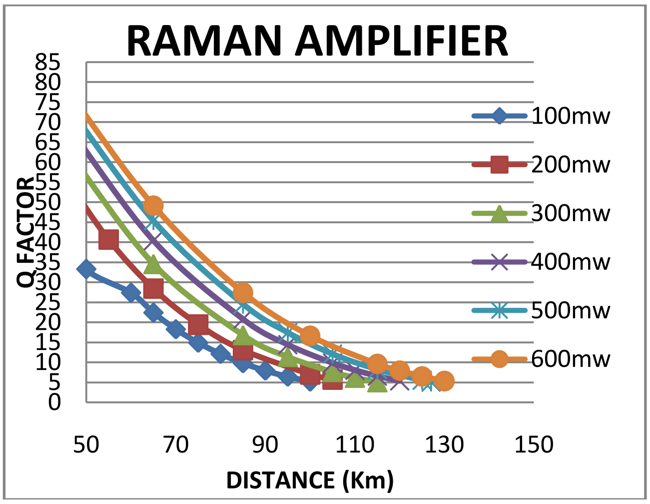

Figure 9: Distance vs Q factor of Raman amplifier for various Raman pump powers(mw)

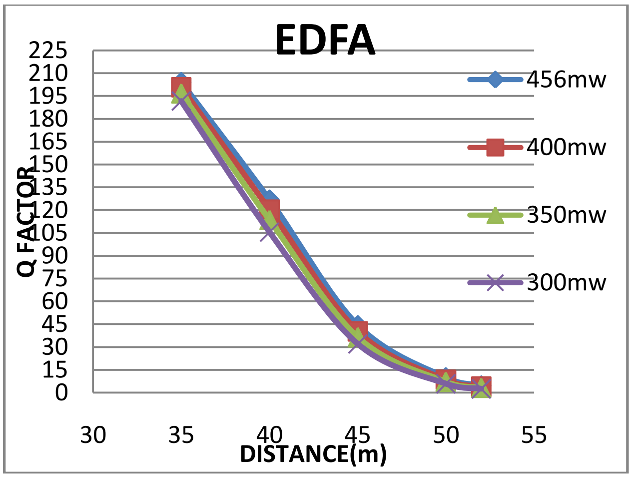

Figure 10: Distance vs Q factor of EDFA for various EDFA pump powers(mw)

4.3 Effect of line width on Q factor

Spectral line width of optical source also plays a major role in dense wavelength multiplexing systems. To study the effect of line width on the performance of the DWDM optical system, we have considered 50GHz channel spacing in 1550 nm window [17]. When the line width of the laser source is 10MHz, 20MHz, 25MHz and 50MHz .As per the observations from BER analyzer, Q factor comes out to be 32.2548, 32.4041, 32.4559 and 33.5859 which states that Q factor goes high when line width is increased shown in table 2. Line width which also plays significant role in minimizing the non linearity's of optical fiber.

Table 2: line-width vs Q factor

Line width(MHz)	*Q factor*
10	32.2548
12	32.2909
15	32.3386
20	32.4041
25	32.4559
50	33.5859

4.4 Efforts of Hybrid configuration on Q Factor and BER

The Hybrid configuration I covers 120.036Km with Q factor of 32.2548 and 32.2729 for PIN and APD. The Q factor for APD is better than the BER for PIN which is shown in table 3.

Table 3:Q factor for Hybrid configuration I

Length(Km)	*Q factor(PIN)*	*Q factor (APD)*
40.012	227.683	227.748
80.024	222.063	222.24
120.036	32.2548	32.2729

The Hybrid configuration I covers 120.036Km with BER of 1.50492e-228 and 8.39614e-229 for PIN and APD. The BER for APD is better than the BER for PIN which is shown in table 4.

Table 4: BER for Hybrid configuration I

Distance (Km)	*BER (PIN)*	*BER(APD)*
40.012	0	0
80.024	0	0
120.036	1.50492e-228	8.39614e-229

The Hybrid configuration II covers 65.012Km with Q factor of 2.33563 and BER of 0.00955 shown in table 5.

Table 5:Q factor and BER for Hybrid configuration II

Length(Km)	*Q FACTOR*	*BER*
55.012	2.32715	0.00975
65.012	2.33563	0.00955

The Hybrid configuration III covers 65.012Km with Q factor of 2.6557 and BER of 0.003882 shown in table 6.

Table 6:Q factor and BER for Hybrid configuration III

Length (Km)	*Q Factor*	*BER*
65.012	2.6557	0.003882

4.5 Effect of attenuation on Q factor and Bit Error Rate (BER)

With attenuation of 0.9dB/Km the DWDM system is covered distance of 480.144Km compared to attenuation of 0.5dB/Km.Q factor and BER of attenuation 0.5dB/Km and 0.9dB/Km with different distance had shown in table 7 and 8.

Table 7:Q factor and BER of attenuation 0.5dB/Km

Distance(Km)	*Q factor*	*BER*
130.048	194.368	0
160.048	193.438	0
200.060	97.0358	0
240.072	25.3776	2.22811e^-142
280.084	5.37964	3.73083e^-008

Table 8: Q factor and BER of attenuation 0.9dB/Km

Distance (Km)	*Q factor*	*BER*
200.060	56.1871	0
240.072	50.1879	0
280.084	44.4455	0
320.096	38.4701	4.940e^-324
360.108	31.8866	2.0191e^-223
480.144	11.2515	1.1289e^-29

4.6 Effect of Channel Spacing on Q factor and Bit Error Rate (BER)

The performance of 64 channel DWDM systems with the channel spacing as 50GHz, 55 GHz at1550 nm window. It was observed that on increasing the frequency spacing; Q factor increases and the bit error rate decreases. Frequency spacing of 55 GHz gives better Q factor and BER; i.e. 7.37423 and 8.23996e^-14 respectively. DWDM system is covered 520.156Km with channel spacing 55 GHz.

Table 9:Q factor and BER of channel spacing

Channel spacing (GHz)	DISTANCE (Km)	Q factor	BER
50	520.156	6.65019	1.45943e^-11
55	520.156	7.37423	8.23996e^-14

5. Conclusion

In this paper various combinations of optical amplifiers (Hybrid configuration) for a dense wavelength division multiplexed system with different modulation formats was designed. MDRZ modulation format shows maximum Q factor, comparing to CSRZ and DRZ modulation format, and so it is said to be an optimized modulation format. EDFA-RAMAN, SMF+EDFA-RAMAN, SMF+EDFA-RAMAN +DCF are used instead of fiber link. EDFA-RAMAN is found to have the best performance among the three types in the terms of quality factor, BER.EDFA-RAMAN configuration with 55 GHz channel spacing, MDRZ modulation format, 0.9dB/Km attenuation, 16 MHz line width and 456mw, 600mw EDFA and Raman pump power gives optimum results in terms of Q factor and BER for a distance of 520.156km. The maximum distance of 520.156 km is achieved by the EDFA-Raman at acceptable BER (8.23996-14), quality factor (7.37423dB) using avalanche photodiode (APD).The role of laser line-width is also investigated as it plays important role to minimize the nonlinearity and four wave mixing .The performance of proposed 64 X 20 high speed system with hybrid configuration I is evaluated in terms of Q factor, BER which clearly states that all the channels are transmitted up to long optical span of 520.156 Km with acceptable Q factor and BER.

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