

Performance of A Multicast DWDM Network Applied to the Yemen Universities Network using Quality Check Algorithm

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Abstract

The current paper, analyzes the performance of applying the multiplexed video signal transmission through the Dense Wavelength Division Multiplexing (DWDM) network based on a quality check algorithm, which determines where the interruption of the transmission quality starts. On the basis of this algorithm, simulations of transmission for specific values of fiber parameters are executed. The analysis of the results shows how the BER and Q-factor change depending on the length of the fiber (single mode fiber, dispersion compensation fiber, and amplifiers) and what kind of an effect the multiplexed channels and the flow rate per channel on transmitted signals. Analysis of DWDM systems is performed in the software package OptiSystem 11, which is designed for systems with flow rates of 2.5 Gb/s and 10 Gb/s per channel.

Keywords: *DWDM Network, BER, Q factor, Quality Check Algorithm, and Multicast.*

1. Introduction

Dense Wavelength Division Multiplexing (DWDM) is a technology that allows multiplexing of multiple optical carrier signals on a single optical fiber by using different wavelengths for transmission of various information. The smallest attenuation of the signal in the optical fiber is achieved by applying the wavelength of 1555 nm or by using the "third optical window" [1,5]. DWDM systems allow the expansion of the existing capacity without laying additional fibers in optic cables. The capacity of the existing system is expanded using multiplexers and demultiplexers at the ends of the system. For the successful transmission of optical signals over long distances, doped fiber amplifiers with erbium (EDFA – Erbium Doped Fiber Amplifier) are used. Erbium is a rare element and, when excited, it emits the light at a wavelength of 1,54 μm , which is the wavelength at which the attenuation of signal power is minimal. Weak signals enter the erbium doped fiber, in which light is injected by lasers pumps [2]. This light excites erbium atoms, and the atoms are releasing the accumulated energy in a form of additional light with wavelength around 1555 nm. As this process continues through the fiber, the signal is amplified. EDFA is available in the C and L windows but with quite narrow range (1530-1560 nm). EDFA can amplify optical signals as much as they can be multiplexed in a given range until a strong enough signal is received [3,4].

2. BER and Q Factor

The performance of an optical communication system is specified by the Bit Error Ratio (BER). BER is the probability that the impulse is interpreted incorrectly (i.e. a logical '1' is detected as '0' and vice versa). Thus, a BER of 10^{-6} corresponds to an average of one error per million bits[5]. The BER value depends on the characteristics of the laser source and the transmission route. With the increase of the flow in optical systems, in both systems with standard single mode optical fiber and systems with special purpose fiber, effects of spontaneous emission, polarization mode dispersion, chromatic dispersion, optical fiber nonlinearities and noise in the receiver are increasing [11]. The criteria used in optical receivers is that BER is less than 10^{-9} [6].

For a fluctuating signal received at a decision circuit, sampling is performed at time $D t$. The sampled value of the signal I varies from one bit to another around the mean value $1 I$ or $0 I$, depending on whether the bit is corresponding to 1 or 0 in the bit stream. The decision circuit compares sampled values with the threshold value $D I$ and calls the bit 1 if $I > ID$ or 0 if $D I < I$. An error occurs if $D I < I$ for bit 1 or if $D I > I$ for bit 0. Both errors can be included in the definition of error probability as

$$BER = p(1)P(0 /1) + p(0)P(1/ 0) \tag{1}$$

where $p(1)$ and $p(0)$ are the probability of receiving bits 1 and 0, respectively. $P(0 /1)$ is the probability that 0 was decided when 1 was received and $P(1/ 0)$ is the probability that 1 was decided when 0 was received. If the probability of occurrence of bits 1 and 0 are equal, then $p(1) = p(0) = 1/ 2$ and BER is given by:

$$BER = \frac{1}{2} [P(0 /1) + P(1/ 0)] \tag{2}$$

The parameter Q can be written as:

$$Q = \frac{I_0 + I_1}{\sigma_0 + \sigma_1} \tag{3}$$

Where σ_1^2 , σ_0^2 are noise variance corresponding to the symbols 1 and 0, respectively [9,10].

3. System Model and Algorithm

Analysis of the DWDM transmission system was performed using the software package OptiSystem 11. The algorithm used for the quality check of the DWDM transmission is presented in Figure 1. This quality check algorithm [2] applies to a fixed flow rate R. The parameter that vary is the length of the span S (km), each span consists of single mode fiber (smf) followed by an EDFA amplifier to compensate the attenuation that can be resulted from smf consists of single mode fiber (smf) followed by an EDFA amplifier to compensate the attenuation that can be resulted from smf followed by dispersion compensation fiber (dcf) that will be used to compensate the dispersion, this dcf also followed by its EDFA amplifier to

resolve the attenuation of dcf. The parameter that is being evaluated is the Q factor, which shows whether the transmission quality is good. The boundary value for this factor is $Q = 6$. The algorithm consists of a cycle for which the number of execution varies, The cycle refers to the number of spans and the number of its executions depends on the values of the Q factor [7,8].

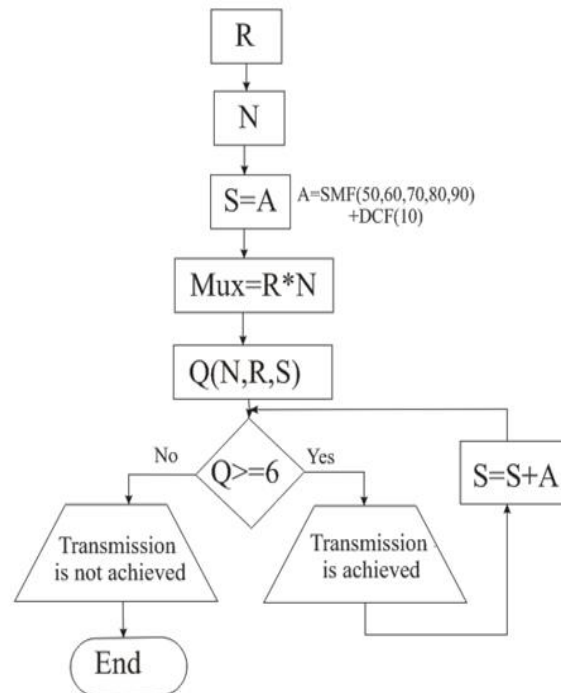


Fig 1: quality check algorithm

4. Steps of the Algorithm

- 1) Set the data rate R may be 2.5 Gbps or 10 Gbps.
- 2) Set the number of channels N. Here we used 4 channels.
- 3) Set the length of the span S that is sum of smf with dcf lengths. The lengths of the smf fiber that are used 50, 60, 70, 80 and 90 km and length of the Dcf fiber is 10 km. For example, if we use 50 smf length then S will be 60 km.
- 4) Make multiplexing Mux for each channel based on the selected data rate.
- 5) Calculate the quality Q based on the given values of the N,R,S.
- 6) If Q greater or equal to a constant value 6 then the transmission will be achieved, but if Q is less than 6 then transmission is not achieved.
- 7) If the transmission is achieved then increase the length of the fiber by making multiple spans and then again calculate Q after each span.
- 8) if the transmission is not achieved then the program go to end.

5. Design Multicast point-to-point DWDM network for Yemen Universities

In this section we designed multicast point-to-point DWDM network for three universities and the Main center, as example. This design can be expanded to all other universities, this network applied the check quality algorithm that is discussed above. The multicast technology is used in this network to send the data to specific receivers.

6. Network Topology

Our network uses point-to-point scheme with multicast behavior. The network consists of four points represents the Main center, Sana'a university, Taiz university and Aden university. All four points are connected by two multicast nodes (see the logical design in figure 2 and physical design in figure 3). Each point can send its data to all other points using this unidirectional path. The main advantage of this topology is if any problems occurred in any multicast path of one point, the network can be work with other paths connected to that point.

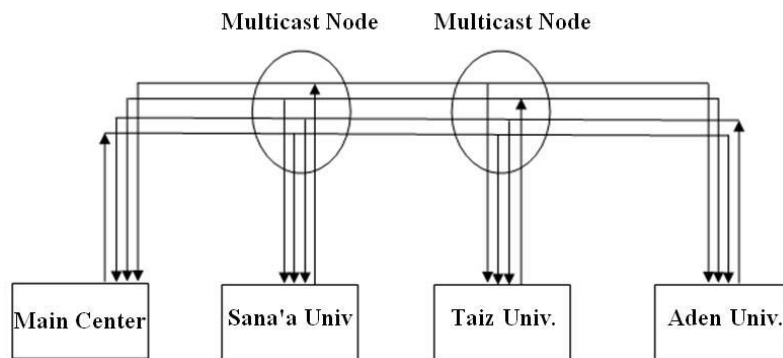


Fig 2: Logical design of the multicast DWDM point-to-point network

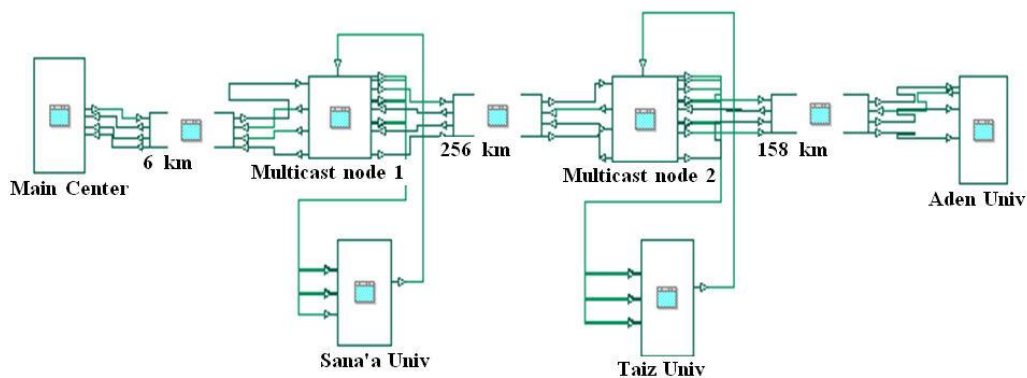


Fig 3: Physical design of the multicast point-to-point network

To simulate this network we will use the optisystem 11 platform. Each point has sender and receiver systems, the Main center has its sender that is transmitter (figure 4). The properties of the transmitter is set 4 channels, and set the frequency to 1555 nm, set the frequency spacing to 100 GHz (0.8 nm), set the power to 5 dBm and, linewidth to 0.1 MHz and, bit rate to 2.5 Gbps or 10 Gbps and modulation type to Non-Return Zero (NRZ).

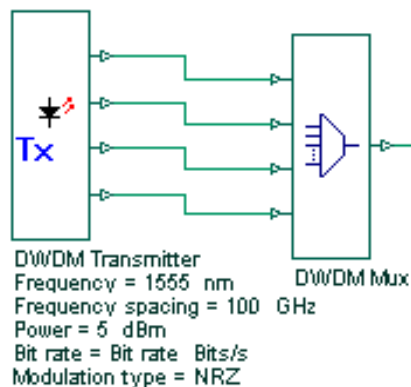


Fig 4: The transmitter and multiplexer

The signals then multiplexed by using DWDM multiplexer (figure 4) and put them on the optical fiber to propagate to the receivers. The typical type of the optical fiber is single mode fiber (figure 5) that its properties are: set its length to 50 - 90 km, and typical attenuation of smf to 0.2 dB/km, also set its dispersion to 16.75 and dispersion slope to 0.075.

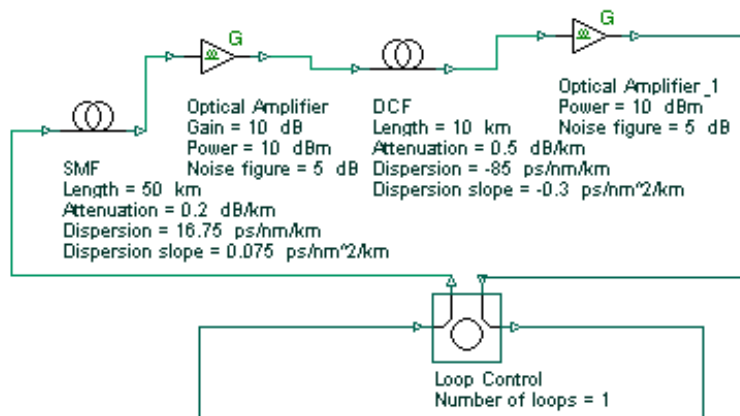


Fig 5: SMF and DCF fibers with amplifiers and loop control to increase the spans.

To compensate the attenuation in smf, we used optical amplifier (figure 5) and its properties are: set gain parameter to 10 dB and power to 10 dBm and noise figure to 5 dB.

But to compensate the dispersion that will be resulted from smf fiber, we will use the dispersion compensate fiber (dcf) (figure 5) and its properties are: set its length to 10 km (approximately 1/5 of the smf length), also set its attenuation to 0.5 dB/km and set dispersion to negative value -85 ps/nm/km and dispersion slope to -0.3 to cancel the dispersion of the smf fiber.

After that, the dcf will require optical amplifier (figure 5) to compensate its attenuation, so the span optical consists of four parts (smf+its amplifier+dcf+its amplifier)

If the signals arrived at the next point, they are de-multiplexed by DWDM de-multiplexer (figure 6) that its properties are: set the ports to 4 channels, set the frequency to 1555 nm, set the frequency spacing to 100 GHz and set the bandwidth to 80 GHz.

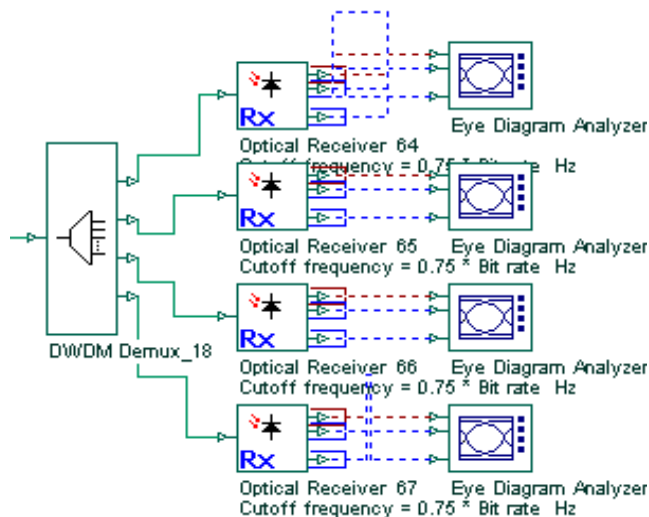


Fig 6: The de-multiplexer and receivers.

Then, each channel go to the specific optical receiver (figure 6) that its properties are: set the photodetector to PIN and cutoff frequency to $0.75 * \text{bit rate}$ to cut the signals that have greater than 0.75 frequency.

Also, the multicast node is simulated by the optisystem each multicast DWDM node (see figures 7,8) contains multiplexers, demultiplexers, splitters and ON/Off gates, the splitters are used to send the same data to access networks and propagates to next point (next university), but to specify the receivers that we want to send this data, we should make ON/Off gates in each sub-path in the network. Here, the simulated node is created without on/off gates to see the all outputs in the receivers.

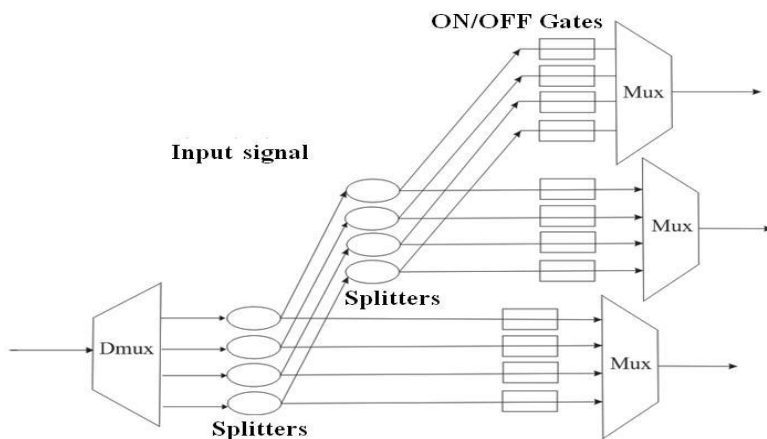


Fig 7: Logical Design of the Multicast node

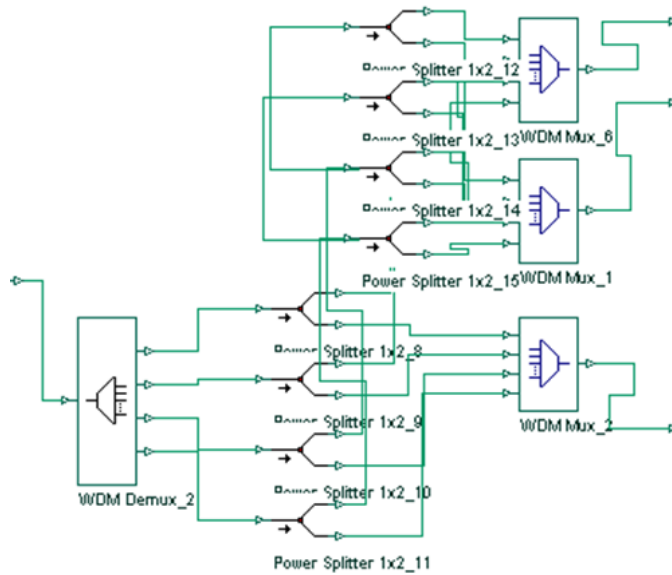


Fig 8: Physical design of the multicast node

Now, the algorithm is tested, by applying it on the optical span S and its multiples between any two points of the network, we will suppose that the first point is the sender and the second point is the receivers, after the signals propagated by the fiber and received by the next point. The Q factor is calculated for the given values of S , R and N . If the condition $Q \geq 6$ is met, quality transmission is achieved and then the number of spans is increased by 1 (A extra km). After that, the algorithm will start from the part related to the calculation of Q , that is the cycle will be repeated until the condition $Q < 6$ is met.

When the condition is not met, the cycle is not repeated, and the current spans are the values for which high-quality transmission is not possible. So the cycle is ended.

At the receiver, a Eye diagram analyzer is set to determine the values for BER and Q based on which one can determine the performance of the transmission system. Results showed that the change of BER and Q depends on the length of the fiber, i.e. on the number of the spans.

Tables 1,2,3,4 and 5 provide the Q and BER parameters at 2.5 Gb/s and 10 Gb/s. Based on the obtained values of BER, the graphs shown in Figures [9 -13] were drawn, showing that the value of the Q factor decreases with the change in the length of the span section. The Purple dashed straight line represents the limit at which signal transmission quality distorts.

Tables 1,2,3,4 and 5 provide the Q and BER parameters at 2.5 Gb/s and 10 Gb/s.

Table 1 At Smf=50km,dcf=10km And data rate=2.5 Gbps				Table 2 At Smf=60km,dcf=10km And data rate=2.5 Gbps				Table 3 At Smf=70km,dcf=10km And data rate=2.5 Gbps			
span	Q	ber	Length(km)	span	Q	ber	Length(km)	span	Q	ber	Length(km)
1	19.5	10 ^{-085*}	60	1	25.4	10 ⁻¹⁴²	70	1	23.8	10 ⁻¹²⁶	80
5	16.4	10 ⁻⁰⁶¹	300	5	20	10 ⁻⁰⁹⁰	350	5	24.8	10 ⁻¹³⁷	400
10	11.7	10 ⁻⁰³²	600	10	22	10 ⁻¹¹⁰	700	10	15.8	10 ⁻⁰⁵⁷	800
15	9.2	10 ⁻⁰²⁰	900	15	16	10 ⁻⁰⁵⁷	1050	15	15.8	10 ⁻⁰⁵⁷	1200
20	8.3	10 ⁻⁰¹⁷	1200	20	16.5	10 ⁻⁰⁶¹	1400	20	10.6	10 ⁻⁰²⁶	1600
25	7.5	10 ⁻⁰¹⁴	1500	25	14.3	10 ⁻⁰⁴⁶	1750	25	10	10 ⁻⁰²³	2000
30	7.1	10 ⁻⁰¹³	1800	30	14.2	10 ⁻⁰⁴⁶	2100	30	8	10 ⁻⁰¹⁵	2400
At Smf=50km,dcf=10km And data rate=10 Gbps				At Smf=60km,dcf=10km And data rate=10 Gbps				At Smf=70km,dcf=10km And data rate=10 Gbps			
span	Q	ber	Length(km)	span	Q	ber	Length(km)	span	Q	ber	Length(km)
1	19.4	10 ⁻⁰⁸⁴	60	1	22.5	10 ⁻¹¹²	70	1	14.3	10 ⁻⁰⁴⁶	80
5	16.2	10 ⁻⁰⁶⁰	300	5	10.6	10 ⁻⁰²⁶	350	5	3.1	0.00060	400
10	12.5	10 ⁻⁰³⁶	600	10	3.1	0.00083	700	10	2.8	0.0019	800
15	8	10 ⁻⁰²³	900	15	2.8	0.0023	1050	15	0	1	1200
20	7.1	10 ⁻⁰¹³	1200	20	2.2	0.0079	1400	20	0	1	1600
25	5.8	10 ⁻⁰⁰⁹	1500	25	3.1	0.00064	1750	25	0	1	2000
30	4.5	10 ⁻⁰⁰⁶	1800	30	0	1	2100	30	0	1	2400

Table 4 At Smf=80km,dcf=10km And data rate=2.5 Gbps				Table 5 At Smf=90km,dcf=10km And data rate=2.5 Gbps			
span	Q	ber	Length(km)	span	Q	ber	Length(km)
1	19	10 ⁻⁰⁸²	90	1	25.3	10 ⁻¹⁴²	100
5	18.3	10 ⁻⁰⁶⁷	450	5	12.7	10 ⁻⁰⁵⁸	500
10	12.7	10 ⁻⁰³⁷	900	10	0	1	1000
15	8.5	10 ⁻⁰¹⁸	1350	15	0	1	1500
20	5.6	10 ⁻⁰⁰⁹	1800	20	0	1	2000
25	2.9	0.00140	2250	25	0	1	2500
30	0	1	2700	30	0	1	3000
At Smf=80km,dcf=10km And data rate=10 Gbps				At Smf=90km,dcf=10km And data rate=10 Gbps			
span	Q	ber	Length(km)	span	Q	ber	Length(km)
1	11	10 ⁻⁰²⁹	90	1	10.2	10 ⁻⁰²⁵	100
5	2.7	0.0023	450	5	2.3	0.0071	500
10	0	1	900	10	0	1	1000
15	0	1	1350	15	0	1	1500
20	0	1	1800	20	0	1	2000
25	0	1	2250	25	0	1	2500
30	0	1	2700	30	0	1	3000

(*): means the errors can be resulted every 10⁸⁵ bits.

The following figures (9-13) indicate that with an increasing length of the fiber for both systems 2.5 Gbps and 10 Gbps, there is a slight decrease in quality and the bit error rate (BER) is increased.

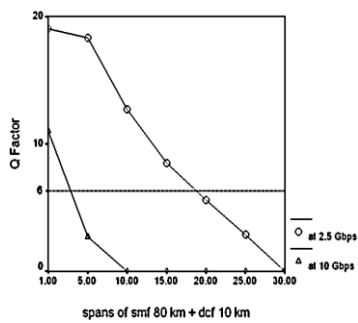
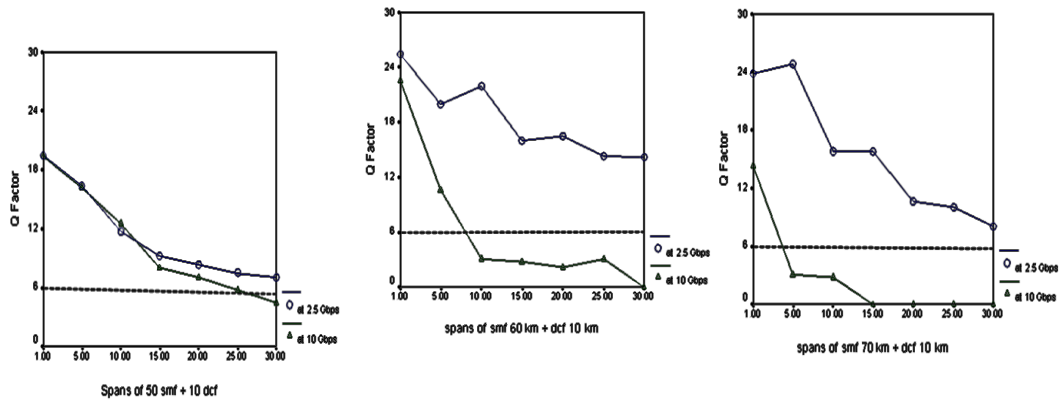


Fig 12

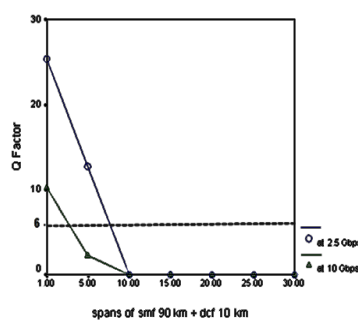


Fig 13

figures (9-13) :increasing length of the fiber for both systems 2.5 Gbps and 10 Gbps

The eye diagrams represented by figures 14 and 15 show that with an increasing length of the fiber for both systems, 2.5 Gbps and 10 Gbps, the Eye diagram will be more closed, so the large Eye diagram the best quality in signal.

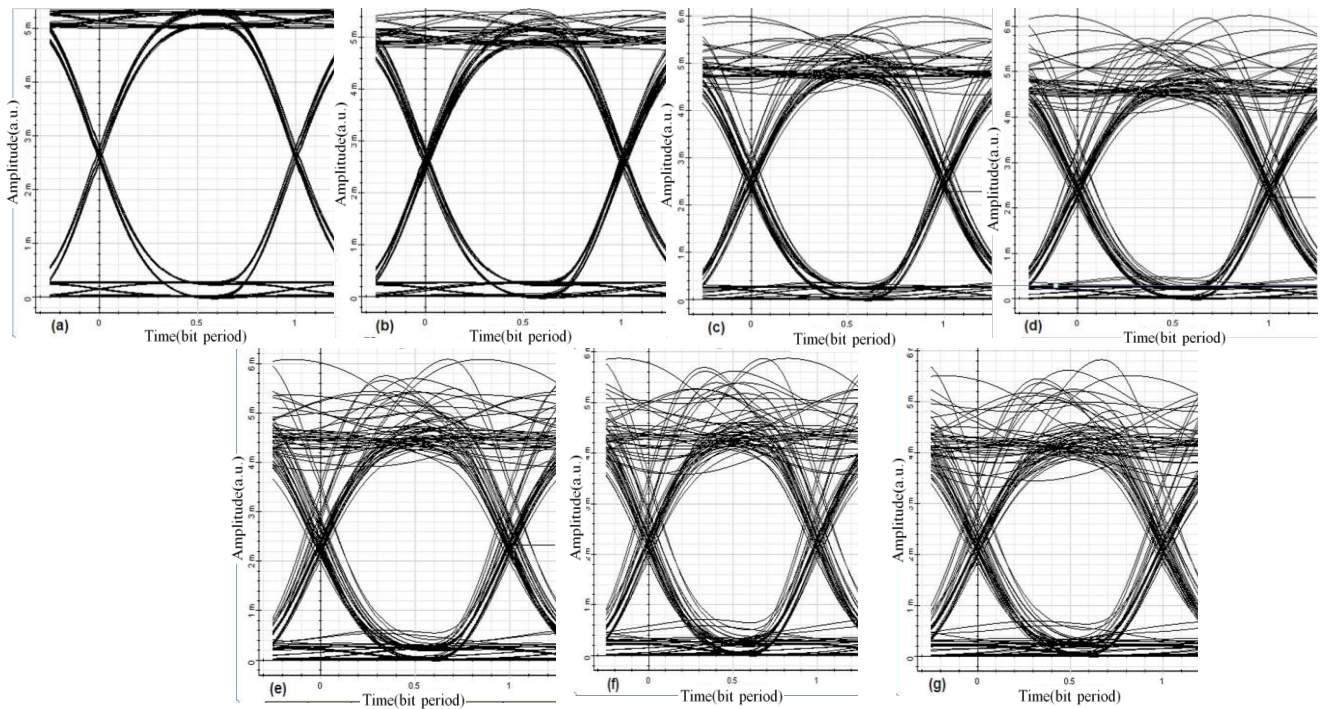


Fig 14 (a,b,c,d,e,f,g): Eye diagrams of optical 50 smf + 10 dcf spans 1, 5, 10, 15, 20, 25 and 30 respectively at 2.5 Gbps data rate

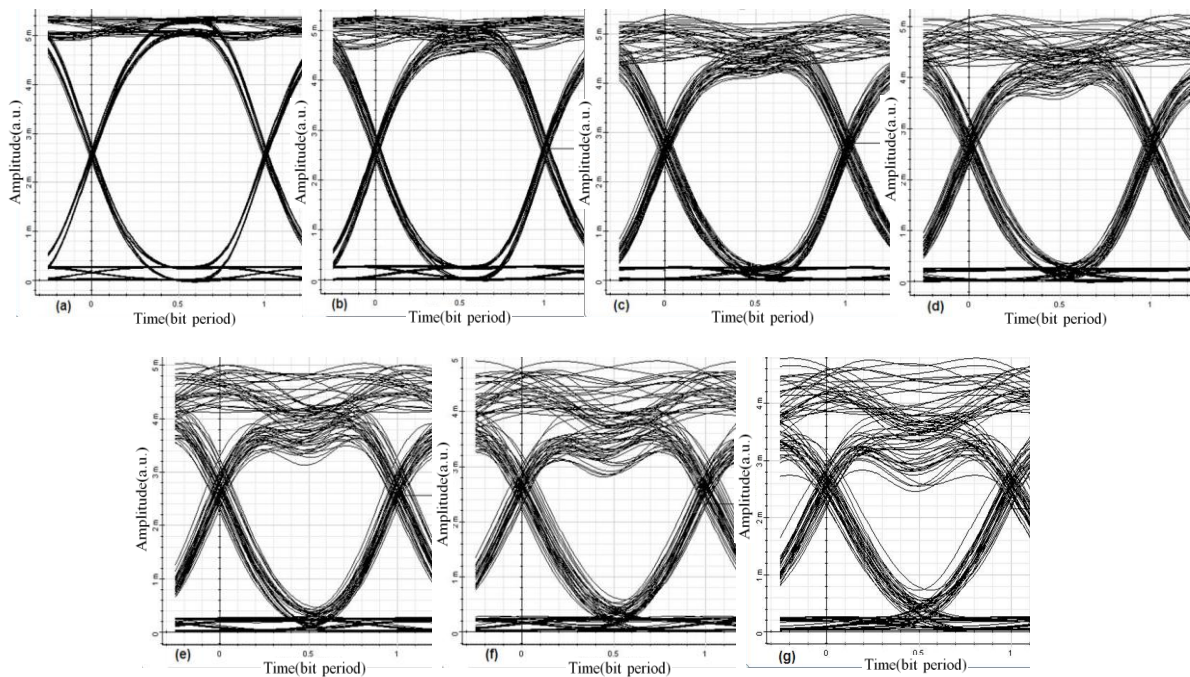


Fig 15 (a,b,c,d,e,f,g): Eye diagrams of optical 50 smf + 10 dcf spans 1, 5, 10, 15, 20, 25 and 30 respectively at 10 Gbps data rate

7. Conclusion

With increase in the length of the optical fiber that means increasing the number of the optical spans, the result is decreasing the quality factor Q and increasing the Bit Error Rate (BER). Also, the results show that the spans of 50, 60 km smf and 10 dcf km yields better Q and BER because the suitable length of dcf fiber that should be 1/5 or 1/6 the length of the smf fiber. Based on the given power transmission and power of the amplifier the results show that the 2.5 Gbps system yields better Q and BER than the 10 Gbps.

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