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Wavelength effect in 100Gbit/s WDM transmission in a telecommunication network

***Abstract**. These Optical transport networks are today the basic infrastructure of modern communications systems for the transfer of data between nodes. This paper proposes a transparent optical architecture for metropolitan area networks. This multi-service architecture allows supporting both 100Gbit/s WDM-PON transmission system and the wavelength raport to offers a performance suitable for this network architecture. we consider architecture based on the combined use of optical link and increase bit rate with wavelength associate. the simulation of this study was used by optisystem, the system is composed of 100Gbits with 100Km optical fiber length based on the different input design parameters such as input signal power, optical fiber length and attenuation coefficient. The results are discussed in terms of quality factor (Q-factor) and eye diagram*

***Streszczenie.** Te optyczne sieci transportowe są dziś podstawową infrastrukturą nowoczesnych systemów komunikacyjnych do przesyłania danych między węzłami. W artykule zaproponowano przezroczystą architekturę optyczną dla sieci metropolitalnych. Ta wielousługowa architektura pozwala na obsługę zarówno systemu transmisji 100Gbit/s WDM-PON jak i raportu długości fali, oferując wydajność odpowiednią dla tej architektury sieci. rozważamy architekturę opartą na łącznym wykorzystaniu łącza optycznego i zwiększeniu przepływności wraz ze skojarzeniem długości fali. Symulacja tego badania została wykorzystana przez optisystem, system składa się z 100Gbits o długości światłowodu 100Km w oparciu o różne parametry wejściowe projektu, takie jak moc sygnału wejściowego, długość światłowodu i współczynnik tłumienia. Wyniki omówiono pod kątem współczynnika jakości (Q-factor) i wykresu oka * (**Efekt długości fali w transmisji WDM 100Gbit/s w sieci telekomunikacyjnej**)*

Keywords: Optical Fibre, WDM, ROADM, Q-Factor, BER
Słowa kluczowe: Światłowód, WDM, ROADM, Q-Factor, BER

Introduction

To Human activities are increasingly in need of telecommunications systems to transmit a bigger data. This growth in bandwidth's request continues to become more and more considerable and impressive. Due to the rapid development, optical fiber communications have become one of the most important factors for modern communication systems. The Fiber-optic networks that implement wavelength division multiplexing (WDM) are now extensively used in modern communications and studies indicate that it will form a very important part in the next generation of the networks architectures in the future [1], the design and calculat each part of the network in order to optimize transmission resources, the bandwidth efficiency and relative costs for 100 Gb/s WDM transport and switching architectures is a the main challenge for telecommunication network [2].

WDM system, multiple optical carriers of different wavelengths are modulated by independent electrical data it considered as frequency-division multiplexing (FDM) Fig.1 shows the schematic of a WDM system. CW laser operating at ϑ_j , j=1,2,3,…n is modulated by electrical data j. The modulated signals are combined using a multiplexer and then launched to a fiber-optic link, the channels are demultiplexed using a demultiplexer in the end of optical fiber link [3].

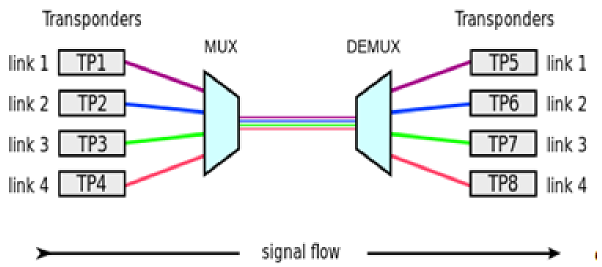

Fig.1. Schematic of a WDM system

Digital signal electricity Fig.2 and to transpose it into the optical domain to guarantee transmission with low losses, in complete immunity to electromagnetic disturbances and to very high bit rate for the resulting composite signal [4].

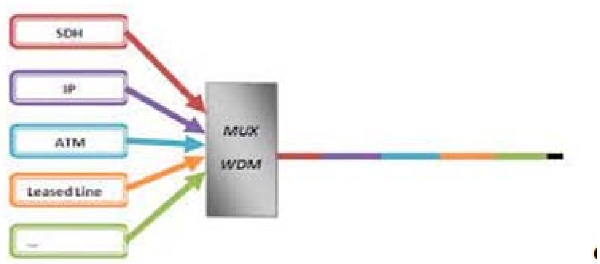

Fig.2. Principe Multiplexing with different protocols

The wavelength range of WDM bands is an approximation value and is considering O-band which is 1260 nm to 1360 nm range is equivalent to 14 THz bandwidth. Meanwhile, combination of S-band, C-band and L-band with a range of 1460 NM to 1625 NM provides another 15 THz bandwidth present in fig.3. The total available bandwidth per fiber optic in O- band, S-band and C-band only is around 30THz of the low-loss regions of a standard G.652 single-mode fiber [5].

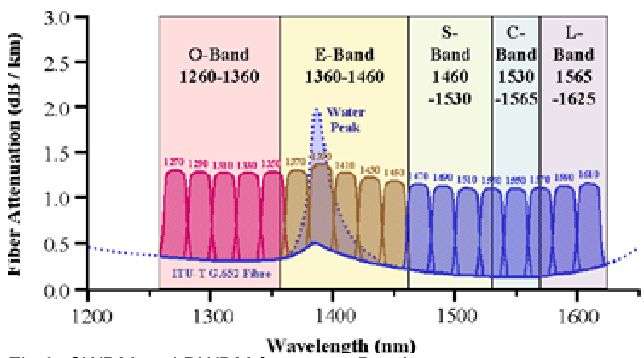

Fig.3. CWDM and DWDM frequency Band

Many schemes for realizing the residual CD monitoring have been proposed and demonstrated, a CD monitoring scheme was proposed by comparing the phase of recovered clock of received I and Q channel signals of a DQPSK modulated data [6]. Recently, delay tap asynchronous sampling has been proposed for multiparameter monitoring, and even applied to commercial WDM system [7]. In paper [8] a demonstration was made for a signed CD monitoring experiment and simulation study for 100Gbit/s CS-RZ DQPSK signal based on an enhanced delay-tap asynchronous sampling scheme by evaluating the asymmetry ratio of delay-tap plot. Optical coherent detection electrical domain equalization is the most prospect technology in practical application among high-speed long-distance optical fiber transmission technologies. A constructing coherent detection optical transmission system is proposed, using DSP module to process received signal. The constellation diagram is distinguishable and the data transmission error rate is around zero [9]

This paper we present the result by simulation of transmission system with CS-RZ modulation (carrier suppressed return-to-zero, the second part we propose 100Gbit/s classeWDM systems and provide flexible bandwidth allocation by using wavelength tunability. This systèm can improve the network usage efficiency by the statistical multiplexing effect and the load balancing [10].

Method

In the optical fiber transmission Fig.4, the signal is first encoded or modulated according to a known sequence that can be controlled at reception. This signal is injected into the optical fiber via the transmitter. At the output of the fiber, the signal is received on a photodiode and amplified before being decoded to be returned to its original form [11].
In the optical fiber impairments, we have linear effect and non-linear effect.

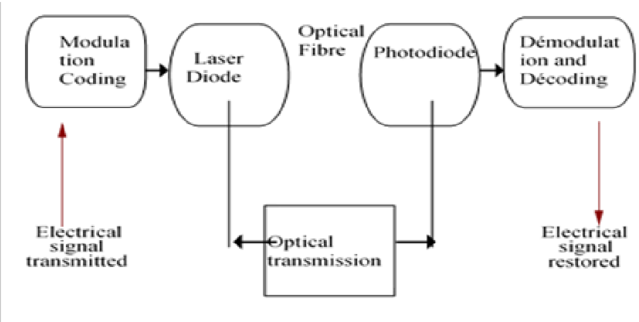

Fig.4. Optical fiber transmission chain

A.Linear effect

Linear effect can be compensated by the following solutions:

Amplifiers

Amplifiers are used to eliminate the optical loss observed in the transmission fiber.There are several types of optical amplifiers such as erbium doped fiber amplifiers (EDFA), RAMAN amplifiers (RFA) and semiconductor optical amplifiers (SOA) ext [12].

Chromatic dispersion

Dispersion Compensation Module (DCM) or Polarization Mode Dispersion Composation (DSP) was an effective process for upgrading single-mode fiber links. The limitation of the use of light transmission on the component (DC) is due to the optical input power, where nonlinear degradations will create a high insertion loss on the link [13]. Dispersion Compensation Module compensate for dispersion at each node, DCMs are a box of coiled fiber (DCF) with opposite CD properties of the span fiber and Matched to each span length.

Coherent optics is considered a promising candidate for realizing single-wavelength passive Optical networks (PONs) at 100 G and beyond. It has been a game changer for enabling ultra-high-speed data transmission in long-haul and metro networks, Interest in coherent optics is dispersion compensated inside DSP, and improved amplifier performance (improved network performance), and Benefits of moving to 100G coherent only network [14].

PMD Polarization mode disperssion

PMD greatly impairs conventional high-speed single-carrier systems, it is shown that for multicarrier systems such as coherent optical orthogonal frequency-division-multiplexed systems (CO-OFDM), it also provides a benefit of polarization diversity against polarization-dependent-loss-induced fading and consequently improves the system margin [15].

B. Linear effect

Four wave mixing (FWM)

When a high-power optical signal is launched into a fiber, the linearity of the optical response is lost. One such nonlinear effect, which is due to the third-order electric susceptibility is called the optical Kerr effect, Four-wave mixing (FWM) is a type of optical Kerr effect, and occurs when light of two or more different wavelengths is launched into a fiber, In the transmission of dense wavelength-division multiplexed (DWDM) signals, FWM is to be avoided, but for certain applications, it provides an effective technological basis for fiber-optic devices. FWM also provides the basic technology for measuring the nonlinearity and chromatic dispersion of optical fibers [16].

Self phase modulation (SPM)

SPM is second-order perturbation technique for the study of self-phase modulation (SPM) and cross-phase modulation (XPM) effects in optical fibers. When the dispersion distance is much shorter than the nonlinear length, it is found that the difference between the first-and second-order solution is negligible. However, as the dispersion distance increases, nonlinearity becomes a stronger perturbation, and the first-order theory is not adequate to describe the SPM effects. However, as the dispersion distance increases, nonlinearity becomes a stronger perturbation, and the first-order theory is not adequate to describe the SPM effects [17].

Optical signal to noise radio (OSNR)

To monitor the performance of wavelength-divisionmultiplexed (WDM) networks, it is essential to measure the optical signal-to-noise ratio (OSNR) of each channel. However, in a dynamically reconfigurable WDM network, each channel may traverse through a different route and a different number of Erbium-doped fiber amplifiers (EDFAs). Recently, to monitor the OSNR by measuring the polarization extinction ratios of WDM signals. However, a minute change in outside temperature could affect the polarization states of WDM signals in transmission fiber. Thus, for the use in a practical network, it is necessary to adjust the polarization state of each channel [18-19].

OSNR was straightforward to measure since WDM signals were not very closely spaced, allowing ASE noise to be measured optically by interpolating the noise level from the spectral gaps between signals. This interpolation method was rendered ineffective by the rise of closer channel spacing in dense wavelength division multiplexing (DWDM) systems and in-line filtering from add/drop filters or reconfigurable optical add/drop multiplexers (ROADMs).The introduction of coherent detection has also enabled the increased use of polarization-multiplexed (PM) signals, the continued increase in adoption of coherent optical transceivers has eased the measurement of several optical performance metrics through the capabilities of the advanced digital signal processing (DSP) embedded in the coherent receiver. Coherent DSP can readily measure signal parameters such as chromatic dispersion (CD) and polarization mode dispersion (PMD) [20-21]. One simple method, commonly known as the "Signal On/Off" method, requires temporarily turning off the channel of interest and measuring the in-band ASE noise in the absence of the signal, this technique can be highly accurate as long as all the elements in the signal path remain relatively stable during the process of turning the signal off and back on. Optical amplifiers will generally maintain a relatively steady state as long as enough channels are present along with the test signal as it is switched on and off [22].

A general schematic of the experimental link with standard single-mode fiber (SSMF) and all-EDFA amplification is shown in Fig.5, the channels coherent transceivers operating with either PM quadrature phase-shift keying (PM-QPSK) or 16-ary quadrature amplitude modulation (PM-16QAM), Additional neighboring channels for generating nonlinear crosstalk were either legacy intensity-modulated/direct-detection or coherent PM-QPSK signals, the non-intrusive OSNR can be measured via OSA traces taken at the beginning (Tx Reference trace) and end (Rx trace) of the link. This optical reach is limited by the OSNR(min) at Transponder receiver.

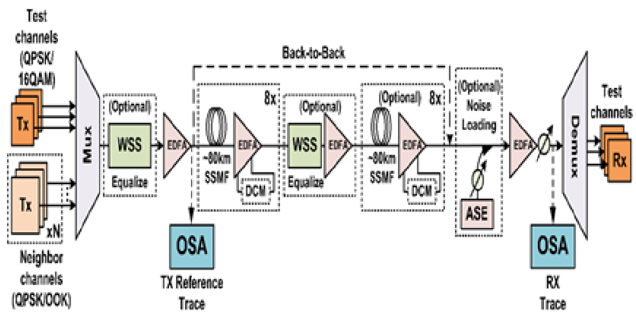

Fig.5. Schematic of experimental fiber transmission link

WDM network design is based on OSNR budget and Optical reach is limited by the OSNR(min) at Transponder receiver Fig.6, Once this value is reached a regen is require.

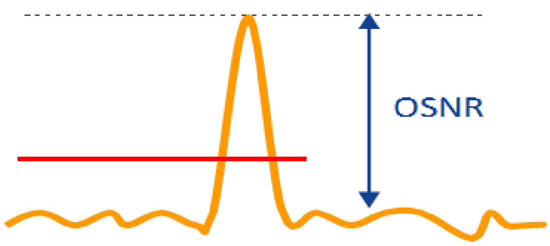

Fig.6. Non-linear effects limit launch power

OSNR is affects minimum by:

- limit rate 100G vs 200G,
- modulation DP-QPSK vs DP-16QAM.
- Fiber type.
- Fiber loss.

Calculating OSNR

To investigate the relation between the signal power and the maximum allowed distance, we consider a noise limited system where other physical effects can be taken into account as power-penalty. Considering a chain of amplifier the OSNR of the end point can be calculated as follows [23].

$$(1) \qquad OSNR = 58 + P_{in} - \Gamma(dB) - NF_{dB} - 10.\log N - M$$

Where noise figure (*NF*) is the same for every amplifier and the span loss (Γ(dB)) is the same for every span. P_{in} is the input power in dBm, M is the margin for other physical effects, and N is the number of spans. We assume that there is an inline amplifier in every l km. This means that if the length of the link is L, N is [L/l], the integer part of the division.

Having into mind that

$$(2) \qquad Q_{dB} = OSNR_{dB} + 10.\log(\frac{B_0}{B_e})$$

Where B_0 is the optical bandwidth and B_e is the electronic (digital) bandwidth of the receiver. The logarithmic Q_{dB} and the linear Q have the following relation:

$$(3) \qquad Q_{dB} = 20.\log Q$$

Substituting equation (2) and (3) into (1) we obtain the linear relation between the maximum allowable distance and the signal power:

$$(4) \qquad L = L_c.P_{mW}$$

Where P_{mw} is the input power in mW, L is the maximum allowable distance, and Lc is the linear factor between them.

$$(5) \quad L_c = 1/10^{(\frac{20.\log Q+10.\log(\frac{B_0}{B_e})-58+\Gamma(dB)+NF+M}{10})}$$

For typical constant values used in telecommunications the L_c is between 500 and 2000.

The effects of an optical node on the signal quality are similar to the impact of an about 90 km long optical fiber, since it has nearly the same attenuation. Using the approximation mentioned previously in the routing algorithm, when the physical effects are taken into consideration, we substituted each node with a 90 km optical fiber. Naturally, more accurate models [24], [25] can be implemented for characterizing the networks

The proposed architecture

The ROADM architecture (WDM) uses transponders as service interfaces to map a client service to a long-range WDM line-side interface. Services are mapped to a trans-/muxponder at the ingress of the network, and then routed all-optically through intermediate ROADM nodes, and recovered at the egress using another trans-/muxponder, as shown in Fig.7.[26]

That we propose in this part fig.8. WDM system with ROADM architecture:

The first link has 6 channels (the simulated band: f1=190THz, f2=190.2THz, f3=190.4THz, ..) fig.8(a).So, this system starts with a multipleser followed by a single mode optical fiber of 50 Km length with an attenuation of 0.2dB/Km.And a chromatic dispersion of 17ps/nm/Km, and 1550nm wavelength, then an optical amplifier configured as a booster and DCF fiber 10Km long with an attenuation of 0.5dB/Km and a chromatic dispersion of -85ps/nm/Km.

Before reaching the receiver R(photodetector with a responsivity of 1A/W, and low Pass Gaussian with cutoff frequency of 0.75 times the rhythm frequency) of each channel, the signal must have passed through the demultiplexer fig.8.(b).

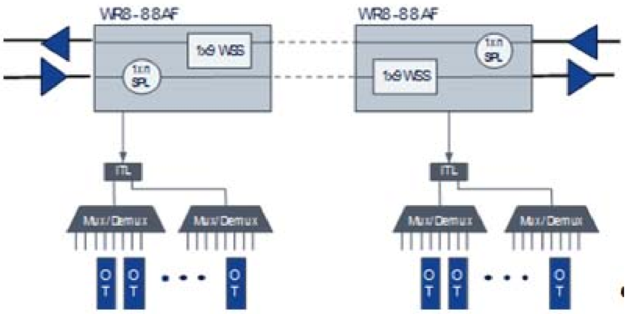

Fig.7. Classic ROADM

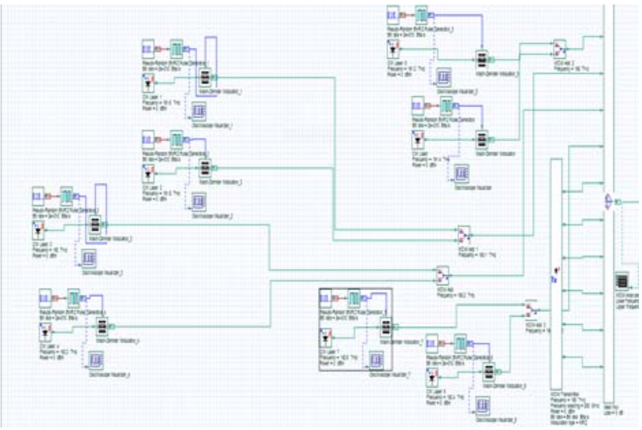

Fig.8(a). 100G WDM transmitted component.

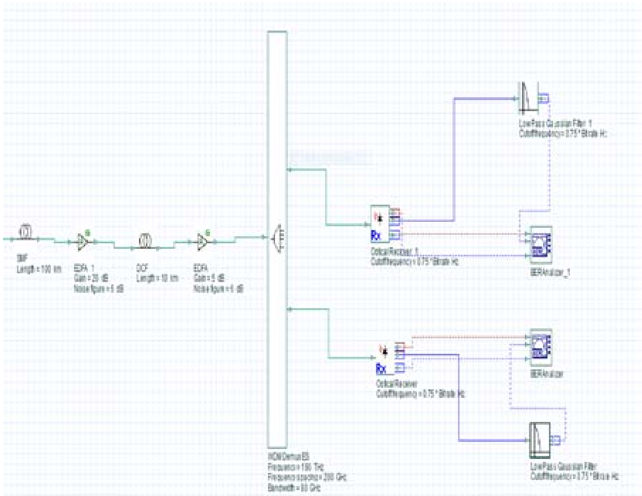

Fig.8(b). 100G WDM transmission support and reception component

Table 1. The performance of Q-factor a function of length

Length FO(km)	Q-factor	BER
40(a)	0	1
50(b)	5.7483	4.11817e-009
60©	4.01901	2.89447 e-005

Table.1. presents the results obtained, the variation of the Q-factor as a function of length FO in the simulated band with spacing between these channels of 0.2 THz. It is noted that the increase in length FO has an influence on the quality of transmission, the more the length increases the more the Q-factor undergoes a considerable change and ecreases, and with 50 Km in consuderably better in Fig.9(b).

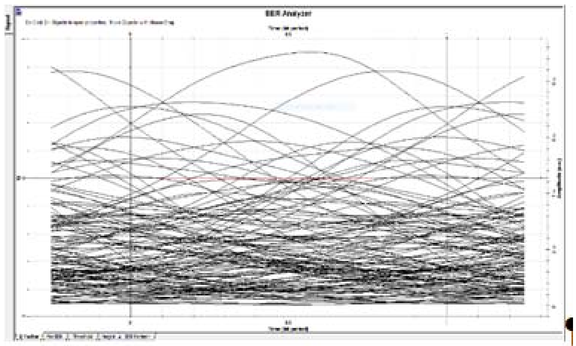

Fig.9 (a). Eye diagram for 100Gbit/s transmission with 40Km length FO

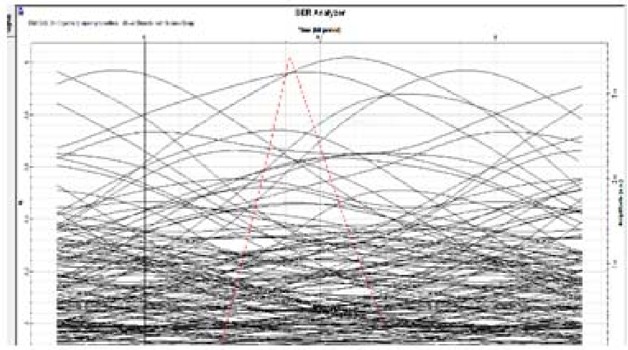

Fig.9 (b). Eye diagram for 100Gbit/s transmission with 50Km length FO

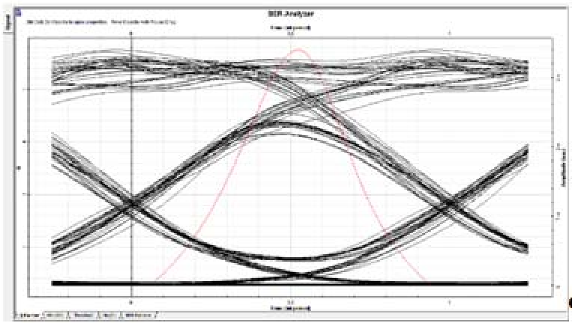

Fig.9 (c). Eye diagram for 100Gbit/s transmission with 60Km length FO

Table 2. The performance of Q-factor a function of bit rate

Bit rate (Gbit/s)	Q-factor	BER
90(a)	7.27025	1.63538 e-013
100(b)	5.7483	4.11817e-009
110(c)	4.67802	1.34386e-006

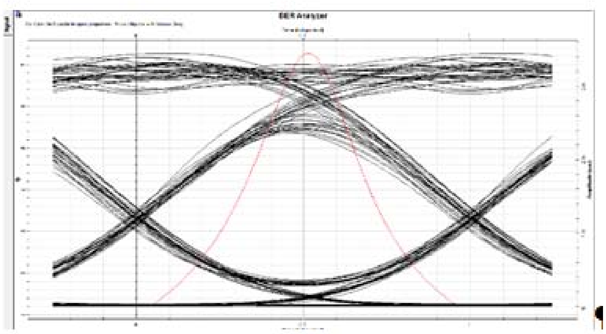

Fig.10(a). Eye diagram for 100Gbit/s transmission with 90Gbit/s

Table.2. presents the results obtained, the variation of the Q-factor as a function of Bit rate, it is noted that the increase in Bit rate has an influence on the quality of transmission, if the bit rate increases the more the Q-factor undergoes a considerable change and decreases, and with 90 Gbit/s we habe a better reception signal Fig.10(a).

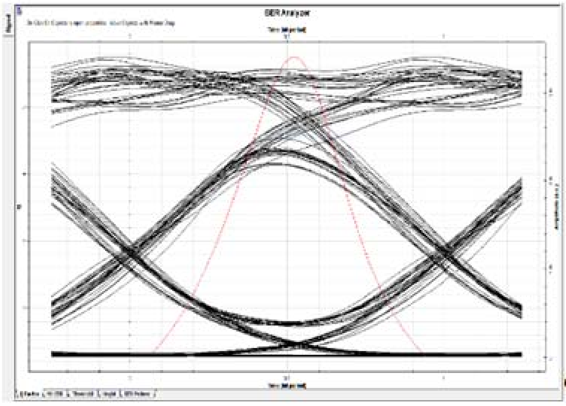

Fig.10(b). Eye diagram for 100Gbit/s transmission with 100Gbit/s

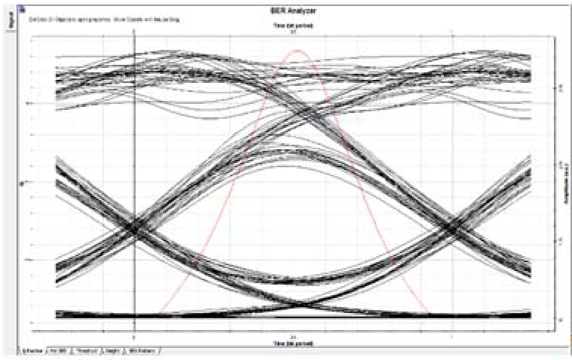

Fig.10(c). Eye diagram for 100Gbit/s transmission with 110Gbit/s

Effect of flow variation on the proposed system: Fig.11. shows a 5-channel WDM system with ROADM architecture (the band simulated; f1=191.5 THz, f2=191.7 THz, f3=191.9 THz,f4=192.1 THz). At the entrance, the length of the sequences is512 bit whose modulation format is NRZ with a external Mach-Zehnder modulator Fig.11(a).).

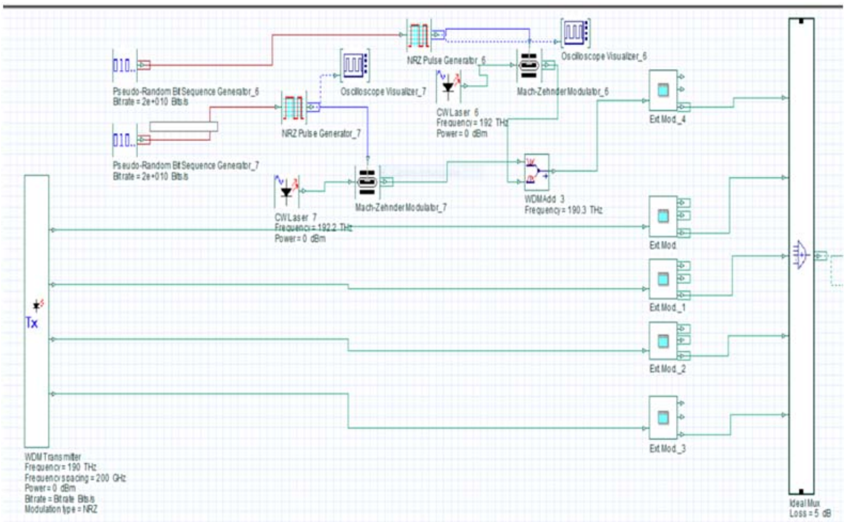

Fig.11(a). 100Gbit/s WDM system transmitted component with ROADM architecture in 200Km length FO

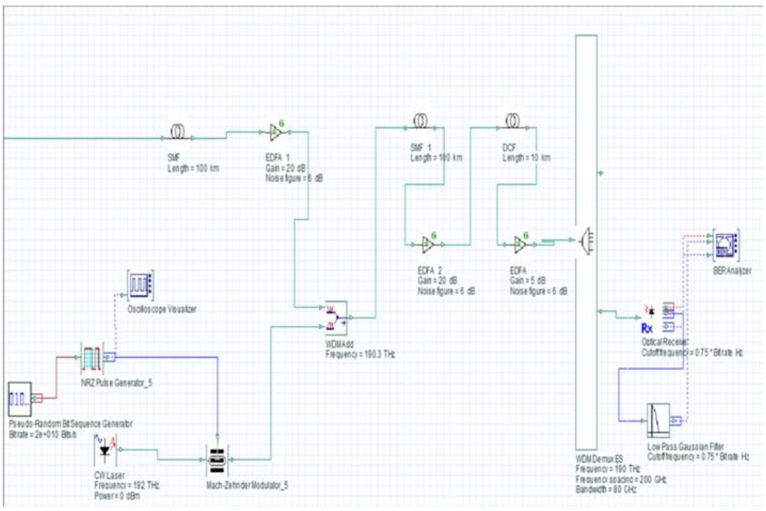

Fig.11(b). 100Gbit/s WDM system transmission support and reception component with ROADM architecture in 200Km length FO

So this system starts with a multiplexer followed by an optical fiber single mode 200 km long with an attenuation of 0.2dB/km and a chromatic dispersion of 17 ps/nm/km, then an optical amplifier configured EDFA as a booster and a DCF fiber 10 km long with an attenuation of 0.5 dB/km and a chromatic dispersion of -85 ps/nm/km. Before attack the receiver (a PIN photodiode: sensitivity -18dBm with 1 A/W response and electrical filter Bessel lowpass of order 4 and cutoff frequency 0.8 times the rhythm frequency) of each channel, the signal must be passed through the demultiplexer Fig.11(b

Table 3. The performance of Q-factor and BER a function of wavelength

Wave lebgth (nm)	Q-factor	BER
1575(a)	2.87171	0.000994264
1600(b)	4.8962	4.79081e-007
1625(c)	6.43866	6.01723e-011

Table 3. present respectively the variations of the quality factor and those of the BER as a function of wave length in the simulated band with a spacing between these channels of 0.2 THz. We note that the increase in wavelength has an influence on the quality of transmission, the more the flow increases, the better the value of the quality factor. The BER is undergoing a change considerable by registering a decrease in BER given the improvement in the quality of transmission.

Rersults and discussion

The results obtained was compared with the effects of FO length on Q-Factor Fig.12(a). and effects Bit rate on Q-Factor Fig.12(b), clearly show that the bit error rate performance BER and the Q factor are the key indicators allowing the operator to monitor the quality of his network and determine any degradation that may affect the quality of service for wave length 1550nm.

For the first architecture used 100Gbit/s transmission in WDM we have presented, for each deployment, the calculation of the link budget helps the choice of transmission equipment to be installed, It will depends essentially:

- data rate.
- Length of the FO.
- CD chromatic disparsion.
- OSNR calculation.
- Optical return loss.
- PMD only required on poor (or suspect) PMD routes.

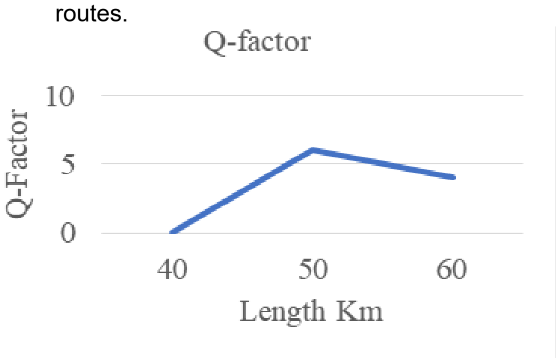

Fig.12(a). Effects of FO length and Bit rate on Q-Factor

For the second part we have proposed the use of 100 Gb/s WDM interfaces with a ROADM architecture, we note that the increase in wavelength has an influence on the quality of transmission, the more wave length increases, we enregistre the better value of quality factor. The BER is undergoing a change considerable by registering a decrease in BER given the improvement in the quality of transmission Fig.13.

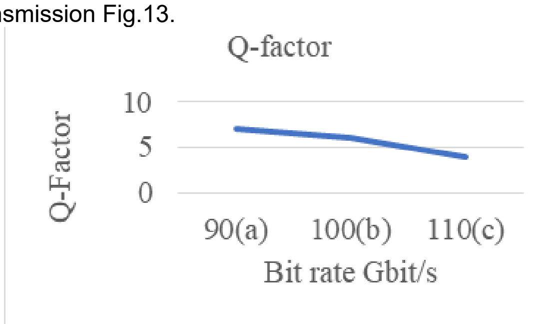

Fig.12(b). Effects of FO length and Bit rate on Q-Factor

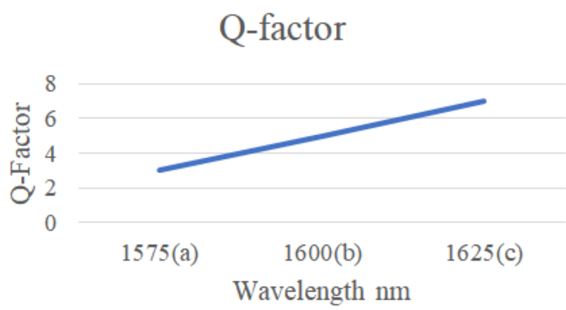

Fig.13. Effects wave length on transmission qualité for 200Km

Conclusion

This paper proposed 100Gbit/s-class WDM systems that provide flexible bandwidth allocation, we studied and compared the principle of the parameter impacting 100Gbit/s transmission of the fiber link shown in eye diagram. We demonstrate a simple length FO and Bit rate monitoring scheme by evaluating Q-factor and BER for 100Gbit/s signal, This scheme can easily differentiate the relationship between Bit rate and wave length before each deployement:

Good, accurate fiber data is critical, and information needed upfront in order to provide optimized, lowest cost, WDM network design.

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