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Research Article

Performance of backbone line Pristina-Skopje in 10 GBPS & 40GBPS using WDM and EDFA Amplifier Technology

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Abstract

Telecommunication networks now days require high speed and transmission capacity. Such a trend is present in Kosovo too. The overall backbone transmission technology in Kosovo is based on fiber optic. To reach this requirement it is necessary to develop and use optical networks which are based on advanced optical technologies, such as WDM/DWDM transmitting technology and different amplifiers. However, the communication systems with fiber optic are facing with different problems with the signal losses such as attenuation, dispersion, scattering, absorption etc. The developments of new methods and devices in optical technology make significant improvements, and they have strong impact on transmission performance on communication systems with fiber optics. The main focus in this case study at my paper would be aimed to achieve an improvement in performance in transmission systems with optical fiber in the real transmission backbone line between two capitals Pristina – Skopje with a distance length ~ 109 km, using OptiSystem 13.0, which is a simulator device. My target in this paper is to analyze two cases of the transmission system 10 Gbps and 40 Gbps. The first transmission cases will be without EDFA (Erbium Doped Fiber amplifier) amplifier, and in the second case I will use EDFA amplifier. From these two cases we will see the difference between transmission line with EDFA amplifier and without EDFA amplifier in the transmission system 10 Gbps and 40 Gbps. The results which I have presented in graphical and tabular form will clearly show the impact of amplifiers in increasing the quality of the transmitted signal by using the EDFA amplifiers in transmission systems with fiber optics will help for achieving a long distances transmission and high capacity, without needing to add additional optical cables, in such way will maintain low cost of transmission systems.

Keywords: *Optical fiber, WDM technology, EDFA amplifier, backbone line, Transmission.*

1. Introduction

In the last years the use of optical fiber in communications systems is growing very quickly and can be used to transmit light and thus information over long distances. Optical networks which are based on optical technology in terms of efficiency are described in functionality which is related to routing, service protection, and are comprised from optical nodes that are interconnected in the topologies.

Telecommunication networks nowadays require high speeds and capacity. Transmitter systems based on fiber optic have largely replaced the radio transmitter systems for long haul optical data transmission and have much more efficiency than systems based on electrical cables. But they are facing with continuous problems for transmitting too (Keiser, 2011).

In this paper I will explain shortly the types of optical cables, the role of WDM/DWDM technology and the role of optical amplifiers. After this, I will explain and analyze a real telecom service operator (2nd operator) with fiber length 109 km and 8 coupling points in two case studies for 10 Gbps and 40 Gbps with EDFA amplifier and without EDFA amplifier.

1.1 Optical fiber

Optical cable is a flexible cable, contains one ore many optical fibers, and consist of several main parts:

- Core (the light goes through)
- Internal cladding - surrounding the core with an optical material and makes the light to be reflected from the edges towards the core.
- Buffer coating - is plastic cover and protects the optical fibers from damage and humidity (Keiser, 2011).

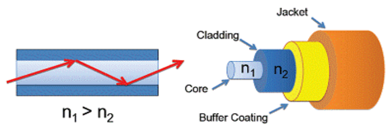

Figure 1 Optical cable (http://www.ni.com/white-paper/12953/en)

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Based on the mode of transmission of the signal, optical fibers are divided in: single-mode fiber and multi-mode fiber.

Single mode fiber has small core diameter of ~ 9 µm and transmit infrared laser light in wavelength between 1.300 and 1.550 nanometers (nm).

Multimode fibers usually have a diameter from 50 µm to 100 µm and transmit in wavelength from 850 nm to 1.300 nm (Goff, 1999), (Agrawal, *et al*, 2010).

Some of main factors that influence the optical signal losses are: attenuation, dispersion, scattering, absorption. Attenuation causes weakening of the signal (the optical effect of radiate energy) and the dispersion causes the expansion of the pulses that influences two effects scattering and absorption also macro or microbending losses and coupling or injection losses etc. (Eberlein, 2013), (Kumar and Deen, *et al,* 2014)

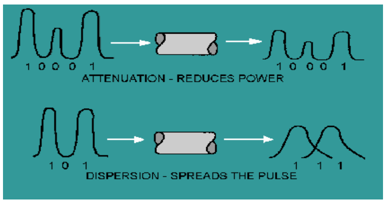

Figure 2 Factors of signal losses in optical fiber (http://dluong1.bol.ucla.edu/swarthmore/e78/Fiber_Optics.htm)

1.2 WDM Technology

WDM (Wavelength-Division Multiplexing) is a technology that has to do with multiplexing of several information carriers of signals in an optical fiber. This technique allows communication in both directions and is based on the use of different wavelengths (or colors) arising from a light source (LED or Laser diodes) to multiplex the information without losses in the transmission carrier (Keiser,2012) (Goff, 1999).

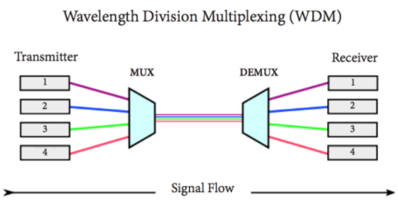

Figure 3 Multiplexer and demultiplexer (https://precisionopticaltransceivers.wordpress.com)

DWDM (Dens Wavelength-Division Multiplexing) technology system is used in the fiber optic single-mode transmission in C band, it is 1.550 nm and usually use a density space of 40 channel frequency spacing to 100 GHz, but it is possible to use 80 channels in the frequency spacing of 50 GHz channels (Keiser, 2011), so we can double the number of transmitted channels. Some technologies like ultra-dense Wavelength-Division Multiplexing have the ability to transmit more channels in the frequency channel spacing 25 GHz and 12.5 GHz.

1.3 Amplifier technology

Amplifier technology is based on optical fibers and in most cases the gain medium is a glass fiber doped with rare earth elements which have very good properties of amplification, and are used in the fiber optic transmission systems. Some of rare-earth elements are Er (erbium), Tm (thulium), Yb (Ytterbium), Pr (praseodymium) or combination between them (e.g. Er / Yb), each of them operate in a different spectral band (Becker, Olson, & Simpson, 1999).

The element of erbium Er^{3+} is adequate for amplification in case of using DWDM's technology in the spectral range of 1.3 µm and 1.5 µm. EDFA (erbium-doped fiber amplifier) was the first optical amplifier and has revolutionized the optical communication in the early 1990s. Now days, they are widely used in all kinds of fiber communication systems.

Two adequate wavelengths for optical frequency excitation of EDFA's are 980 nm and 1480 nm and producing stimulated emission at 1530 nm - 1565 nm range in C band (Becker, Olson, & Simpson, 1999), (Kartalopoulos, *et al*, 2008)

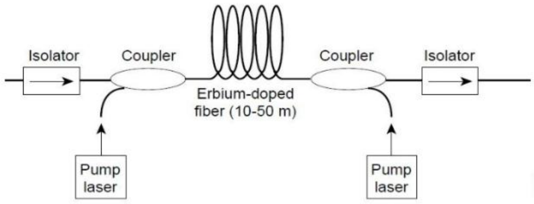

Figure 4 A schematic diagram of a doped fiber Amplifier (www.fs.com/images/ckfinder/images/tutorial/Erbium-doped7Fiber/Amplifier.jpg)

2. Case study

In this case study I will present real case study based in the real telecom service operator in Kosovo (2nd operator) with fiber length 109 km and 8 coupling points.

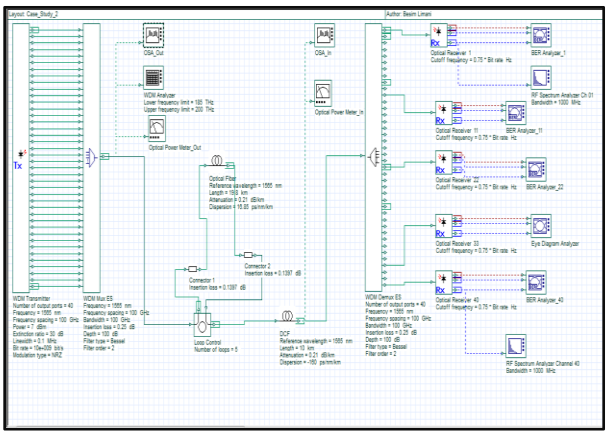

Figure 5 Optical network simulator scheme (2nd operator)

This case presented in figure 5 is designed on the simulator OptiSystem 13.0, in this sketch I present the real optical network backbone line implemented between the two capitals of Pristina - Skopje with length ~ 109 km. The case is simulated so that the optical cable does have real losses, and have active elements such as WDM transmission, WDM multiplexer, WDM demultiplexer etc.

2.1 Technical data of the optical cable and active devices used in the simulator

Optical cable which is presented in the simulator belongs to the category G.652 SM fiber and technical data of this optical cable are shown in table 1.

The attenuation in the optical cable is real, as it given by the manufacturer, and the DCF cable increase the value of dispersion compensation, while other losses are as result of connectors and coupling points in the optical cable are presented in connectors 1 and 2, for example as coupling points in the cable are a total of 8 points, the total loss of these points is 1.397 dB, the total loss in the fiber-optic cable with a length of 100 km is 21 dB and the total losses in DCF cable length 10 km is 2.1 dB.

The general losses are as follows

$H_{fo}+H_v+H_{dcf}$ = 21dB + 1.397 dB + 2.1 dB = 24.497dB

H_{fo} - Total losses in the optical cable with a length of 100 km.
H_v - Total loss of coupling points in the optical cable
H_{dcf} - Total losses in the DCF cable with a length of10 km.

For a more realistic presentation of the project in the sketch the optical cable 99 km I have divided in 5 cycles (loops) by 19.8 km, and connectors I have settled in that form as follows:

The Loop Control device with value 5 in the scheme means that optical signal in optical fiber rotates 5 times at a length of 19.8 km, it is the same as the optical signal to traverse the optical fiber along the route of 99 km. The losses of coupling points I have collected in a total of 1.397 dB, to not present all 8 coupling points in the scheme which would be more complicated, and I made this solution as bellow.

The total loss in coupling points I have divided into two points, namely connector 1 and connector 2. I calculated that the signal in the loop must pass 5 cycles, therefore, the loss of each connector I have divided into 5 cycles and as a result I have find the value of 0.1397 dB.

Calculations are made in this way:

Connector 1 (C_1) = 0.1397 dB and
Connector 2 (C_2) = 0.1397 dB

$H_1 = C_1$ *5 cycles = 0.1397dB *5 = 0.6985 dB
$H_2 = C_2$ * 5 cycles = 0.1397dB *5 = 0.6985dB
$H_v = H_1 + H_2$ = 0.6985 dB + 0.6985 dB = 1.397 dB

Table 1 Date of the optical cable G.652 category

Optical Cable Parameters (2nd operator)	Fiber 2 (99 km)	DCF (10 km)
Reference wavelength	1550	1550
Length (km)	99	10
Attenuation	0.21	0.21
Dispersion	16.85	-165
Dispersion slope	0.075	-0.075
Beta 2	-20	-20
Beta 3	0	0
Differential group delay	0.2	0.2
PMD coefficient	0.5	0.5
Mean scattering section length	500	500
Scattering section dispersion	100	100
Self-phase modulation	NO	NO
Effective area	80	80
Max. nonlinear phase shift	3	3
Boundary conditions	Periodic	Periodic
Filter steepness	0.05	0.05
Lower calculation limit	1200	1200
Upper calculation limit	1700	1700
Calculate graphs	NO	NO
Number of distance steps	200	200
Number of wavelength/time steps	200	200

Technical data of the WDM/DWDM multiplexer, demultiplexer and transmitter are presented below in the following tables.

Table 2 Technical data of the WDM/DWDM transmitter

WDM transmitter parameters	Values	Unit
Number of output ports	40	channel
Frequency	1565	nm
Frequency spacing	100	GHz
Power	7	dBm
Extinction ratio	30	dB
Linewidth	0.1	MHz
Initial phase	0	deg
Bit rate	10.00E+9	bits/s
Modulation type	NRZ	
Duty cycle	0.5	bit
Position	0	bit
Rise time	1/(Bit rate) *0.05	s
Fall time	1/(Bit rate) *0.06	s
Transmitter type	EML	
Noise bandwidth	6.40E+11	Hz
Noise bins spacing	6.40E+11	Hz

Table 3 Technical data of the WDM/DWDM multiplexer

WDM multiplexer parameters	Values	Units
Number of output ports	40	channel
Frequency	1565	nm
Frequency spacing	100	GHz
Bandwidth	100	GHz
Insertion loss	0.25	dB
Depth	100	dB
Filter type	Bessel	
Filter order	2	
Sample rate	128	GHz
Noise threshold	-100	dB
Noise dynamic	3	dB

Technical data of the WDM / DWDM demultiplexer are presented in the following table:

Table 4 Technical data of the WDM/DWDM demultiplexer

WDM demultiplexer parameters	Values	Units
Number of output ports	40	channel
Frequency	1565	nm
Frequency spacing	100	GHz
Bandwidth	100	GHz
Insertion loss	0.25	dB
Depth	100	dB
Filter type	Bessel	
Filter order	2	
Sample rate	128	GHz
Noise threshold	-100	dB
Noise dynamic	3	dB

The values of direct measurement in the line of optic signal loss in the coupling points are shown below in fig. 6.

The measurement of optical signal loss in real network is done with OTDR[2] device and is presented in the figure below:

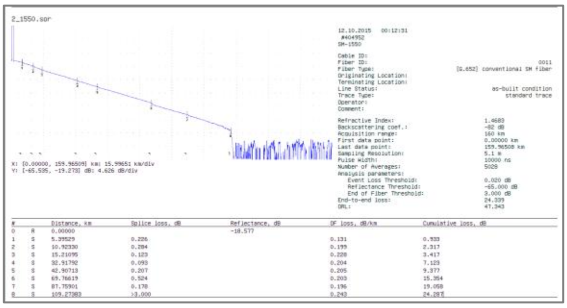

Figure 6 The measurement of optical cable Pristina-Skopje (2nd operator)

2.2 Data transfer with 10 Gbps capacity in the simulator

To illustrate the simulated optical network, I will generate 10 Gbps traffic to benefit the reference value, which will be used as comparative values in other case study's. The wavelength band which operate with the simulation is C band 1530 nm - 1565 nm. The total loss in the fiber-optic cable will be 24.497 dBm, the value of the power transmission laser device is 7 dB, based on the real value of optical transmitter manufacturer Cisco SFP-10G-ZR-S dedicated to transmit in 80 km distance with capacity 10 Gbps in optical cable type G.652. The DCF (Dispersion Compensated Fiber) will be used for chromatic dispersion compensation, caused along the wayfaring of the optical signal.

Transmitting power in WDM transmission is 7dB, in the output of WDM multiplexer will be 19.700 dBm, and the input in WDM demultiplexer will be – 4.587 dBm as shown in figure 7.

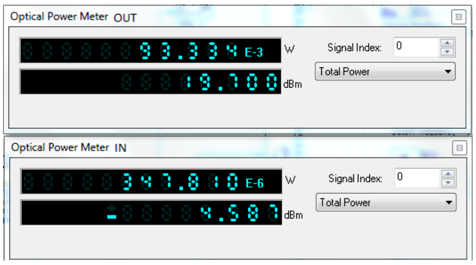

Figure 7 The power of the transmitter output signal to the multiplexer and the input of the demultiplexer

This loss or weakening of the signal is calculated according to the formula as follows:

$$P_{in} = P_{out} - \alpha$$

Transmission power: $P_{out} = 19.700$ dBm,
the total losses along the optical cable: $\alpha = 24.497$ dBm, than the input power is:

$$P_{in} = P_{out} - \alpha = 19.700 \text{ dBm} - 24.497 \text{ dBm} = - 4.797 \text{ dBm}.$$

In output of demultiplexer will be connect the receiver of the optical signal and in this receiver we can measure the signal losses in the value of bits, BER (Bit Error Rate) is a key indicator parameter to estimate the value of signal transmission at 10 Gbps after passing along the optical network.

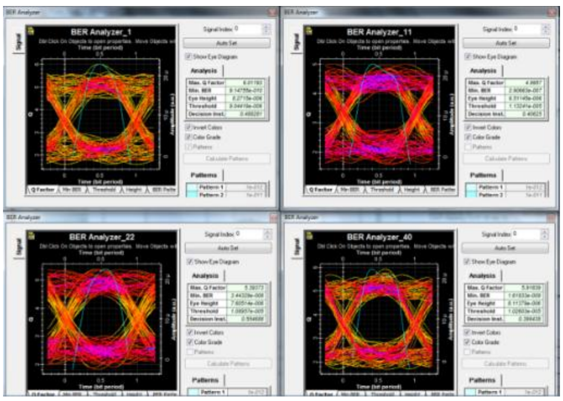

Figure 8 The value of the BER measured from BER analyzer device. Operator 2

[2] OTDR – Optical Time-Domain Reflectometer

To know the exact value of BER for each λ wavelength should connect a BER analyzer device at the exit of each optical receiver as shown in figure 8. BER values for channels 01, 11, 22, and 40 are presented in tables 5, 6, 7 and 8.

Whereas in the form of tabulating are presented in the following tables:

Table 5 The measured values of the BER analyzer of ch_1 at 10 Gbps

The 1st data channel	Value	Unit
Wavelength	1565	nm
Max. Q Factor	6.011	
Min. BER	$9.14 * 10^{-10}$	bps
Eye Height	$8.27*10^{-6}$	
Threshold	$9.044*10^{-6}$	
Decision Instant	0.48	bit period

Table 6 The measured values of the BER analyzer of ch_11 at 10 Gbps

The 11th data channel	Value	Unit
Wavelength	1556.87	nm
Max. Q Factor	4.99	
Min. BER	$2.90*10^{-7}$	bps
Eye Height	$6.51*10^{-6}$	
Threshold	$1.132*10^{-5}$	
Decision Instant	0.40	bit period

Table 7 The measured values of the BER analyzer of ch_22 at 10 Gbps

The 22th data channel	Value	Unit
Wavelength	1548.03	nm
Max. Q Factor	5.39	
Min. BER	$3.44*10^{-8}$	bps
Eye Height	$7.60*10^{-6}$	
Threshold	$1.08*10^{-5}$	
Decision Instant	0.55	bit period

Table 8 The values measured by the BER analyzer of ch_40 at 10 Gbps

The 40th data channel	Value	Unit
Wavelength	1533.77	nm
Max. Q Factor	5.91	
Min. BER	$1.61*10^{-9}$	bps
Eye Height	$8.11*10^{-6}$	
Threshold	$1.02*10^{-5}$	
Decision Instant	0.39	bit period

Value of signal and losses can also see from the measurements with the RF Spectrum Analyzer, these values are presented graphically in the following figure:

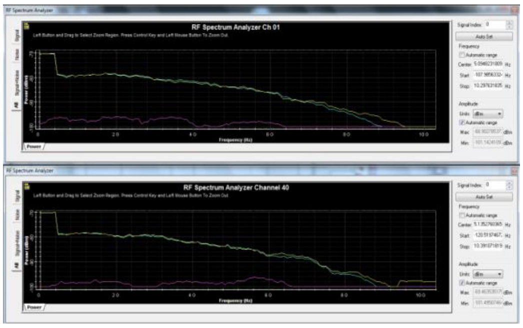

Figure 9 Radiofrequency Spectrum Analyzer

In this figure we see that the noise signal approaches nearly the value of ~ 9 GHz, this appears in the fortieth channel wavelength λ = 1533.77 nm also, where degraded signal do not continue forward. The first channel with wavelength λ = 1565 nm at point of value nearly ~ 9 GHz signal will degraded or lost also.

2.3 Data transfer with 10 Gbps capacity in the simulator using EDFA amplifier

Now in the presented scheme of simulator network (2nd operator), I will connect EDFA amplifier to amplify the optical signal and to achieve better result in the transfer data. In figure 10 is shown the scheme with EDFA amplifier.

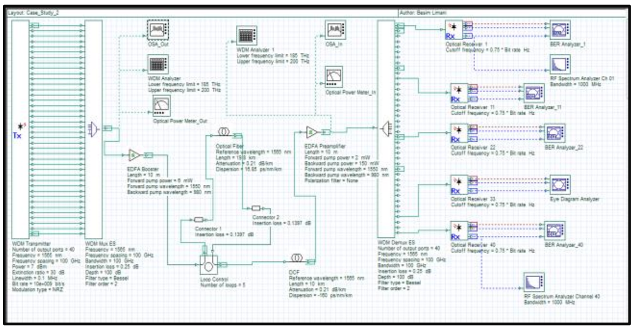

Figure 10 Optical network simulator scheme 10 Gbps with EDFA (2nd operator)

Table 9 Values of the EDFA Booster

Description	Value	Unit
Core radius	2.2	μm
Er doping radius	2.2	μm
Er Metastable lifetime	10	ms
Numerical aperture	0.24	
Er ion density	1 e + 024	m^3
Loss at 1550 nm	0.1	dB/m
Loss at 980 nm	0.15	dB/m
Length	10	m
Forward pump power	6	mW
Backward pump power	150	mW
Forward pump wavelength	1550	nm
Backward pump wavelength	980	nm
Noise center frequency	1550	nm
Noise bandwidth	5	THz
Noise bins spcing	125	GHz
Noise threshold	-100	dB
Noise dynamic	3	dB

Table 10 Values of the EDFA preamplifier

Description	Value	Unit
Core radius	2.2	μm
Er doping radius	2.2	μm
Er Metastable lifetime	10	ms
Numerical aperture	0.24	
Er ion density	1 e + 024	m3
Loss at 1550 nm	0.1	dB/m
Loss at 980 nm	0.15	dB/m
Length	10	m
Forward pump power	2	mW
Backward pump power	150	mW
Forward pump wavelength	1550	nm
Backward pump wavelength	980	nm
Noise center frequency	1550	nm
Noise bandwidth	5	THz
Noise bins spcing	125	GHz
Noise threshold	-100	dB
Noise dynamic	3	dB

The difference between the EDFA booster and preamplifier is just on the value of the power of the forward pump where EDFA booster increase the power to greater levels than possible from the source is 6 mW, and EDFA preamplifier which increase the received power sensitivity is lower respectively 2 mW, because at these power values are achieved the best results of the amplified signal. After connecting the amplifiers, we became optical signal values as presented in figures 11 and 12 and tables 11,12,13 and 14.

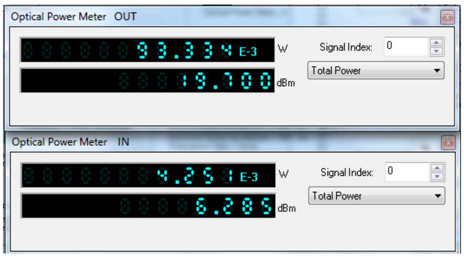

Figure 11 The power of the transmitter output signal to multiplexer and the input to demultiplexer using EDFA amplifier.

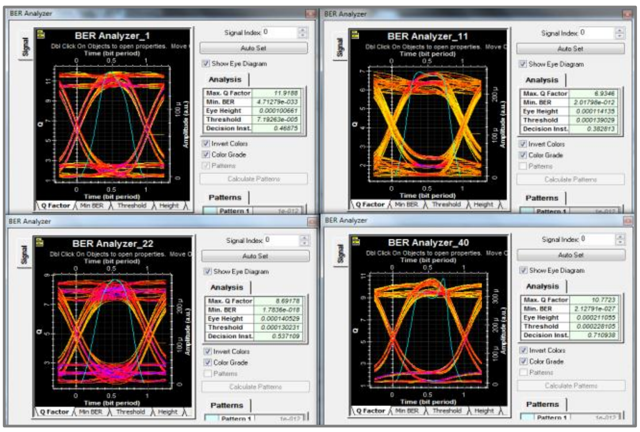

Figure 12 The value of the BER measured from BER Analyzer with EDFA

Table 11 BER values of 10 Gbps with EDFA ch_1

The 1st data channel	Value	Unit
Wavelength	1565	nm
Max. Q Factor	11.91	
Min. BER	$4.712*10^{-33}$	bps
Eye Height	0.0001	
Threshold	$7.19*10^{-5}$	
Decision Instant	0.46	bit period

Table 12 BER values of 10 Gbps with EDFA ch_11

The 11th data channel	Value	Unit
Wavelength	1556.87	nm
Max. Q Factor	6.93	
Min. BER	$2.01*10^{-12}$	bps
Eye Height	0.00011	
Threshold	0.00013	
Decision Instant	0.38	bit period

Table 13 BER values of 10 Gbps with EDFA ch_22

The 22th data channel	Value	Unit
Wavelength	1548.03	nm
Max. Q Factor	8.69	
Min. BER	$1.78*10^{-18}$	bps
Eye Height	0.00014	
Threshold	0.00013	
Decision Instant	0.53	bit period

Table 14 BER values of 10 Gbps with EDFA ch_40

The 40th data channel	Value	Unit
Wavelength	1533.77	nm
Max. Q Factor	10.77	
Min. BER	$2.12*10^{-27}$	bps
Eye Height	0.00021	
Threshold	$0.00022*10^{-5}$	
Decision Instant	0.71	bit period

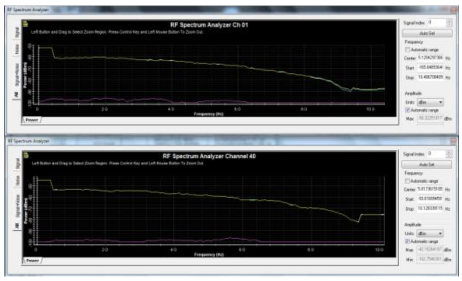

Figure 13 Radiofrequency Spectrum Analyzer

In the figure 13 we see that by using the EDFA amplifier the signal in ch_1 and in the ch_40 does not lose and transmission exceeding 10 GHz.

2.4 Data transfer with 40 Gbps capacity in the simulator (2^{nd} operator)

In the presented scheme of simulator network shown in figure 14 I will try to transmit data at 40 Gbps capacity. In this scheme the values of the WDM transmitter will be changed from 10 Gbps to 40 Gbps, the value of signal depth in WDM multiplexer and WDM demultiplexer now is 100 dB due to better performance of signal, as are presented in tables 15, 16, 17 and 18.

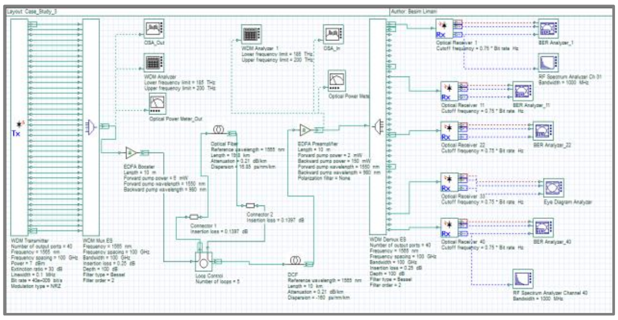

Figure 14 Optical network simulator scheme with 40 Gbps (2nd operator).

Whereas the values of the optical signal obtained after the measurements are shown in Figures 15, 16 and in the following tables.

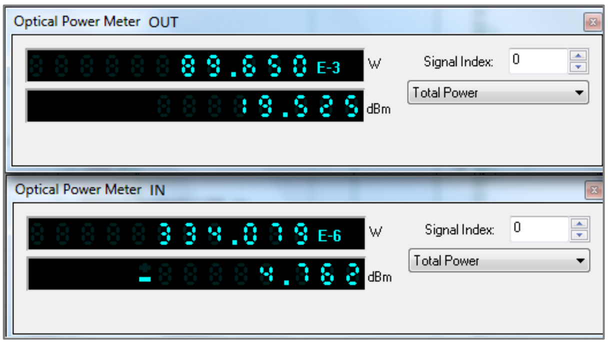

Figure 15 The power of the transmitter output signal to multiplexer and the input to demultiplexer

From this measurement is shown that the total optical signal losses are 24.287 dB.

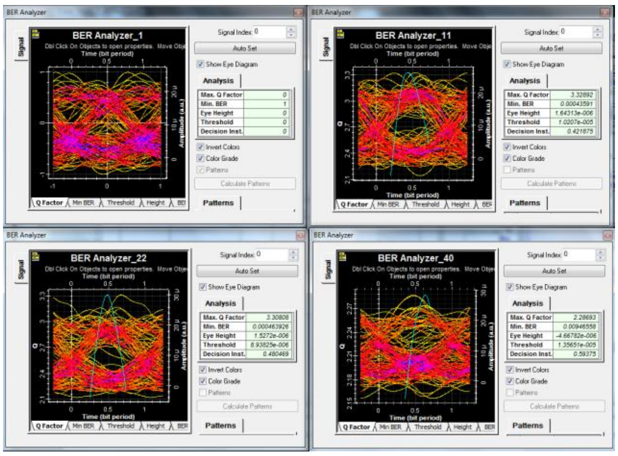

Figure 16 The value of the BER measured from BER Analyzer by 40 Gbps

Table 15 BER values of 40 Gbps ch_1

The 1st data channel	Value	Unit
Wavelength	1565	nm
Max. Q Factor	0	
Min. BER	1	bps
Eye Height	0	
Threshold	0	
Decision Instant	0	bit period

Table 16 BER values of 40 Gbps ch_11

The 11th data channel	Value	Unit
Wavelength	1556.87	nm
Max. Q Factor	3.32	
Min. BER	0.00043	bps
Eye Height	$1.64 * 10^{-6}$	
Threshold	$1.02 * 10^{-5}$	
Decision Instant	0.42	bit period

Table 17 BER values of 40 Gbps ch_22

The 22th data channel	Value	Unit
Wavelength	1548.03	nm
Max. Q Factor	43.30	
Min. BER	0.00046	bps
Eye Height	$1.52 * 10^{-6}$	
Threshold	$8.93 * 10^{-6}$	
Decision Instant	0.48	bit period

Table 18 BER values of 40 Gbps ch_40

The 40th data channel	Value	Unit
Wavelength	1533.77	nm
Max. Q Factor	2.28	
Min. BER	0.0094	bps
Eye Height	$-4.66 * 10^{-6}$	
Threshold	$1.35 * 10^{-5}$	
Decision Instant	0.59	bit period

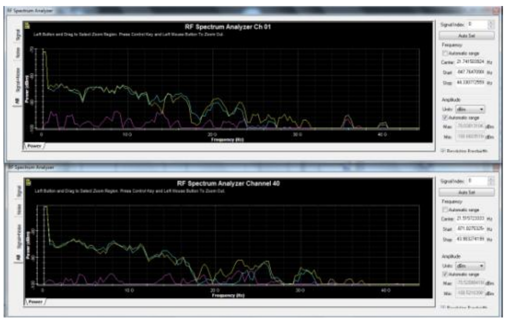

Figure 17 Radiofrequency Spectrum Analyzer

The figure 17 above shows that 40 Gbps transmission without use of EDFA amplifiers degraded already in 20 Gbps.

2.5 Data transfer with 40 Gbps capacity in the simulator using EDFA amplifier

Noting that the topology at approximately same value, the same as it was presented in figures 5 and 10 have achieved to transmit 10 Gbps at full capacity and I have not yet transmitted 40 Gbps at full capacity, then I will connect EDFA amplifier to improve optical signal values. The scheme or the amplifier topology with EDFA amplifier is shown in figure 18.

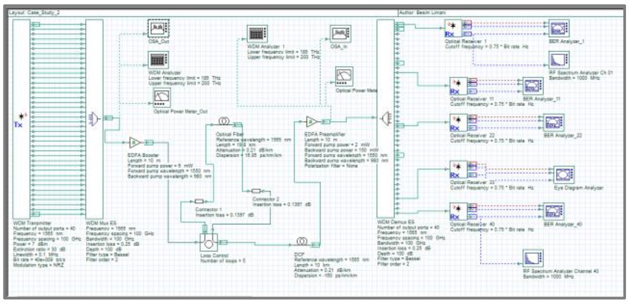

Figure 18 Optical network simulator scheme 40 Gbps with EDFA (2nd operator)

If we now examine the values of amplifiers in scheme above note that the value of the signal amplifier in the first amplifier (booster) is 6 mW respectively 7.78 dB, while in the second amplifier signal we have in the pre-amplifier value 2 mW respectively 3.01 dB. Improvement of the total value of the optical signal is considerably better as shown in figure 19 from the measurements of Optical Power Meter.

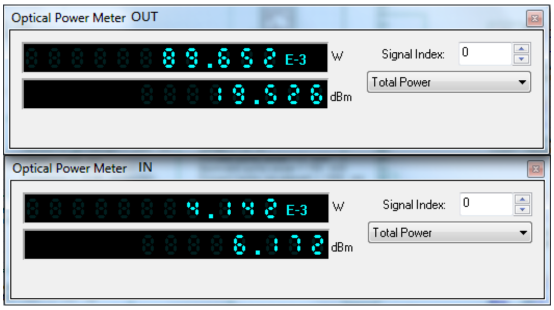

Figure 19 Optical Power Meter

The difference output signal from the multiplexer and input signal from the demultiplexer value is 13.354 dB, this mean that the optical signal during its travel along the optical cable length ~ 109 km has incurred losses of only 13.354 dB. This change improves the loss of optical signal quality which have noticed with measurements made on the simulator as they are presented in figures 20 and 21 below.

While in figure 20 we find the eye height form for channels 01, 11, 22 and 40.

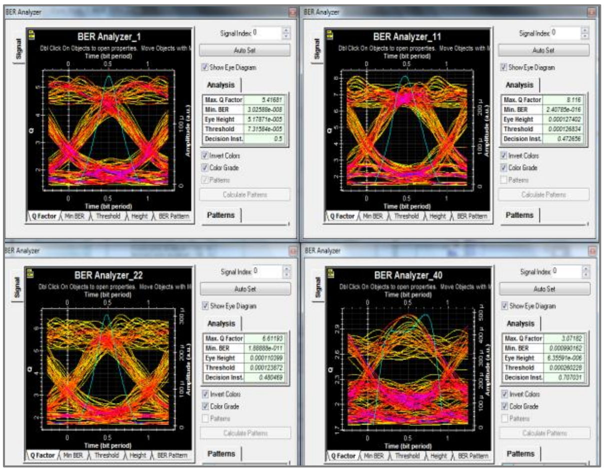

Figure 20 BER Analyzer 40 Gbps with EDFA

The measured values with the BER analyzer are presented in the following tables:

Table 19 BER values of 40 Gbps with EDFA ch_1

The 1st data channel	Value	Unit
Wavelength	1565	nm
Max. Q Factor	5.41	
Min. BER	$3.02 \cdot 10^{-5}$	bps
Eye Height	$5.17 \cdot 10^{-5}$	
Threshold	$7.31 \cdot 10^{-5}$	
Decision Instant	0.5	bit period

Table 20 BER values of 40 Gbps with EDFA ch_11

The 11th data channel	Value	Unit
Wavelength	1556.87	nm
Max. Q Factor	8.11	
Min. BER	$2.40 \cdot 10^{-16}$	bps
Eye Height	0.00012	
Threshold	0.00012	
Decision Instant	0.47	bit period

Table 21 BER values of 40 Gbps with EDFA ch_22

The 22th data channel	Value	Unit
Wavelength	1548.03	nm
Max. Q Factor	6.61	
Min. BER	$1.88 \cdot 10^{-11}$	bps
Eye Height	0.00011	
Threshold	0.00012	
Decision Instant	0.48	bit period

Table 22 BER values of 40 Gbps with EDFA ch_40

The 40th data channel	Value	Unit
Wavelength	1533.77	nm
Max. Q Factor	3.07	
Min. BER	0.00099	bps
Eye Height	$6.35 \cdot 10^{-6}$	
Threshold	0.00026	
Decision Instant	0.70	bit period

This improvement of the signal is shown from measurements made with RF Spectrum Analyzer in figure 21.

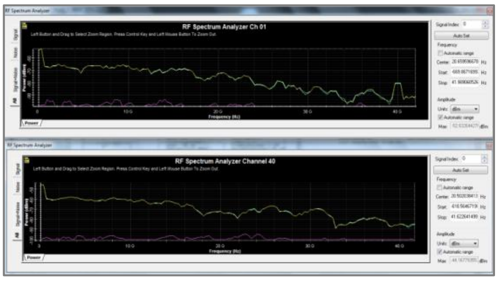

Figure 21 Measurements made in the simulator with RF Spectrum Analyzer

In the figure 21 we see that by using the EDFA amplifier the signal in ch_1 and in the ch_40 does not lose and transmission exceeding 40 GHz.

Conclusions

In this case study I have analyzed the performance of transmission on the transmission backbone line Pristina - Skopje with optical fiber, which is based on simulation of software application (OptiSystem 13.0). Based on WDM transmission technology analysis of 10 Gbps and 40 Gbps, I have analyzed each transmission in two cases, the first case study with EDFA amplifier and the second case study without EDFA amplifier, and I have presented results in graphical and tabular form.
In each exposed figure, appears that the optical signal in the case of using EDFA amplifiers have better form and value, than in cases where we do not use signal amplifier.

If we focus on channels without EDFA amplifier and channels with EDFA amplifier, then it appears that the error rate of bits is much lower in each channel in which is used EDFA amplifier.

Also, if we focus in Q - Factor without EDFA amplifier and with EDFA amplifier values we see that Q-Factor value in channels with EDFA amplifier is higher than in channels without EDFA.

This confirms the theory of the relationship between Q-Factor and BER's that: the signal has better values if Q-factor value is higher and the BER value is lower

Without EDFA amplifier it is difficult to achieve transmitted target of data values, and the transmitted signal will be often degraded before reaching its target. That means we have a losses of signal.

Therefore, from the realized results, it appears that the using WDM/DWDM technologies and EDFA amplifier in transmission systems with fiber optics, will help for achieving a long distances transmission and high capacity, without needing to add additional optical cables, in such way will maintain low cost of transmission systems.

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