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NG-PON2 Network With 120Km Fiber Length Using Fiber Bragg Grating FBG

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Abstract

Next generation optical network are of great importance in face of the increasing number of subscribers and the increasing number of services provided by telecommunications companies around the world and the high quality of these services. Next generation optical network NG-PON2 which use TWDM technology are one of the latest standards set by the ITU-T organization and are especially used for FTTH applications to connect the fibers optic to the subscribers homes at the lowest cost and highest quality. This research examines the possibility of modifying the structure of ONU units for NG-PON2 using Fiber Bragg grating or what it is called FBG in order to increase the transport distance to 120km across single-mode optical fiber based on OptiSystem software, and comparing the final result of the research with the standard values of these system.

Keywords: NG-PON2; FBG; FTTH;T WDM ; PON; ONU.

1. Introduction

The steady increase in the number of subscribers and services provided by ISP's such as IPTV services, interactive games and virtual reality service and the need for high data rates have led to the development of communication networks to meet this increase and provide suitable solutions to deliver these services to subscribers with high quality.The basic standard for NG-PON2 networks has been initiated by the ITU since 2011 to be completed around the end of 2015 [1], and The aim of this work was to develop fiber optic network technologies to increase the transmission speed beyond the 10Gbps.

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NG-PON2 networks are based on the aggregation of multiple XG-PON networks with each other using WDM technology on the downlink to double the transmission speed. The XG-PON network offers data rate on the downlink of up to 10Gbps and on the uplink 2.5Gbps, The NG-PON2 of four pairs of wavelengths can achieve a downlink speed of up to 40Gbps and uplink 10Gbps or 40Gbps [1]. NG-PON2 networks use WDM technology on the downlink and TDM on the uplink, i.e. they use hybrid aggregation technology, so they are called TWDM-PON networks [1,2]. ITU-T G.989 sets out a complete set of requirements and recommendations describing the NG-PON2 network communications system. This standard specifies a transmission rate of up to 40Gbps on both downlink and uplinks to service 256 ONU units over a fiber optic length 40-60Km using four pairs of wavelengths. This study proposed to find a way to modify the OLT module on the transmitting terminal using fiber Bragg grating FBG with the EDFA optical amplifier, to multiplying the downlink data rate to 200Gbps to serve 512 ONUs at a distance of 60Km from the main center. After designing the proposed system and run the simulation, we compared the final results with the standard values of the NG-PON2 networks adopted in ITU-T G.989 by the International Telecommunication Union (ITU) to demonstrate the advantages and feasibility of using the FBG with this type of network within the OLT.

1.1. TWDM networks

figure.1 shows the TWDM infrastructure consisting of according to ITU-T G.989 standard [1]:

- The OLT which contains four transceiver for both downlink and uplink direction. The four transmitters signal are multiplexing using WDM multiplexer for transmission over the optical fibers on downlink. WDM Demultiplexer are used to Demultiplex the received signal on the uplink, with the possibility of multiplying the number to eight transceiver according to ITU-T G.989 and possible use of optical amplifiers in the OLT.
- Optical distribution network (ODN) is mainly composed of the single mode optical fiber (SMF) and the optical splitters that distribute the optical signal to the ONUs.
- ONU's units at subscribers end that transmit and receive at specified wavelengths using calories transceiver.

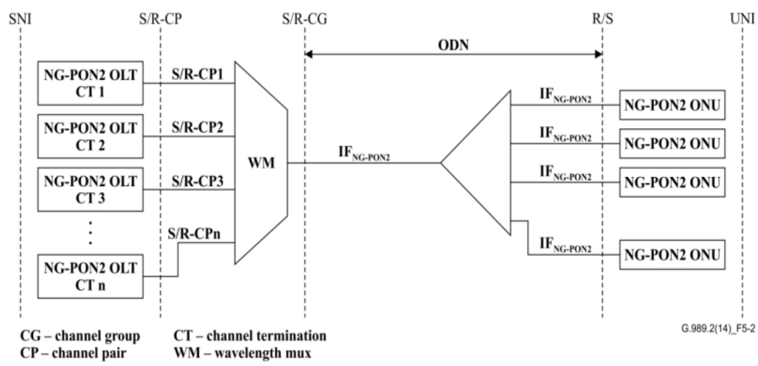

Figure 1: TWDM infrastructure [1]

S/R-CG point and R/S point are the points that are used to measure the optical power on both downlink and uplink direction also according to ITU-T G.989 standard, and they have been adopted in this study.

2. Proposed network design

TWDM-PON networks consist mainly of four transceiver placed next to each other within the OLT in the main telecommunication center. The signals from the transmitters are collected on the downlink using the WDM multiplexer to place the collected signal on the optical fiber and transfer it to the subscriber devices after passing through number of optical splitters that share and distribute the signal to the largest possible number of subscribers while maintaining the quality of the services provided. The OLT of TWDM-PON networks is often performed by combining four pairs of tunable transmitters and receivers for a 40Gbps transfer rate, and this number can be doubled to a transfer rate of 80Gbps[1]. The model was designed using the OptiSystem program. The downlink was only simulated for the TWDM-PON system with the ONU structure modified with the addition of the fiber Bragg grating (FBG) and an optical amplifier (EDFA) to increase the optical fiber length from 40Km to 120Km and then compare the final results with standard values in the standard ITU-T G.989.2. figure.2 shows the outline of the studied model consisting of OLT with four transmitters whose signals are collected using the WDM multiplexer to be transmitted over 120 km optical fiber at 40Gbps data rate and divided by two stage of splitters, the first optical power splitters using 1:4 splitter followed by 1:64 splitter to distribute the signal to 256 subscribers.

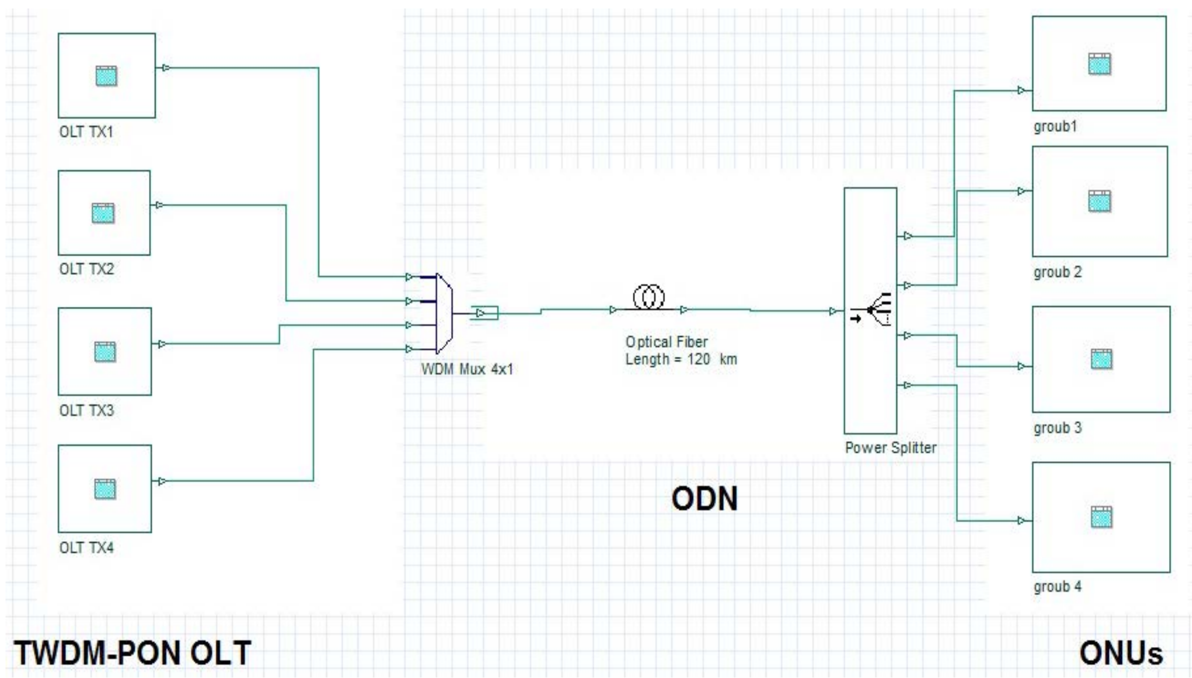

Figure 2: Proposed network design

The ONUs were divided into four groups as shown in the figure.2. Each group contains 64ONU and thus the total number of ONU is 256 ONU, Fig.3 shows the components of the first group of subscribers and is the same for the four groups.

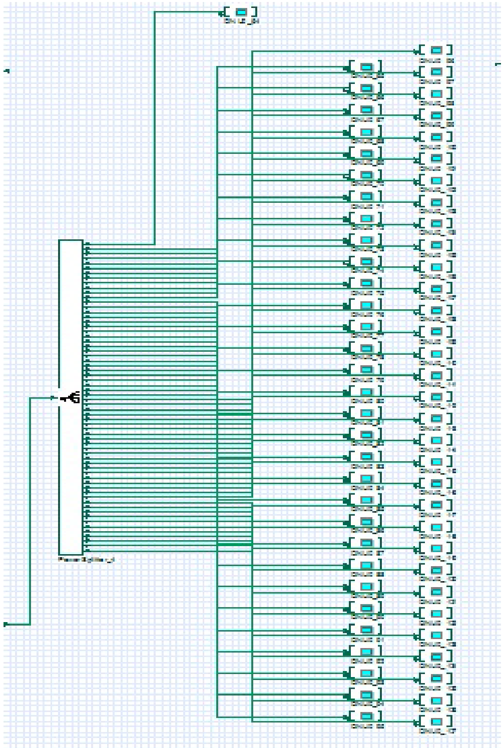

Figure 3: Group 1 components

Each transmitter in the OLT and is set up of a digital data generator (PRBS) which generates a series of digital data that will be sent to the optical fiber followed by a NRZ code and a continuous CW laser laser that gives continuous laser beam modulated by digital data using an external MZM rate as shown in figure.4.

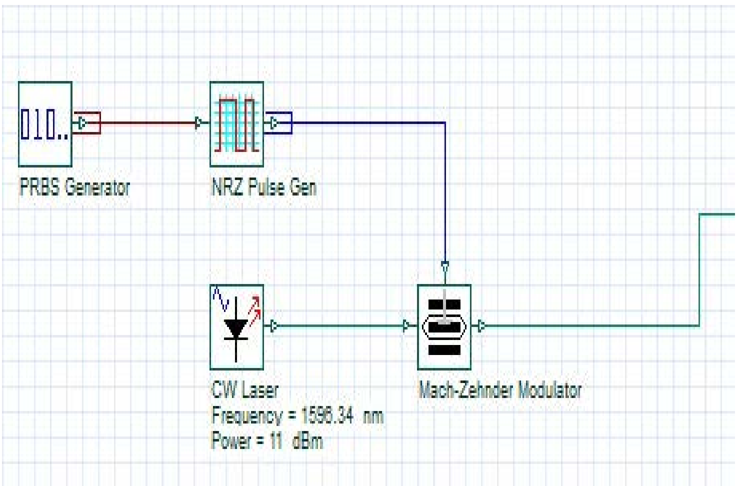

Figure 4: OLT infrastructure

The optical signals from the four transmitters are collected using the WDM multiplexer. figure.5 shows the optical spectrum of the four signals sent and collected using the WDM multiplexer at 1596.34 nm, 1597.19nm, 1598.04nm and 1598.89nm taken after the WDM/MUX.

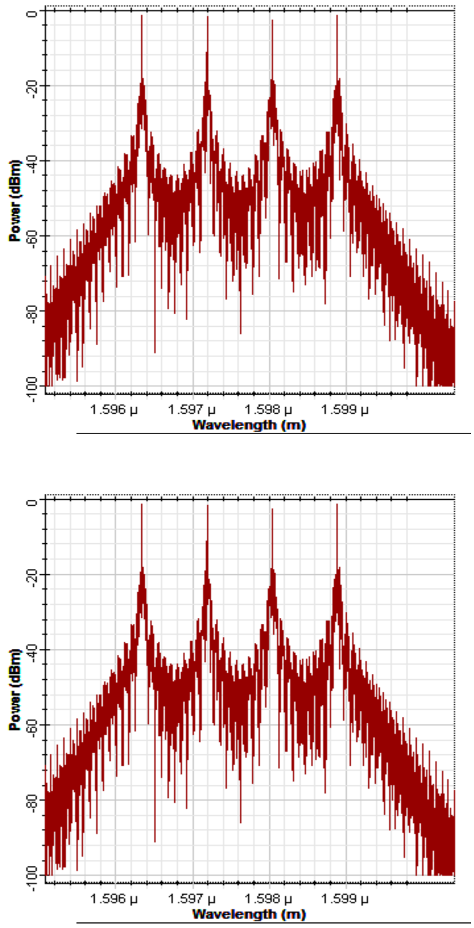

Figure 5: optical signal spectrum after WDM/MUX for downlink

The signal after that travels through a SMF optical fiber for a distance of 120Km.

Optical splitters are used within the ODN at the subscriber's end to split the signal to as many subscribers as possible because they are low in cost and do not require electrical power to operate, taking into account the loss of partition and the capacity available on the network [7]. The ONU unit at the subscribers is configured as shown in fig.6 from an EDFA and an FBG followed by an APD detector that converts the optical signal to an electrical signal that is filtered using a low-pass filter and extracts data from it.

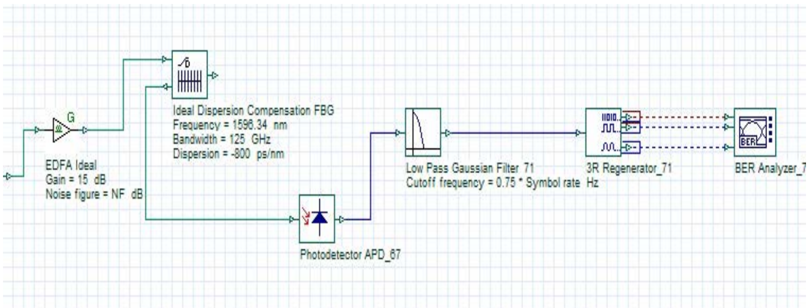

Figure 6: ONU infrastructure

Table (1) shows the most important parameters of the studied model.

Table 1: Proposed network design parameters

Parameter	**Value**
Data rate	4 x 10=40Gbps
Coding	NRZ
Number of channels	4
Channel spacing	100GHz
Laser power	3dBm to 12dBm
Splitters losses	(7.3 dB) for 1:4 (20.5 dB) for 1:64
Optical fiber length	120Km
Number of ONU	256

3. Results and discussion

Most of the studied values which used in the comparison are based on the first optical channel and for the first subscriber, taking into consideration that all optical channels and all subscribers have the same characteristics and therefore have similar values. The final simulation results were compared with the standard results in ITU-T G.989 to demonstrate the potential and advantages of using FBG in this type of network at the ONU user end, as well as comparing them with some results of similar previous research. When reviewing ITU-T G 989.2 we find that for a single optical channel at a 40Gbps data rate, the maximum transmitted signal at S/R-CG point is in the domain 7-11 dBm and the receiving signal power is about -28 dBm and the bit error rate BER at this values is 10^{-3} After transmitting the signal for a distance of 40 Km over a SMF fiber with typical values for both inductance and dispersion (0.2 dB/Km and 16.75ps/nm/Km dispersion). When the optical fiber length increases from 40Km to 120Km (80Km increased), the delay increases by 0.2x80=16dB. Therefore, we use an EDFA amplifier with a 15 dB amplification factor to overcome this loss of signal capacity. In addition to the attenuation, the length of the optical fiber increases the distortion at the optical signal as a result of dispersion. This is what the FBG will work on, as mentioned in the previous paragraph. If we consider that the fiber dispersion is 16.75ps/nm/km, the total value of the dispersion along the 120Km length will be:

120 x 16.75=2010 ps/nm

While the value when the length of the fiber 40Km is equal to:

40 x 16.75 = 670 ps/nm

An increase of 1340 ps/nm, an FBG with a dispersion value of -800ps/nm was added to compensate for this increase.

figure.7 shows the eye diagram of the receiving signal after transmission to a distance of 120Km with a transmission rate of 40Gbps and transmitting power of 11 dBm at S/R-CG point.

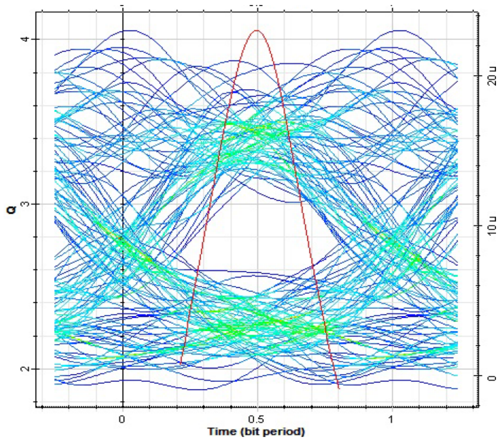

Figure 7: eye diagram of the receiving signal after transmission to a distance of 120Km

The figure shows an eye diagram that can be considered acceptable for the received signal with a bit error rate of 2.4 x 10^{-5} and Q = 4.05 and a receiver power of -25dBm at R/S point which is close to the standard values.

Table (2) shows a comparison between the standard state values taken from ITU-T G989.3 and the case studied after adjusting the ONU structure and adding an FBG.

Table 2: comparison between the standard state values from ITU-T G.989.3 and the study result

	Study results			**ITU-T G989.2 [1]**		
Data rate	40Gbps			40Gbps		
Fiber length	120Km			40-60Km		
Number of ONU units	256 ONU			256 ONU		
Maximum Tx power at S/R-CG	7dBm	9dBm	11dBm	7dBm	9dBm	11dBm
Rx power at R/S point	-29dBm	-27dBm	-25dBm	-28dBm		
BER	1	10^{-3}	10^{-5}	10^{-3}		

It is noted from the table that the value of the BER decreases in order to send 11dBm. The measured transmission distance is three times the standard distance. For 7dBm we can see that the BER = 1, which means that the signal is highly distorted and impossible to retrieve. We also notice a clear improvement in the receiving power level from -28dBm to -25dBm for a transmitter power of 11dBm.

figure.8 shows the relationship of the transmitted signal power with the receiver sensitivity for the first optical channel at a wavelength of 1596.34nm, for two different values of FBG, the first value of -800 ps/nm and the second value of -700 ps/nm.

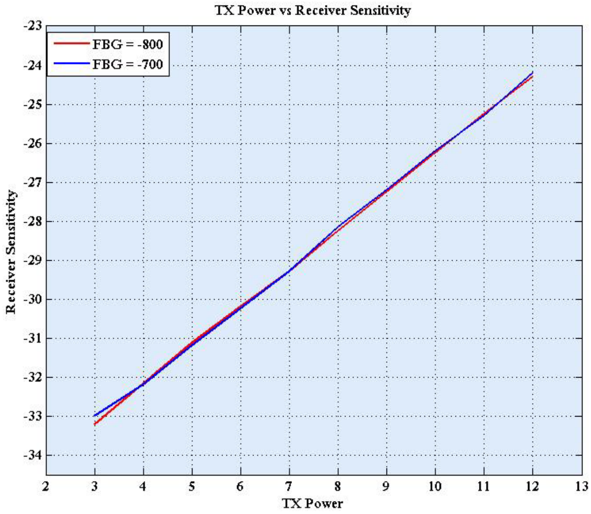

Figure 8: relationship of the transmitted signal power with the receiver sensitivity, for two different values of FBG

It is possible to observe that the dispersion value of the FBG does not affect the relationship between the transmitted signal power and the receiving signal power.

figure.9 shows the relationship of the transmitted signal power with the BER for different values for FBG dispersion.

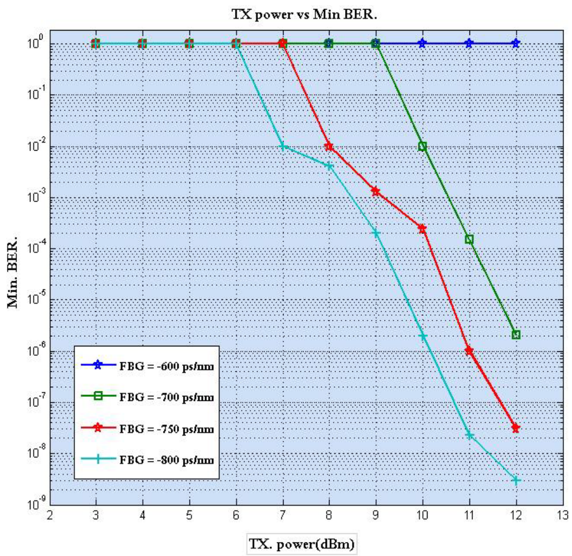

Figure 9: relationship of the transmitted signal power with the BER for different values for FBG dispersion.

figure.9 shows that for all dispersion values of the FBG, the BER value decreases when the signal power being increased but we note that at the dispersion value of -600 ps/nm, none of the transmitted data can be retrieved and BER = 1, For the same values as the transmitted signal power, the BER value is lower and the FBG offset value is increased to send 12dBm to BER = 10^{-9} for FBG = -800 ps/nm and BER = 10^{-6} for FBG = -700 ps/nm.

4. Conclusion

NG-PON2 networks based on TWDM technology are promising technologies because of the bandwidth available to subscribers, enabling operators to serve their subscribers with better services and are therefore of great interest to both companies and service providers. In this research, a NG-PON2 network model was designed to serve 256 subscribers at 40Gbps data rate and a 120Km fiber length with OptiSystem software. The design was based on the use of the FBG within the ONU module to compensate for the dispersion along the optical fiber length and to improve the quality of the receiving signal to detect it correctly and with the lowest bit error value. The study showed good values for both the quality factor and the BER compared to the standard values set at the length of 40Km. For a length of 40Km, the BER value was 10-3 at 11dBm on the downlink at the wavelength 1596.34nm. When the optical fiber length is increased to 120Km, we obtained a BER value of (10^{-5}) at the same transmission power on the downlink and at the same wavelength. We also noted from the results for the previous effect that the value of the BER of the received signal was affected by the dispersion value of the FBG. For 12dBm we can note that BER = 10^{-9} for FBG = -800 ps/nm and BER = 10^{-6} for FBG = -700 ps/nm.

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