Evaluation of the Performance of a HPON Network Using SNR Changes Resulting from an Increase in the Length of Bidirectional Optical Fiber

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ABSTRACT:
A hybrid TDM / DWM PON network with 64 users was designed by a bidirectional optical fiber in this paper. Having analyzed the performance of the hybrid network on the basis of signal to noise ratio (SNR), the parameter was calculated for different fiber lengths. All designing procedures were performed by optisystem software and measured values were represented and evaluated. As expected, the result showed that, due to an increase in the length of the fiber, the amount of noise increased and consequently, the signal to noise ratio decreased. However, it was found that the used topology was able to receive information in both upstream and downstream for fibers with a length up to 30 km and parameters of Q factor, the bit error ratio, and the signal to noise ratio are desired and acceptable for fibers of 30 km length.

KEYWORDS: Hybrid TDM/WDM PON; SNR; OPTIWAVE.

1. INTRODUCTION

Due to the growing number of users and their communication needs on the one hand and the inability of copper lines and wireless approaches in response to this increasing trend on the other hand, a lot of attention is given to PON networks [1]. Passive optical networks (PON) are important because of the lack of restriction on the fiber transmission bandwidth and the reduced cost of broadband services. Like other FTTx networks, PON constitutes three main components of OLT in CO, some ONU and an ODN network (Figure 1). PON networks are called so due to the fact that the networks can't use active components in infrastructure. In fact, if RN in German FTTx networks is active, the network is called active optical network (AON); otherwise, in the case of using a passive RN, it will be called passive optical network [2].

From among the common multiplexing methods, TDM and WDM are used in PON networks. Due to restrictions in TDM-PON network, the network is used for short distances at low speeds with low number of users [3]. The WDM-PON network is able to provide services for a large number of users over long distances.

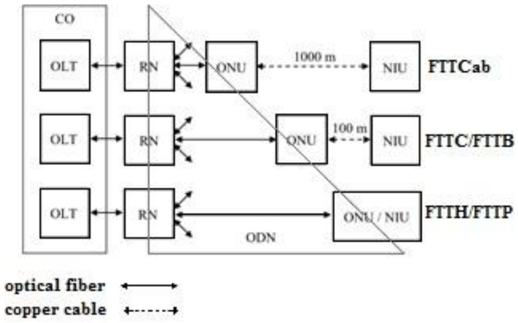


Fig. 1. Different types of FTTx architectures [4].

The price of these networks is, however, much higher than that of TDM-PON networks. Therefore, due to these different properties, TDM / WDM PON were proposed for the maximum use of optic fiber capacity and network optimization [5-7].

The combination of two techniques TDM-PON and WDM-PON has excellent transmission properties such as the ability to provide services to a large number of users, the ability to provide high-capacity services per user. Hybrid TDM / WDM PON (HPON) technique is also cost effective from the perspective of its economic aspects. In TDM / WDM PON, high splitting ratios are provided by TDM- PON and the large number of wavelengths by WDM-PON. Fig.2 depicts the structure of a HPON network. In the hybrid method, WDM technique is used to exploit the long distance between OLT and ONU. The signal is divided into separate wavelengths using an AWG demultiplexer. In the hybrid method, the time splitting demultiplexer is located in the nearest possible point to the target that is accessible to the network [3].

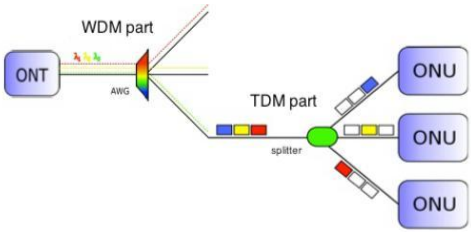


Fig. 2. Hybrid passive optical network.

This paper is an attempt in designing an optimal structure of the hybrid TDM / WDM PON (HPON) network using Fabry Perot (FP) laser. FP laser is used mainly for this reason that it can adjust its own wavelength with WDM input wavelength [3].

A communication channels can be described by different variables. Channel momentary gain, channel frequency response, parameters related to channel momentary traffic, parameters related to the fading channel and signal to noise ratio (SNR) are among the variables. Since SNR is considered as one of the main parameters of a communication channel, this article has focused on the calculation of the parameter and the investigation of SNR changes resulting from an increase in the length of the bidirectional optical fiber [8-9].

In the second part of the article, the various parts of the designed topology are described. The results of the simulation are presented in the third part and then the conclusion is given in Section IV.

2. DESIGNING THE TOPOLOGY IN OPTIWAVE

Fig. 3 shows the general block diagram related to the topology simulated in this study. The block is divided into several main parts of upstream and downstream transmitters, upstream and downstream receivers and FP laser feed. 32 wavelengths with 100-GHz gap in each band have been used in this design.

The CW laser array is applied in the transmitter part that allows all 32 lasers be grouped together. CW laser makes the compatibility of lasers as simple as possible. CW laser output is turned into a single stream by an AWG that is configured as a multiplexer. Figure 4 shows the signal at the output of the AWG. This signal contains 32 waveforms with a distance of 100 GHz.

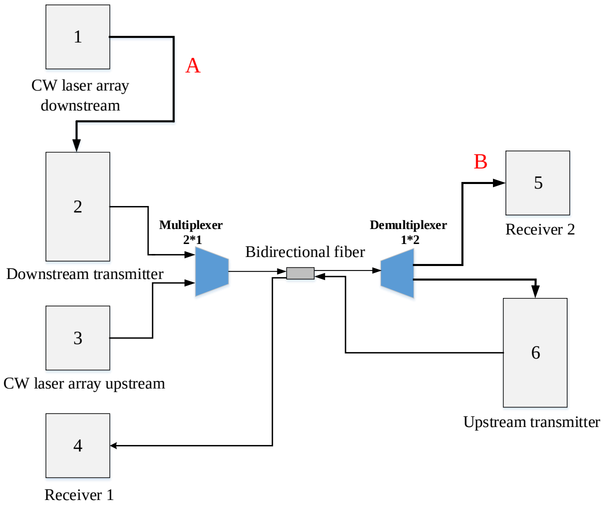


Fig. 3. General block diagram used in this study.

When the signal was multiplexed, consecutive filtering operations, strengthening and TDM multiplexing were exercised on it. These steps apply to each of the 32 channels. Figure 5 shows the FP laser circuit and how to use TDM multiplexer related to any one of the 32 channels. As seen in the figure, the input signal is generated by PRBS and is given to the input of RZ pulse generator. FP laser's output signal and the output signal of TDM transmitters are shown in figures 6 and 7, respectively.

When the signal was multiplexed, consecutive filtering operations, strengthening and TDM multiplexing were exercised on it. These steps apply to each of the 32 channels. Figure 5 shows the Fabry Perot laser circuit and how to use TDM multiplexer related to any one of the 32 channels. As seen in the figure, the input signal is generated by PRBS and is given to the input of RZ pulse generator. FP laser's output signal and the output signal of TDM transmitters are shown in figures 6 and 7, respectively.

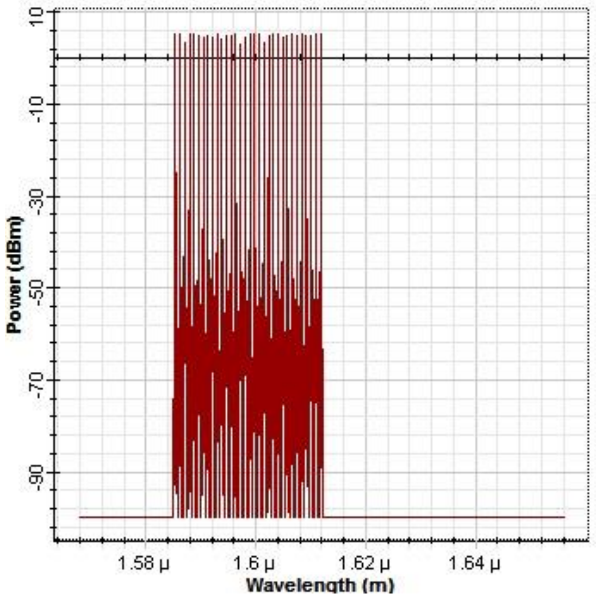


Fig. 4. CW laser array-downstream output

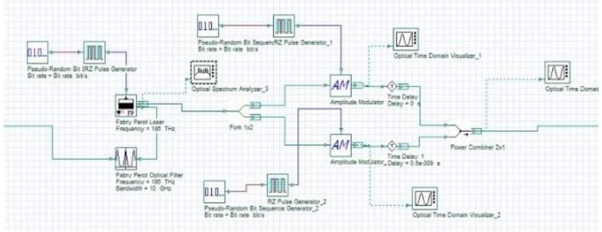


Fig. 5. Fabry-Perot laser and implementation of TDM multiplex.

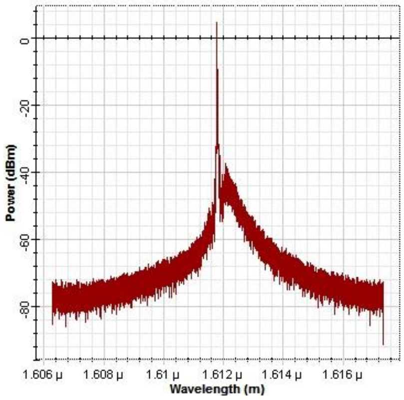


Fig. 6. Fabry-Perot output signal.

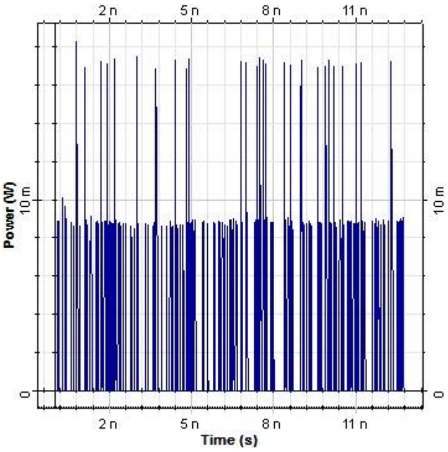


Fig. 7. Two channels in TDM output.

As mentioned earlier, FP lasers are mainly used because lasers are capable of adjusting their own wavelength with the input ones and are located at the upstream transmission instead of being placed in ONU in OLT. Since the above- mentioned designing is done in L and C frequency bands, AWG enters EDFA amplifiers for uplink transmission (EDFA amplifier has a uniform gain at the wavelength range of 1550nm, therefore it is the most suitable amplifier for this wavelength).

EDFA output signal related to FP laser feed of the upstream path (output of block 2 in Figure 4) accompanied with the signal of the data related to the downstream transmission (output of block 3 in Figure 4) must pass from bi-directional optical fiber simultaneously. An ideal 1*2 multi-multiplexer is used for the integration of the two streams. Figure 8 shows the output signal of the ideal multiplexer.

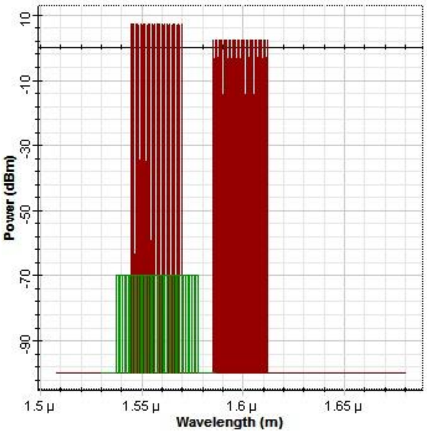


Fig. 8. Multiplexer output before line.

In the receiver, signal is splitted into separate wavelengths by an AWG that is this time configured as a demultiplexer. Each of the 32 AWG output streams is divided into two parts by a power divider and then both signals are modified in a similar way. Both are pushed at first into an APD diode that is set on the highest power to get a signal. After the diode, a low-pass filter and a 3R amplifier are used at the end of the path. The amplifier rebuilds and strengthens the form and the time basis of the signal (Fig. 9). The final element is a BER analyst. The analyst determines the exact properties of the signal after passing through the topology. Eye diagram in the receiver is represented in Figure 10. The output is obtained by RZ pulse generator for a fiber with a length of 5 km and 10 Gbps bit rate.

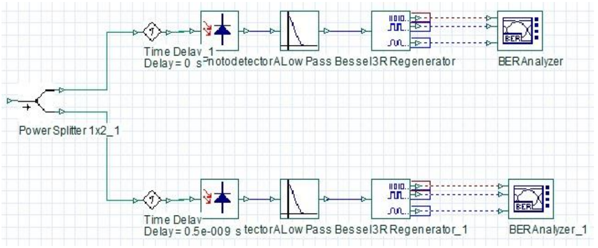


Fig. 9. Receiver circuit.

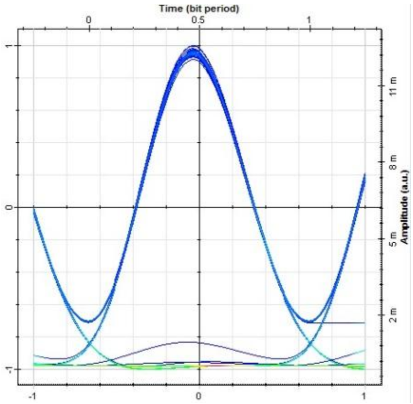


Fig. 10. Eye diagram showing the first channel of the topology with 10 Gbps on fiber length 5 km and RZ coding.

3. SIMULATION RESULT

3.1. Investigating the Designed Topology

Topology properties are carefully measured in this section. Parameters measured include the amount of power loss between the transmitter and receiver, as well as the evaluation of the quality of the output signal using parameters of Bit error rate and Q factor. Reduction in the output power level represents the power loss between two given points of topology. For the discussed topology, these points are shown by A and B in Figure 4. The values for Q factor, BER and Eye height are also achieved using BER analyst. Table 1 shows the measured values of these four parameters for fibers of length 5, 15 and 30 kilometers and the bit rate of 10 Gbps. Table 2 shows the values of these parameters for fiber with a length of 5 km and for bit rates of 2.5, 5 and 10 Gbps. To better understand the changes in the parameters, the curve of the changes is plotted in Fig.11. As it can be seen, an increase in the length of the fiber worsens the performance of the topology; however, the circuit's performance is desirable in fiber of up to 30 km, in which case the information are acceptably transmitted and received. A similar trend is also seen when the bit rate increases (figure 11. b).

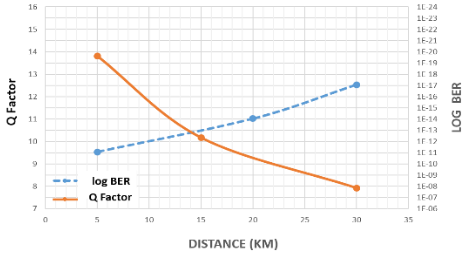
Table 1. Analysis of HPON network at different distance with 10 Gbps.

Distance (km)	5	15	30
Q factor	13.81	10.18	7.94
BER	$8.46*10^{-18}$	$9.12*10^{-15}$	$8.74*10^{-12}$
Drop of output level (dBm)	6.71	7.42	8.35
Eye height	$1.1*10^{-2}$	$8.3*10^{-3}$	$3.3*10^{-3}$

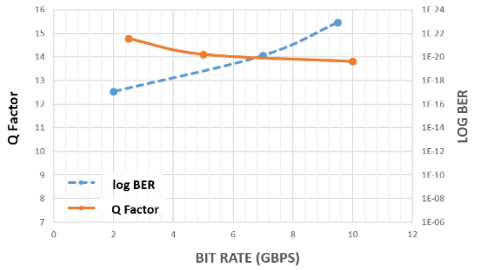
Table 2. Analysis of HPON network at different Bit Rate on fiber with a length of 5 km.

Bit Rate (Gbps)	2.5	5	10
Q factor	14.78	14.11	13.81
BER	$1.27*10^{-23}$	$7.84*10^{-21}$	$8.46*10^{-18}$
Drop of output level (dBm)	5.86	6.13	6.71
Eye height	$5.56*10^{-2}$	$3.9*10^{-2}$	$1.1*10^{-2}$

All results listed are related to downstream path and a quite similar trend are seen in upstream direction. Q factor values of the upstream path are represented in figure 12. As it can be seen, the upstream path's performance is worse than that of the downstream path, but the difference in parameters is negligible.



(a)



(b)

Fig. 11. Changes of different parameters of network: a) due to an increase in the length of fiber, b) due to an increase in the bit rate.

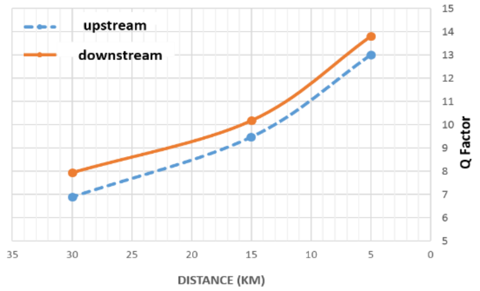
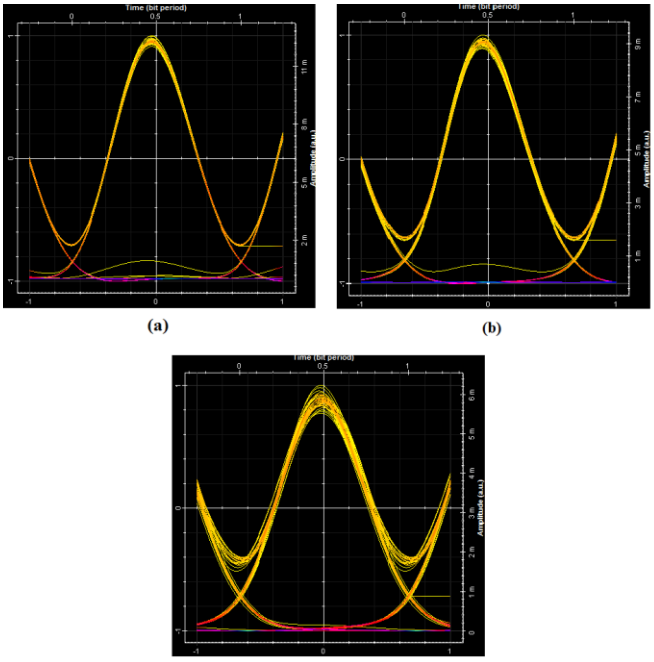


Fig. 12: changes of Q factor as a result of increased fiber length in both upstream and downstream paths.

3.2. SNR Changes Resulting from an Increase in the Length of Bidirectional Optical Fiber

Figure 12 shows Eye diagram of the discussed topology for different fiber lengths and constant bit rate of 10 Gbps.

At the next stage, the amount of SNR is obtained for relatively long fibers of 2 to 35 km and 4 km steps by WDM Analyzer element in the OPTISYSTEM library. Values are listed in Table 3. The curve for SNR change is plotted in Figure 13. As it can be seen, SNR changes are negligible in the topology designed to the fiber with length of 30 km and don’t have a significant impact on the network performance, and the above network will be able to receive and send information in distances of up to 30 km.



(a) (b)

(c)

Fig. 13. Eye diagram in bit rate of 10 Gbps for fibers with a length of a) 2km, b) 15km, c) 30km.

Table 3. SNR changes resulting from increased fiber length.

Distance	2	6	10	14	18	22	26	30	35
SNR	88.7	88.3	87.8	87.2	86.7	86	85.5	84.7	81

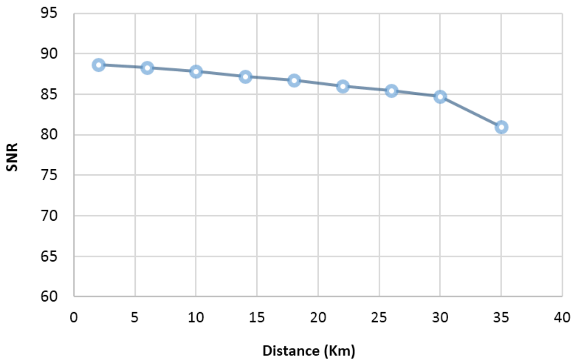


Fig. 14. The curve for SNR changes resulting from increased fiber length.

4. CONCLUSION

Given the importance of HPON networks in communications systems, this paper explores a descriptive topology for them. Modern parts such as FP laser and AWG are applied in the topology. Using AWG instead of the conventional dividers has the advantage that in AWG, increased number of output will not increase the amount of attenuation. Because of this feature, the proposed topology is very flexible in increasing the number of users. As expected, all parameters of power loss, and bit error rate and Q factor decreases with an. Despite these errors, however, the parameters measured are normal and the signal is properly transmitted. All the results obtained from the simulations are the expected results. The values obtained for the patency rate of Eye diagram are acceptable which implies the appropriateness of signal to noise ratio. SNR values also confirm this issue.

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