Received: 02.05.2016
Accepted: 15.01.2017

Performance of EDFA Amplifier Position (Pre-, Post- and In-Line Amplification) for Reach Extendibility of GPON-FTTH

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Abstract - This article is dealing with simulation of deployment of EDFA optical amplifier in different positions (post- amplifier or booster, in line and pre-amplifier) used for GPON downstream, which depend essentially on the opt-geometric parameters (ions erbium density and length of the fiber doped erbium) and the effect of those parameters to optimize the performance for extending the reach up to 60 km of and with 1:128 split ratio of the GPON. The performance of this system has been evaluated in terms of the quality factor, eye diagram and the minimum of BER with various simulations by sweeping fiber length and input signal power. It has been found that, the pre-amplification was performed and found to be superior with good results to inline and post amplificationn methods.

Keywords: *GPON access, EDFA booster, preamplifier, post-amplifier, eye diagram*

1. Introduction

Due to the plurality of end user types and very heterogeneous nature of services, internet data traffic in access networks has been becoming very dynamic and unpredictable[1]. This makes passive optical networks (PONs) are an attractive solution and the most important class of fiber access network in the world .Current passive optical networks (Gigabit PON (GPON)) is a promising solution to the increasing needs of higher bandwidth demands demand.

GPON is defined by ITU-T recommendation series G.984 [2], [5]. Its main characteristic is the use of passive splitters in the fiber distribution network, enabling one single fiber from the provider's central office to serve multiple homes and small businesses. Theoretically GPON have the same basic wavelength plan and use the 1490 nm wavelength for downstream traffic and 1310 nm wavelength for upstream traffic [3]. 1550 nm is reserved for video services and can be used for a distance approximately 60 km.

But, due to the losses at the remote node, and in electronic components present at the ONU and ONT makes the signal traverse only 20 Km. So, the requirement needs large link power budget and gives rise to the use of optical amplifiers in GPON systems to extend bandwidth and reach in optical networks.

2. System Amplifier

The advancement in the optical communication for access network transmission leads to development of powerful optical amplifiers, which amplifies the optical signal directly without having to convert the signal into the electrical domain and offer the potential to reduce bandwidth transport costs of access networks [4].

Currently and in order to extend distance limited by fiber loss as well as increase a number of subscribers of GPON, erbium doped fiber amplifiers (EDFA) have attracted significant attention because of features such as polarization independent gain, low noise, low cost and very low coupling losses.

Basically there are three system configurations for the use of EDFA in the design of fiber optic communication system, namely, as power booster is used to amplify the signal transmitted to provide high input power to the fiber span. In line amplification is to compensate for fiber loss in the transmission. Pre-amplification is known to provide

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high receiver sensitivity by amplifying the signal before it falls on the photo detector [6].

3. Setup Schemas

The main object of this paper is to optimize the value of BER in passive optical network using EDFA amplifier in different power compensation methods (post, pre and inline-amplifier) in order to achieve the maximum distance of 60 Km of SMF (Single Mode Fiber) and 128 subscribers. A diagram of the downstream of the GPON structure is shown in Figure 2. At the OLT (optical Line Terminal) transmitter, DFB laser directly modulated generates a signal data at 1550 nm and 5 dBm a booster is placed right after the transmitter to boost the launched signal, this later is launched into the 80Km fiber span with an attenuation coefficient of 0.2 dB/km and 17 ps/nm.km to compensates signal a EDFA in-line amplifier is fixed at the distance of L_1 = 40 km from OLT and L_2 = 20 km to ONTs.

The output of an optical fiber (L_2) goes to the 1: 128 power splitter with 24 dB of loss and then the signal is transmitted to the individual end user. A pre-amplifier is needed to increase the intensity of the launched signal before it goes to the receiver, the GPON uplink receiver (ONT) consists of avalanche photodiode (APD) to detect signals and low pass Bessel, 3R regenerator, Bit Error Rate (BER) meters and eye diagram analyzers to evaluate performance of each receiving end.

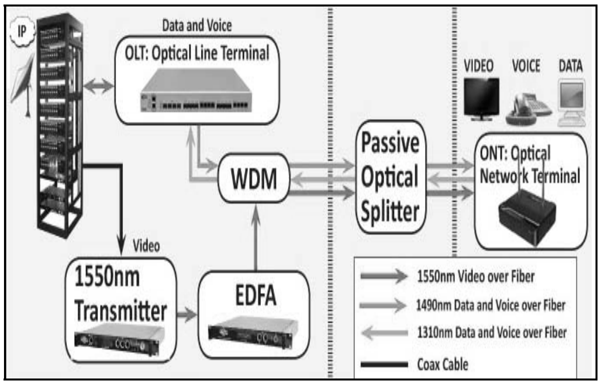


Figure 1. GPON system with EDFA amplifier concept

The gain of the EDFA depends on a number of device parameters: erbium ion density and length of the fiber doped erbium (amplifier length)…ect, in this part, the effects of these quantities on the action and performance of erbium amplifiers such as amplifier quality factor Q are investigated. The flowing parameters values were used table (1):

Table 1. Typical EDFA parameters

Symbol	Parameter	Value
Pin	Signal input power	0 to10 dBm
λ	Signal wavelength	980 nm
Pp	Pump power	200 mw
L_{EDFA}	Amplifier length	0 to 28 m
D	Core radium	0.22 µm
C	Erbium ion density	1e+24/m^{-3} to 5e+25/m^{-3}
NA	Numerical aperture	0.6

The effect of erbium concentration of EDFA used in three positions (booster, pre- and in line amplification) on GPON system was performed in term of Q -factor. Figure 3 shows that for threes configurations, the performance reduces when we increase the erbium concentration up C > 1+025/m^{-3}. So it is cleared from graphs that the optimal value of erbium concentration is around 1e+25/m^{-3} which the pre-amplifier provides overall better result with good Q factor (Q = 15.8) as compared to inline amplifier (Q =10.2) and lower value of Q = 6 for booster amplifier.

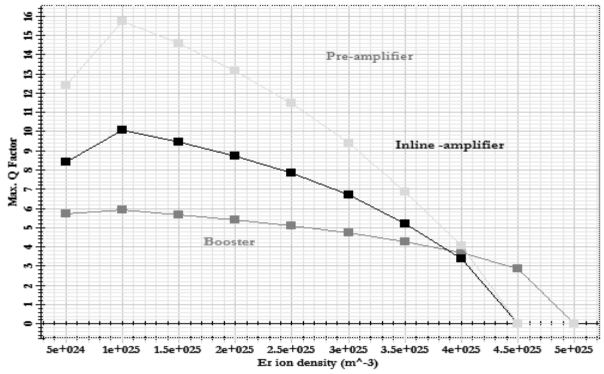


Figure 2. Q factors as a function of erbium concentration for in-line amplifier, booster and preamplifier

Also, the effect of sweeping the amplifier length L EDFA (0 to 28 m) for the optimum Q-factor in all positions of EDFA amplifier with fixed erbium concentration at 1e+025/m^{-3} is shown in the graphs (figure 3). As can be seen, that there is change of Q-factor via EDFA length, however the Q factor increases rapidly from 0 m length to near 7 m and decreases up this value. Whereas, the optimum length (L_{EDFA} = 7 m) offers a good performance and provides a higher Q factor (over 15.8) for pre-amplifier configuration followed by inline (over 10.2) and booster amplifier (over 6), respectively.

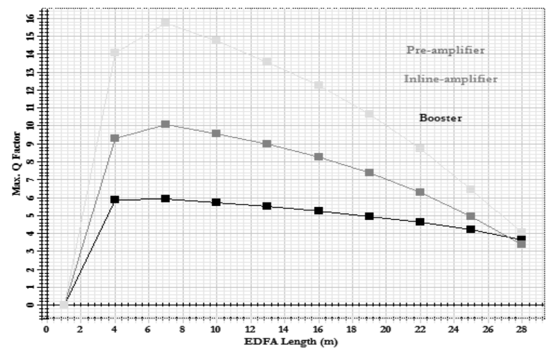


Figure 3. Q factors as a function of EDFA length for in-line amplifier, booster and preamplifier

The performances of GPON at signal input power of 10 dBm and with EDFA in the function of an in-line, pre-amplifier and booster have been compared. For all cases, the EDFA was characterized by various parameters opt-geometric (D = 2.2 um, LEDFA = 7 m, C = 1e+25/m^{-3} , P_p = 200 mw, NA = 0.24, ƛ = 980 nm). The proposed simulation has been analyzed by changing fiber length and signal input power.

To analyze the system, the results of the first ONT have been taken. Figure.4 depicts the graphical representation of Q factor as a function of length. The better Q factor is provided by the booster (26.19 dB) as compare to other amplifiers lower to 30 km and up to 40 km preamplifier has highest Q-factor as compared to inline and booster, respectively. Also inline and preamplifier were able to reach transmission optical distance of 120 Km for GPON with best Q factor (8.03 and 11, respectively), whereas this distance has been reduced to 60 Km with booster amplifier.

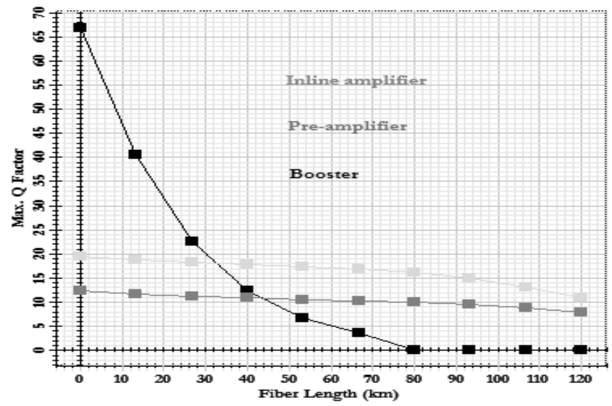
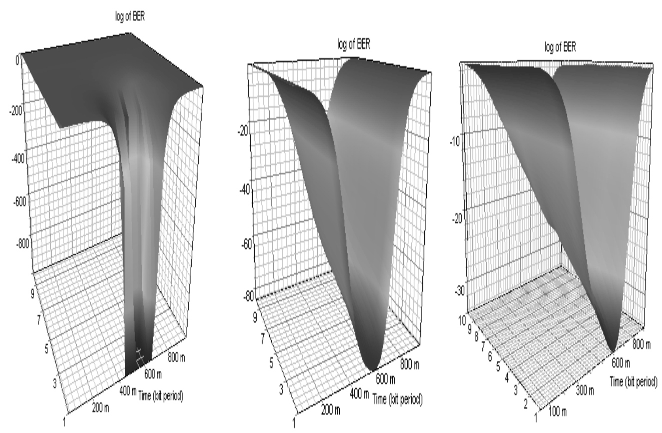


Figure 4. Q factors as a function of fiber length at signal input power of 10 dB for in-line amplifier, booster and preamplifier

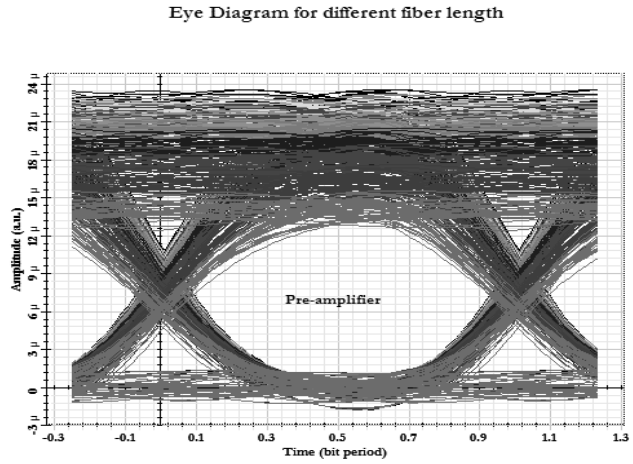
Figure 5 shows the 3D graphical representation of BER as a function of length for threes amplification configurations. The optimum result with Min of BER (over 10^{-21}) is achieved with pre-amplifier up of 120 Km (Figure 5.a), however the in-line amplifier provided the best performance at 120 km with bit error ratio around to 10^{-17} (Figure 5.b) and highest bit error ratio (equal to 10^{-9}) was obtained with applied EDFA booster amplifier at the distance of 60km (Figure 5.c) .



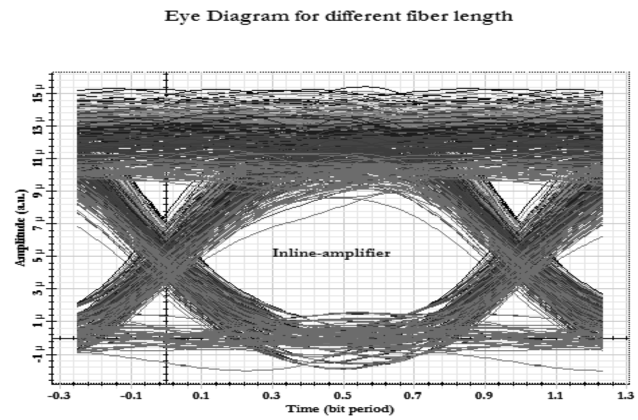
(a) **(b)** **(c)**

Figure 5. 3D BER graphs as a function of fiber length at signal input power of 10 dBm for (a) pre-amplifier (b) inline- amplifier and (c) booster

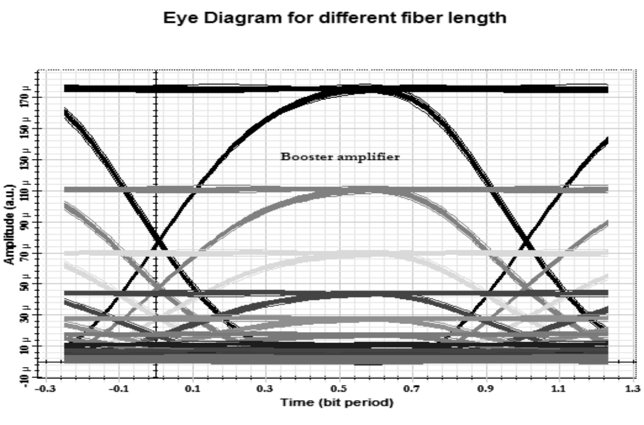
The signal quality is proven by looking at the eye diagrams in figure.5 where the eye diagrams are captured at the highest received power for all configurations. The results are ceased when the BER and the eye have degraded to a level where further measuring and recording is believed to be pointless. For pre-amplification, a clearer and wider eye opening is attained for different fiber length as compared to inline amplification as the signal is less distorted by the generated noise. However, the eye diagram starts to be distorted increasingly by the noise (with narrower eye opening) when the fiber length increases and the received power starts to reduce. Since, thickest eye diagram is obtained when post-amplifier (booster) configuration is applied due to high noise generated that finally distorts the signal quality especially for logger fiber length (up 60 Km).



(a)



(b)



(c)

Figure 6. Eye diagrams as a function of fiber length at signal input power of 10 dBm for (a) pre-amplifier (b) inline- amplifier and (c) booster

In Figure 7 Q-factor for the above three configurations is compared for various input signal power at 1550nm signal wavelength and 60 Km SMF length. For pre-amplifier, maximum Q-factor around 26 was achieved at 21 dBm of signal input power, however for in line and booster amplifier, the optimum Q factor (over 10 and 6, respectively) was founded at 12.5 and 17.8 dBm of signal input power, respectively.

Also, we can notice a good eye opening of the signal and the best position of amplifiers in the GPON for pre amplifier with Min of BER. However where the comparison was made between in line and post-amplification (booster) methods only, we can notice that, for the inline it is also observed that the eye opening and Min of BER are better than the booster for signal input power lower of 19 dBm and up this value the it's the opposite (Figure 8 and Figure 9).

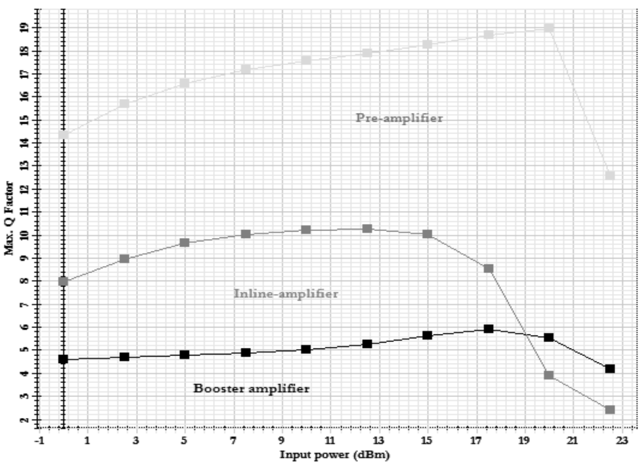
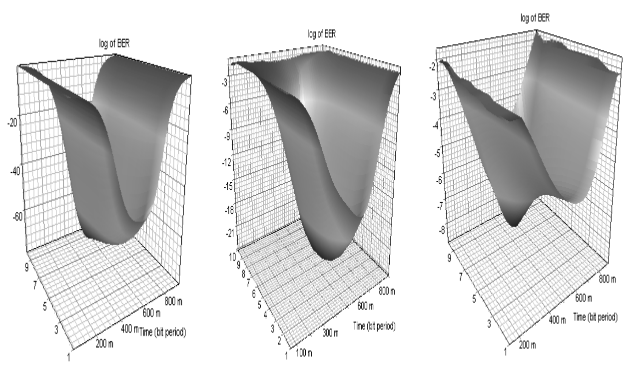


Figure 7. Eye diagrams as a function of signal input power and at fiber length of 60 Km for (a) pre-amplifier (b) inline- amplifier and (c) booster



(a) **(b)** **(c)**

Figure 8. 3D BER graph as a function of signal input power and at fiber length of 60 Km for (a) pre-amplifier (b) inline- amplifier and (c) booster

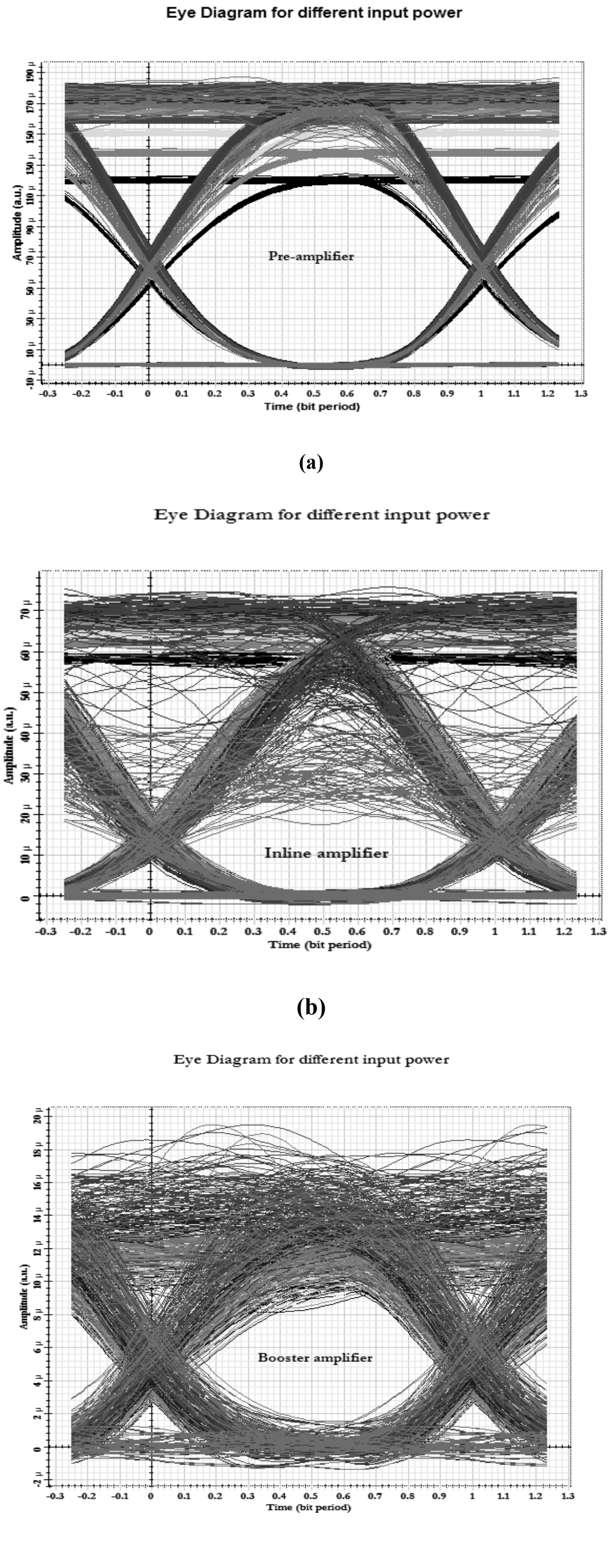


Figure 9. Eye diagrams as a function of signal input power and at fiber length of 60 Km for (a) pre-amplifier (b) inline- amplifier and (c) booster

4. Conclusion

In this study, simulation results for EDFA optical amplifiers placed at three different positions in downstream GPON network were presented and the maximal topology distances for signal transmission to the end users were evaluated. So the knowledge of optimal values of the erbium doped fiber amplifier parameters like amplifier length (L_{EDFA}) and concentrations of erbium ions (C) is necessary to estimate the value of the Q factor and to optimize the gain and noise figure NF.

We can note from our simulation that: when L_{EDFA} = 7 m and C = 1e+025 /m^{-3}, the Q factor is optimum for all positions of EDFA amplifier. Also, from simulation we found out that the best results achieved EDFA pre- amplifier configuration, this later was able to reach transmission distance up to 120 Km with a split ratio of 128 of the GPON, however the worst results in terms of Q factor and eye diagrams are obtained with EDFA booster and the distance of transmission is limited at 60 Km.

Whereas, the worst BER is obtained in the booster amplifier as it gives the highest BER at all received powers when comparison is made between inline amplifiers configurations. So, the pre-amplification configuration hence can be preferred over the other two configurations.

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