Simulation Study on Performance Improvement by Gain Optimization in CWDM Metropolitan Ring Network

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Summary
The main objective of this simulation study is to observe the profile effects of pre-amplification and post-amplification to the value of output power and bit error rate (BER) performance in the metropolitan ring network. Four types of main profile are introduced and studied, its effects on BER performance and output power are compared via maximum number of nodes allowed. We observed the first gain value gives the significant effect to the initial BER value. The effect of over amplifying on degrading the BER measurement also is also highlighted. Finally we propose the BER improvement by optimizing the value of gain based on the load line analysis. The Opti-System simulation is used to obtain the desired research objective and analysis the results.

Key words:
EDFA, gain, load line, BER, ring network, performance improvement, maximum node

1. Introduction

The increase of capacity in transmitting data over 10 Gbps has limits the use of coaxial cable as medium for data transmission. Hence, fiber optic technology has been opted to fulfill the requirement for wide band transmission. Introducing wavelength division multiplexing (WDM) into the fiber optic technology has made it the transmission medium without limits that offers few advantages including higher capacity and speed, ability for transmitting long distance data and a better signal quality. Information transmitted in the domain optic is transferred via point line to point using synchronous optical networking (SONET) / synchronous digital hierarchy (SDH) equipment to create ring and mesh topology network. In this network, the needs of the devices for add drop operation and cross-connecting optical line are executed by optical add drop multiplexer (OADM) and optical cross-connect (OXC) respectively, [1,2]. These two devices have wide application in optical world and have a same basic structure, but both having different characteristics. OADM handled different signal carrier at each of its base, meanwhile OXC operates the same signal carrier. Therefore, both devices have been used at different location for different functions. But if the function of both devices is merged together, the application of optical technology will be tremendously widened.

The devices developer has come to a consensus to fix the OADM to be used in ring configuration while OXC is used in mesh configuration [3,4,5]. However, there are other important elements that can guarantee the signals transmission in long distance range which is Erbium-doped fiber amplifier (EDFA). EDFA which functions at windows C and L was introduced in the early 21st century. It operated in full optical domain and has been replacing the use of repeaters in today's optical communications network [6].

Many studies have been developed and presented which allow an overview of EDFA. Some of them are widening the distance between two spans with the presence of more effective EDFA configuration [7], controlling EDFA gain value to reduce the noise [8] and enhancing the EDFA performance in WDM switch packet network using clamp EDFA [9].

In this paper our initiative focuses on the study of the ideal EDFA gain value in ensuring a good BER performance. Based on a simulation, the connection between BER performance and gain amplification value profile is observed to see its influence towards BER performance in maximum distance achieved as representing by the number of nodes. Finally we propose the important of optimization can improve the BER performance in ring architecture. Considering the load line characteristic is the best method to do network optimization.

2. Load Line

In determining a suitable gain value for any ring network, the value of load line needs to be considered. Load line is referring to a total value of insertion loss of components that connect two optic nodes in any optic ring network. It is formulated based on theoretical value and is given by equation (1), [1]:

$$\text{Load Line} = \text{OADM Node Loss} + \text{Fiber loss} \quad (1)$$

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Meanwhile, the actual insertion loss is defined by equation (2)

Actual insertion loss = Load line (Theoretical loss value) + Operational loss (2)

Therefore the exact Gain value used to compensate losses defined as

Gain value (dB) = Actual insertion loss (3)

Referring to the value of load line obtained, metropolitan ring network are developed with satisfying BER performance using optimum amplified value. The connection between BER performance and amplification gain is in the form of Gaussian negative. Hence, an area called extreme high/active is created where the increase in

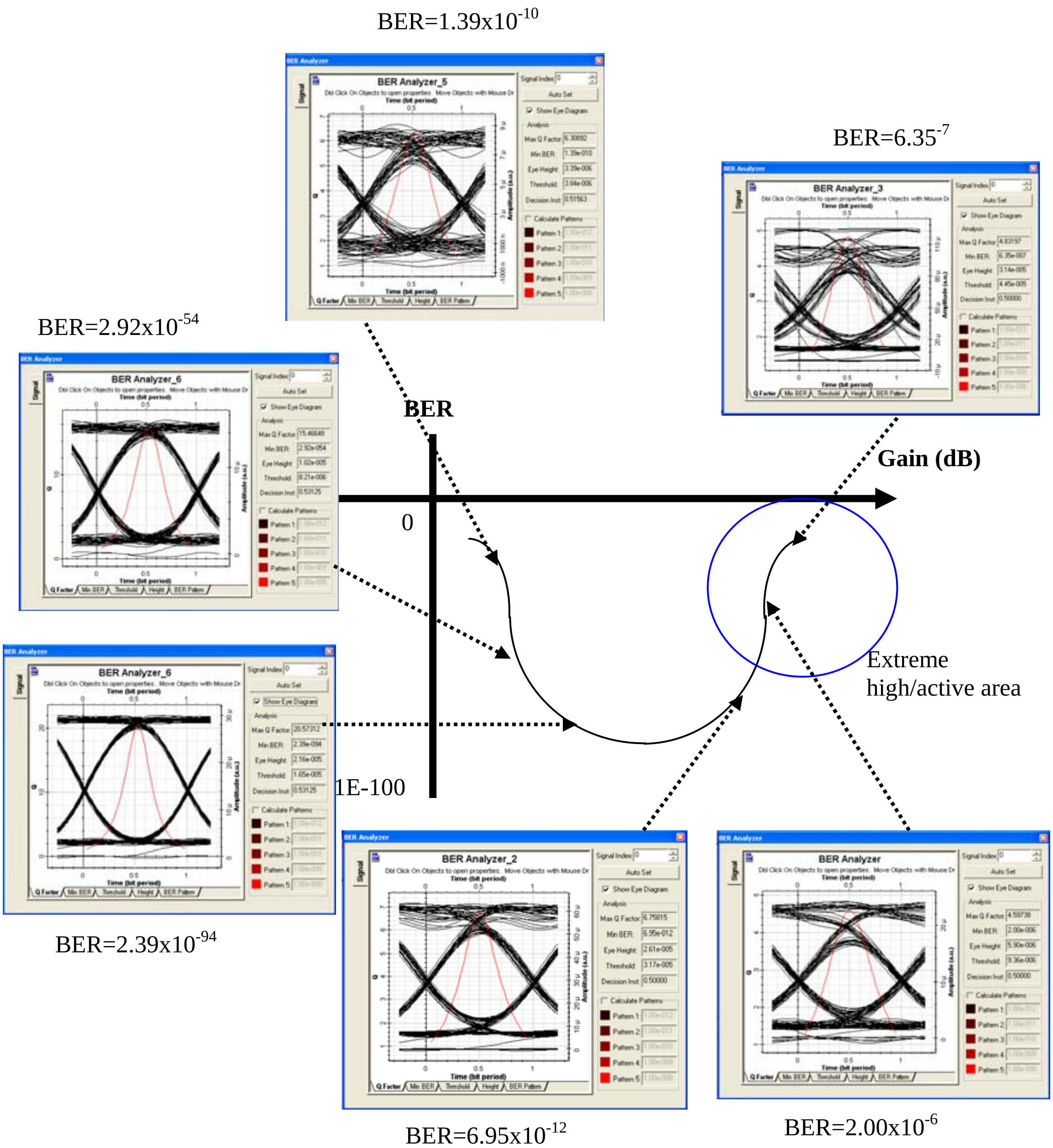


Fig. 1 BER profile versus gain showing an extreme high/active area located at the right Gaussian profile.

gain value will deteriorate the value of this BER performance [1,10]. Therefore, research on amplification value profile is very important in order to avoid the BER profile in the ring network to be in the extreme high/active area. Fig. 1 shows the extreme high/active area in connection of gain and BER performance.

3. Simulation Results: Amplification Profile

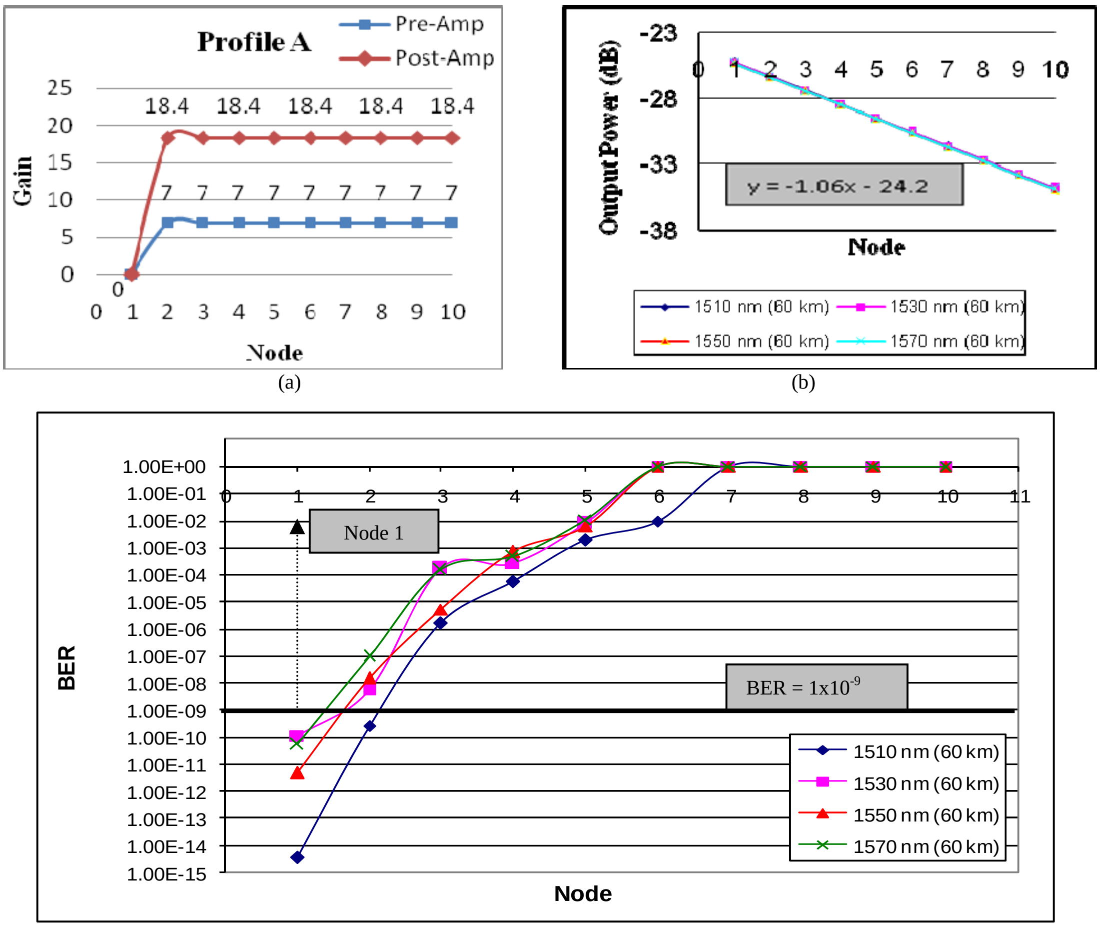
The study examined four different types of amplification value profile, namely A, B, C and D from node 1 to node 10. Besides the loss value which is caused by the load line, the simulation study also determined other losses value which happens from line node to node. Few main parameters have been fixed throughout the simulation as in Table 1:

3.1 Profile A : Amplifier Gain Equal to Load Line

Profile A refers to the total gain, post-amplification and pre-amplification which is equivalent to the load line, 25.4 dB. Besides the loss value which is caused by load line, the simulation study determined other losses value which happens from line node to node. Fig.2 (a) and (b) shows the profile for both amplification gain and the

Table 1: Parameters for the amplification value profile

Parameter	***Value***
Distance between two nodes	60 km
Load line	15 dB +10.4 dB = 25.4 dB
Sensitivity	-25 dBm
Thermal noise at receiver	3.1347 x 10^{-23} W/Hz
Rate of measurement	2.5 Gbps (OC-48)



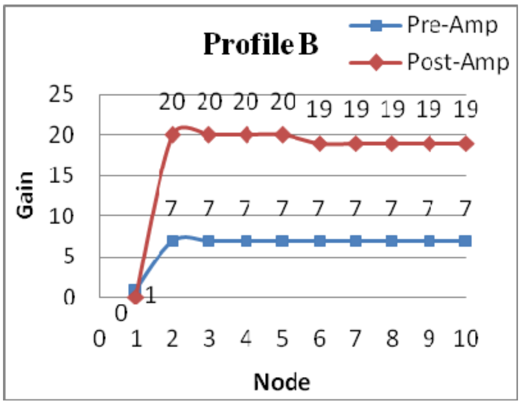
(a) (b)

(c)

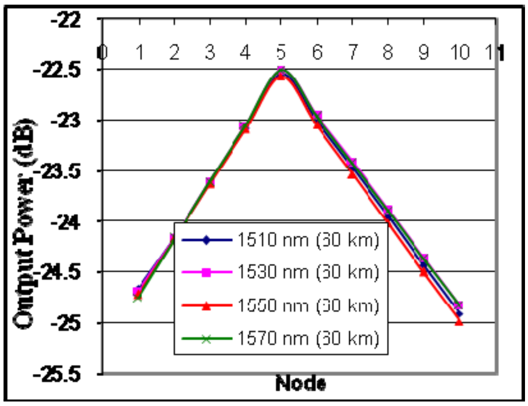
Fig. 2 (a) Post-amplification and pre-amplification gain for profile A (b) Output Power (c) BER Performance profile of power output measured at each nodes respectively. From the simulation, it is observed that there is an increment to the value of loss by 1.06 dB for a data transmitted from one node to another. This shows that there is a decrement of 1dB for sending end power value across node to node. This could be due to the existence of operational loss besides load line loss which is compensated with post-amplification and pre-amplification. Therefore, post-amplification value must be increased by 1dB for each node to compensate this operational loss value. Fig. 2(c) shows the BER profile at each node outside the extreme active power. Therefore BER value is increased with the increment of loss power. The BER performance giving maximum allowed value which is $1x10^{-9}$ at first node only.

3.2 Profile B : Post Amplifier Gain is Slightly Increased

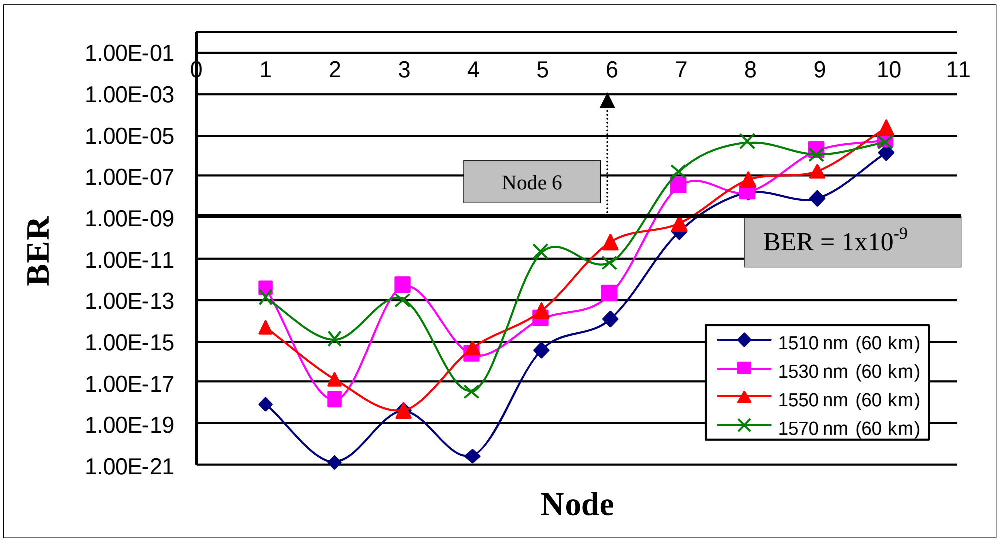
Profile B is the alteration from profile A where the post-amplification value is increased to compensate the operational loss value. Gain value of pre-amplification at first node is increased at 1 dB as shown in Fig. 3 (a). It can be observed in Fig. 3(b) that there is a sudden change to the value of output power with the change of gain value used eventhough the gain is reduced. Although there is an increament of output power at node 6 up to node 10, this conditions did not affect the BER performance value as seen in Fig. 3(c). The BER value keep increasing even if the power is increased. Therefore, it can be concluded that first pre-amplification gives a major impact to the BER performance profile to be formed. BER performance give an allowed maximum value ($1x10^{-9}$) at node 6.



(a)



(b)

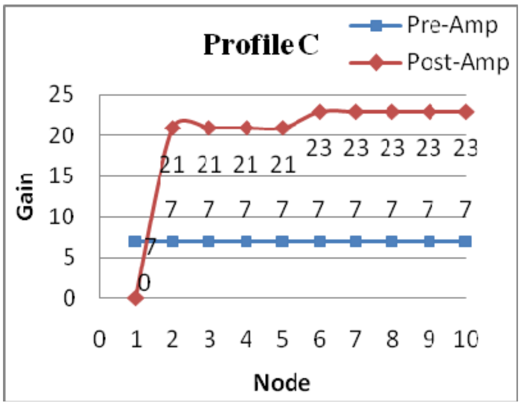


(c)

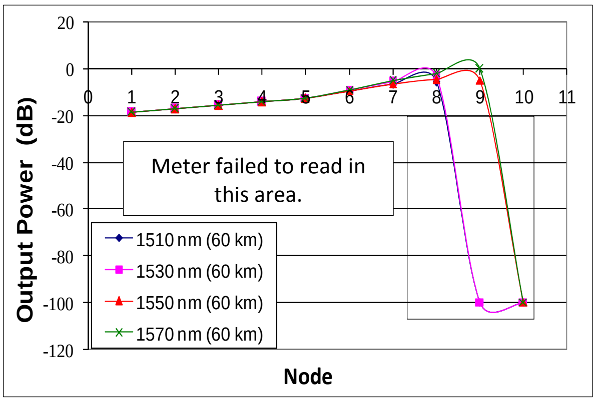
Fig. 3 (a) Post-amplification and pre-amplifier gain for profile B (b) Output Power (c) BER performance

3.3 Profile C : Preamplifier Gain Have Constantly Values

Profile C uses a higher gain value than profile A and B as shown Fig. 4(a). Pre-amplification is fixed with gain 7dB. The increment in gain value increased the output power until it reaches 0 dB. This can be observed in Fig. 4(b). However, this condition does not affect the BER performance value. BER value keep increasing even if the input power node is increased as in Fig. 4(c). The high power progression does accelerate the increment in BER value. This clearly shows the BER performance where its value cannot be increased but the decrement rate can be decelerate with the used of gain value. The performance of BER gives the maximum value allowed ($1x10^{-9}$) at the node 6.



(a)



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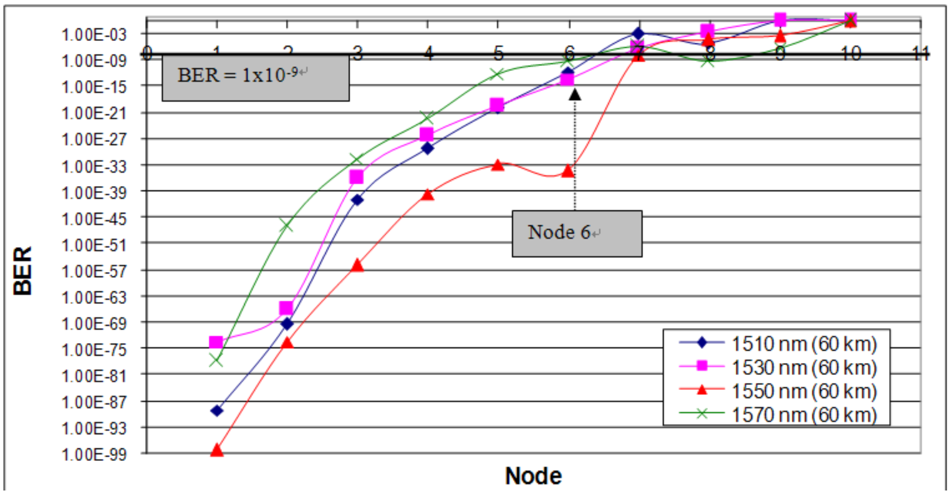
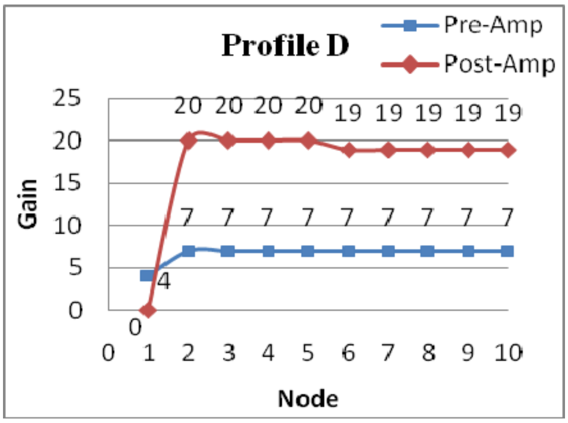


(c)

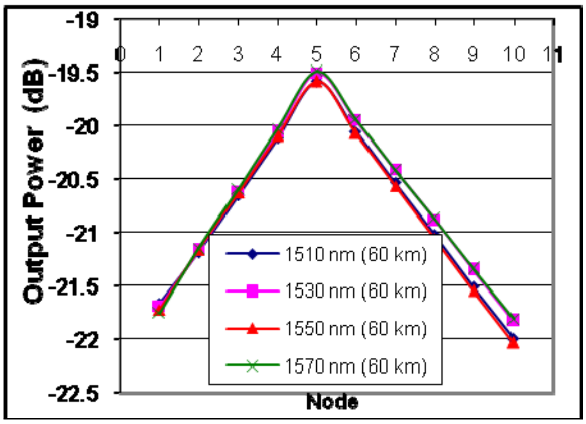
Fig. 4 (a) Post-amplification and pre-amplifier gain for profile C(b) Output Power (c) BER performance

3.4 Profile D ; The First Amplifier Gain is Smaller Than The Next

Profile D uses pre-first gain value which is increased by 4 dB to observe the BER profile created. Gain value for both amplifier is shown in Fig. 5(a) meanwhile output power for each node is shown in Fig. 5(b). Increment in first pre-amplification value causing the beginning BER value relatively smaller. Profile formed is similar to Profile BER B but the increment to the BER value at each node is faster as observed in Fig. 5(c). BER performance gives an allowed maximum value ($1x10^{-9}$) at node 7.



(a)



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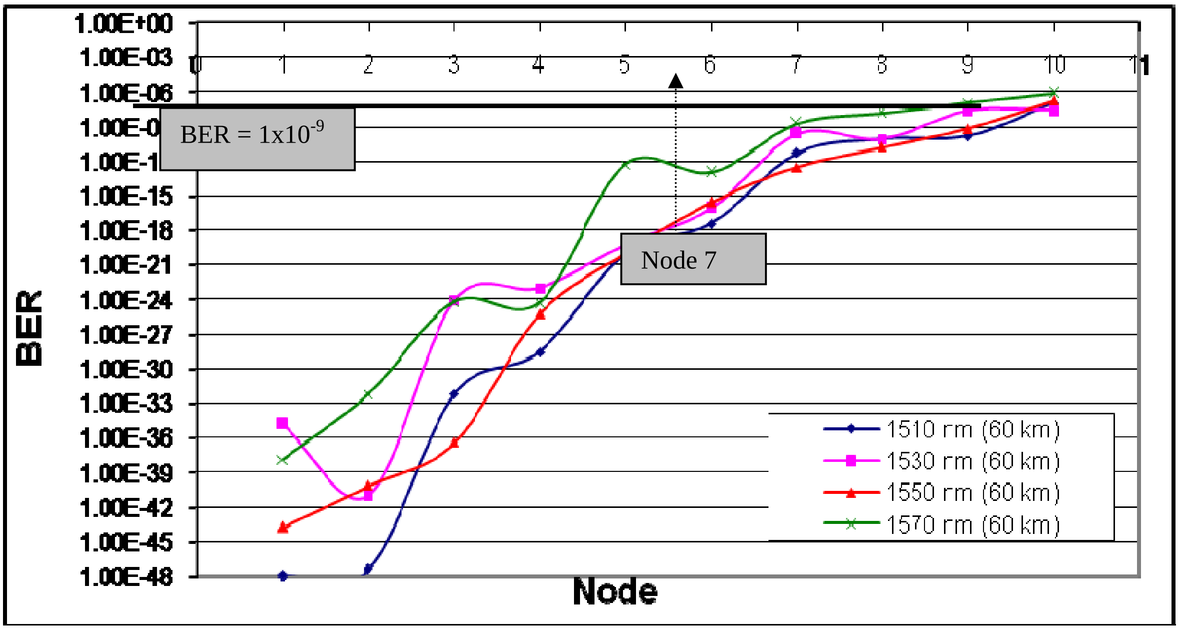

(c)

Fig. 5 (a) Post-amplification and pre-amplifier gain for profile D (b) Output Power (c) BER performance

4. Optimization: Performance Improvement

The load line play important role in optimizing the performance of BER. The gain values equally with the load line decrease the performance of BER linearly but if the gain is slightly bigger than the load line, the BER values are excited before it decrease linearly with slowly. The BER performance is improved by the output power increased. The suggested values for EDFA gain is *load line (dB) + 1 dB* as stated in equation (3). The improvement (Gain 23 dB) can be seen clearly in Figure 6 as compare to value of gain similar to the load line which is 22 dB. The ideal amplifier gain value is determined by the system's load value as shown in equation (2).

5. Conclusions

From this study, it can be concluded that the amplifier gain may affects the BER performance in the recovered area. Any changes in the power level can be compensated or improved by amplifier gain. Optimizing the values can improve by extending the maximum length that can be achieved at minimum BER. Therefore, an optical amplifier configuration is vital to obtain a stable BER performance profile (slow decrement rate) in the secured optical ring network design. The ideal amplifier gain value is determined by the system's load value as shown in equation (3). Table 2 summarizes the node at the maximum allowable value of the BER performance for each profile. The connection between BER performance and amplification gain is in the form of Gaussian negative. Hence, an area called extreme high/active is created where the increase in gain value will deteriorate the value of this BER performance [10]. Therefore, research on amplification value profile is very important in order to avoid the BER profile in the ring network to be in the extreme high/active area.

Table 2 Node at maximum allowable value of BER performance

Profile	***Node***
Profile A	1
Profile B	6
Profile C	6
Profile D	7
Optimizing (Figure 6)	> 9

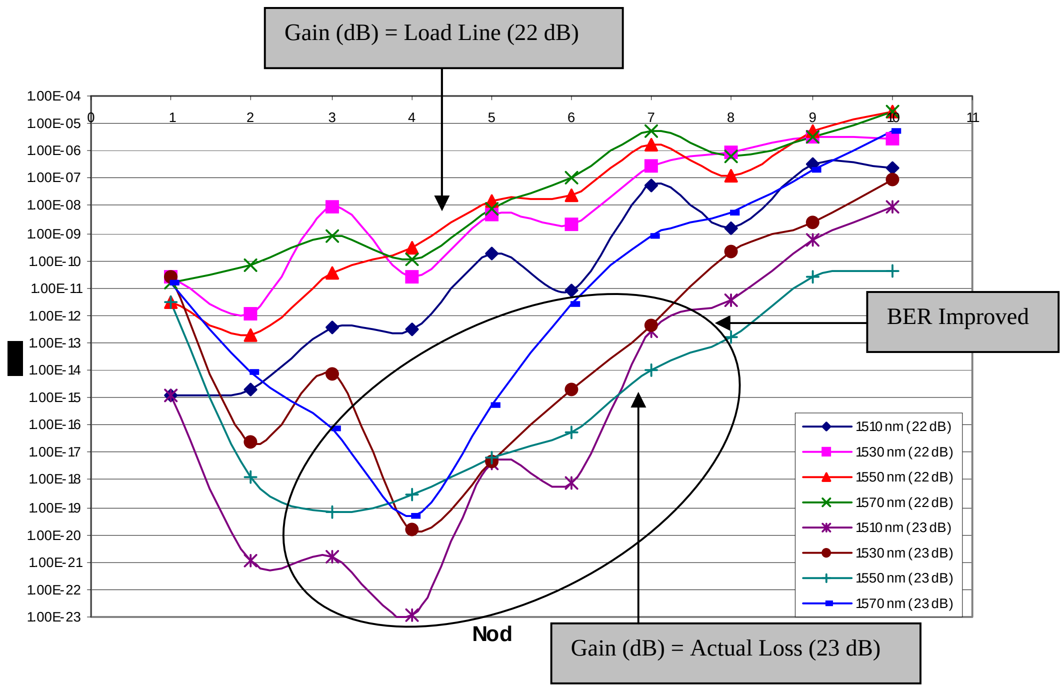

Fig. 6 Adding 1 dB on amplifier gain affect the BER performance at every node. Improvement on BER assures the maximum number of node can be extended.

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