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Design & Implementation of Performance Parameters Based on Carrier Distributed WDM Passive Optical Networks

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Abstract— **Data volumes in Internet have experienced an extra ordinary growth over the last few years. While provider backbones have been upgraded accordingly in terms of bandwidth to please these demands, access networks remained extensively ignored and are at risk of becoming bottle necks soon. This paper presents various performance parameters based on carrier distributed WDM passive optical networks. In this research work, the main subject of connection provisions and performance analysis in WDM network ensuring quality of service requirement of the connection requests from client in the network in optical networks.In WDM networks, optical splitting is widely used to achieve multicasting. It removes complications of optical-electronic optical conversions. Effect of wavelength assignment and length of fiber on various parameters is also numerically calculated.The important parameters like delay, BER and blocking probability is also analyzed. All this work is simulated on MATLAB tool.**

Keywords— **Passive Optical Networks, WDM-PON, Wavelength Assignment, Rayleigh Scattering Parameters**.

I. INTRODUCTION

Optical network are high-capacity telecommunication network based on optical technologies and components that provide routing, grooming and renovation at wavelength level as well as wavelength-based services. It uses Optical Fibers for data transmission. The advantages of Optical networks can be used for long distances, easy to connect and has long-term financial profits, lasts for a long time and has a high bandwidth. Optical networks are based on the emergence of optical layer in transport networks deliver higher capacity and reduced costs for new applications such as net, video and multimedia communication and advanced digital facilities. [1].

In optical network customers are demanding more services and options and are carrying more and different types of data traffic. Optical networks provide the required bandwidth and flexibility to enable end-to-end wavelength services and meet all the high-capacity and varied needs. Optical fiber offers much higher bandwidth than conventional copper cables. A single fiber has a possible bandwidth on the order of 50THz. Meanwhile, it has low cost, extremely low bit error rate (typically 10^{-12}, compared to 10^{-6} in copper cables), low signal attenuation and low signal alteration. In addition, optical fibers are safer from tapping, since light does not radiate from the fiber and it is nearly impossible to tap into it secretly without being detected. As a result, it is favoured medium for data transmission with bit rate more than a few tens of megabits per second over any distance more than one kilo-meter. It is also the preferred means of realizing short distance (a few meters to hundreds of meters), high-speed (gigabits per second & above) interconnection inside large systems. In past few decades, optical fibers have been widely deployed in all kinds of communication systems. [2].

Optical fiber has been used in two generations of optical network. In first generation, it was essentially used for transmission and simply to provide capacity, since it provides lower bit error rates and higher capacities than copper cables. All switching and other intelligent network functions were handled by electronics. Thus, the bandwidth was limited by the electronics at the fiber endpoints. Presently, transmission rates are restricted to 10 Gb/s (OC-192) in commercially available systems. Examples of first generation optical networks are SONET and SDH networks.[3]

Many new applications and services have emerged rapid growth of internet and telecommunications industry resulting in a rush of data on voice networks. This surge of data rendered voice telecommunications infrastructure insufficient in metropolitan area resulting in a metro gap. This dilemma provided us with a dire need to replace or upgrade existing telecommunications infrastructure. So to cope with changed realities and enable new applications and services to utilize huge bandwidths available in long haul backbone networks, optical network based on AWG multiplexers and AWG de-multiplexer can supplement existing metro networks and increase their capacity to overcome metro gap [4].

Optical transport network technologies refer to all computing and communications networks which employ optical fibre as a transmission medium and include the optical component technologies: technologies for physical, data link and network layers and related control layers. The most advanced network concepts explore use of optics beyond transmission, to implement switching and simple resource allocation functions. It analyses the current status and trends in both components and networks [5].

The paper is planned as follows. In section II, we deliberate related literature review with the proposed scheme. In

Section III, It describes passive versus active optical networks. In Section IV, it describes system architecture and analyse the different parameters of Rayleigh scattering in impairing the upstream signal. Section V contains main results, graphical analysis. Finally, conclusion is given in Section VI.

II. RELATED WORK

In literature, several proposed Rayleigh noise drop in wavelength-division-multiplexed passive optical network. Then they suggest a novel scheme to effectively suppress carrier backscattering problem in carrier-distributed WDM-PONs. By simply replacing upstream modulation arrangement of conventional on-off keying with differential phase-shift keying (DPSK), the system tolerance to carrier RB is substantially improved by 20 dB, as carrier back scattering can be considerably rejected by notch filter-like destructive port of delay-interferometer at optical line terminal, which is used suddenly to demodulate the upstream DPSK signal. As no thoughtful spectral up-shifting is required in this scheme, neither other modulator nor complicated modulation/demodulation circuit is needed at ONU/OLT. In terms of optical notch filter used to decrease backscattering light, the standard Delay interferometer used in future arrangement is also more favourable than non-standard filters [5].

Some authors propose a novel colourless optical transmitter based on all-optical wavelength conversion using a reflective semiconductor optical amplifier for upstream transmission in wavelength-division-multiplexed passive optical systems. The proposed optical transmitter for optical network unit is composed of an electro-absorption modulated laser, a photosensitive coupler and amplifier. Through cross-gain modulation in amplifier, the upstream data from pump light are imposed onto a continuous-wave probe light provided from central office. An optical delay interferometer at CO tailors the chirp of upstream signal to increase bandwidth of the system and dispersion tolerance. The proposed optical transmitter is based on fast gain recovery of amplifier governed by carrier-carrier scattering and carrier-phonon relations [6]. End-to-end real-time optical orthogonal frequency-division multiple-access passive optical networks (PONs) with adaptive dynamic bandwidth allocation(DBA) and colourless optical network units (ONUs) are experimentally established, for first time. Next generation Passive Optical Network (PON) technology has been developing to consolidate metro and access networks in order to offer improved capacity, high split ratio and compact deployment cost per subscriber. However, transmission of signals to long distances up to100km leads to increased propagation delay whereas high split ratio may lead to long cycle times resulting in large queue occupancies and long packet delays.

This paper investigates problem of dynamic wavelength allocation and fairness control in WDM optical networks. A network topology, with a two-hop path network, is considered for mainly three classes of traffic. Each class corresponds to a source &destination pair. For each class call inter-arrival &holding times remain studied. The objective is to find a wavelength allocation policy to take full advantage of weighted sum of users of all the three programs. In a conventional WR network, an entire wavelength is assigned to a given connection. This can lead to inferior channel utilization when individual sessions do not need entire channel bandwidth [7].

III. PASSIVE VERSUS ACTIVE OPTICAL NETWORKS

In active networks management and collecting traffic statics from remote locations is possible. Based on these statistics the network can be reconfigured from remote locations. For passive configurations active monitoring is only possible at the SNI and UNI. The path between SNI and UNI acts like a black box. Any modification, like rerouting, in the network should be done on side. Besides this problem, there are more differences between Passive and Active networks, they are summarized now [8].

(i) Dynamic links and management

In active optical networks the switching and routing hardware can create isolated optical paths from source to destination. These are called “Point-to-Point” (P2P) connections. Network operators can configure the manageable, or active, hard- ware to create a network with the required functionality. In case of a passive configuration as described [12][13] and [14] the splitters have a static configuration. As a result only at the termination points management is possible.

(ii) Topology

Active networks can be configured as P2P or “Point-to-Multipoint” (P2MP) net- works at the physical level. The networks defined only are configured as a P2MP at the physical level. However with the use of software a P2P topology can be emulated in a passive configuration. A P2P network is most secure since each link is a physical link between two nodes. In passive and active P2MP configurations all information is broadcasted in the Down stream1 direction to all users which can be a security problem.

(iii) Physical reach

The physical reach between head end and user is for active networks many times more than passive networks. This is due the fact the active components can act as an optical amplifier or repeater. In a passive network all power at the head end has to be enough to serve at least 64 users as defined. Another aspect which limits the maximum distance to 20 km is the ranging procedure.

(iv)Upgrading a network

When networks or sub-networks are upgraded, an active network can partially shut down depending on its configuration. For passive networks the whole network should be down to modify it [9].

(v) Bandwidth Usage

The usage of bandwidth in an active network differs from the use in passive net- works. In active networks there are separate transmitters and receivers connected by a physical link; therefore they can have their own wavelength and capacity. Passive networks use a shared fiber between provider and splitter which has to serve multiple users per wavelength. These are some examples to deal with when designing and working with PONs. To control the development of PONs some standards have been published. Each standard describes several solutions and regulations which can help to design a network. Some of these standards are still in development and are not finalized this.

IV. SYSTEM ARCHITECTURE AND RAYLEIGH PARAMETERS

A. *System Architecture*

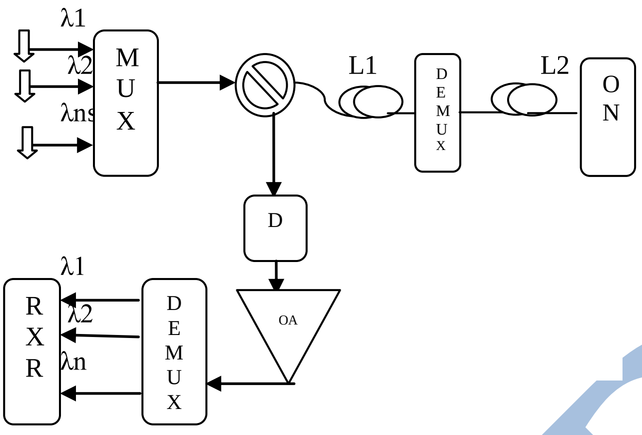


Figure 1: Proposed System Architecture

Fig. 1 shows the proposed architecture of a WDM-PON. As downstream plus upstream signals are transmitted over different wavelength bands in carrier-distributed WDM-PON, backscattering from upstream signal will not affect with the downstream signal, and vice versa. Only passive components are used such as optical fiber, splices and circulators etc. PONs reduces the fiber deployment in both the local exchange office and local loop.

In multi-hop network design, selection of a proper logical topology is followed by the wavelength allocation process. The wavelength allocation process is important because it determines wavelength requirements, and operation of network. The simplest scheme for the wavelength assignment assigns one wavelength channel to each of the logical links. An alternative scheme, which needs a smaller number of wavelengths and transmitters, is assignment of one wavelength channel per end-node. If number of wavelength channels in network is smaller than number of end-nodes, these schemes will flop. In such a case, shared channel methods can be useful in the wavelength assignment process. If the required number of wavelengths exceeds available number of wavelengths, it is possible to employ multiple broadcast stars in the network. In this case, the number of available wavelengths will be scaled up by the number of broadcast stars in the network.

At the CO, the upstream signals are first sent to a DI before being de-multiplexed by an arrayed waveguide grating (AWG). The DI which filters out red-shifted chirp of the converted signal substantially improves the receiver sensitivity and dispersion tolerance. A single DI can be used to equalize multiple WDM channels provided that the free-spectral range (FSR) of DI is equal to a factor of the channel spacing. It should be noted that in the proposed scheme both the probe and pump signals propagate back to the CO and thus it is necessary to filter out the pump signal using optical filters. To avoid using additional optical filters on the link, we can employ non-cyclic AWGs at the remote node and at the CO [10].

B. *Components Used*

1. *Transponders*

Transponder is basic element for transmission and reception of optical signal from channel. A transponder is generally characterized by maximum bit rate it can handle with and the maximum distance the optical pulse can travel without degradation. Transponders convert an optical signal from one wavelength to an optical pulse with another wavelength. Another important function of transponder device is the conversion of broadband signal to a signal associated with specific wavelength by optical to electrical to optical conversion.

For detection purposes, it uses photo-detector. This photo-detector generates an electrical current proportional to incident optical power. Photo-detectors are made of semiconductor materials. Photons incident on a semiconductor are absorbed by electrons in the valence band. As a result, these electrons acquire higher energy and are excited into the conduction band, leaving behind a hole in valence band. When an outer voltage is applied to the semiconductor, these electron-hole pairs give rise to an electrical current, termed the photocurrent [12].

2. *Wavelength Cross Connect*

Wavelength cross connect is a switching device whose function is to switch or connect any wavelength from the input port to any one of out port in the fiber. The functioning is completely in optical domain. An OXC with N input and N output ports capable of handling W wavelengths per port can be thought as W independent N×N optical switches. The polarization-independent Acoustic optical tunable filters (AOTF) can be used as a two input, two-output dynamic wavelength cross connect [12].

3. *Couplers*

A passive optical network services a passive (not requiring any power) device to split optical signal (power) from one fiber into many fibers and reciprocally, to add optical signals from several fibers into one. This device is an optical coupler. In modest form, an optical coupler consists of two fibers attached together. Signal power received on input port is split between both output ports. The splitting ratio of splitter can be controlled by the length of the fused region and therefore is a constant parameter. A directional coupler is used to combine and split signals in an optical network [13].

4. *Circulators*

A circulator is similar to isolator, except that it has multiple ports, typically three or four. In 3-port circulator, an input signal on port 1 is sent out on port 2, a signal on port 2 is sent out on port 3, plus an input signal on port 3 is sent out on port 1. Circulators are useful to construct optical add/drop elements. Circulators operate on same principles as isolators

5. *Multiplexers*

Optical Add-Drop multiplexer is a device which is capable to add or drop one or more wavelengths from the existing WDM system. There are three important domains for an OADM- optical multiplexer, de multiplexer and a method to reconfigure the path between multiplexer and de multiplexer.

De-multiplexers and multiplexers can be cascaded to realize static wavelength cross connects. . The device routes signals from an input port to an output port based on the wavelength [14].

6. *Optical Amplifiers*

An optical amplifier is a device which amplifies the optical signal directly without optical to electrical conversion i.e., all functions occurs in optical domain. In optical fiber, the light pulse itself is amplified. Optical amplifiers provide high gain and low noise for the optical signal; it has importance in the overall bandwidth provided by WDM system. Optical amplifiers offer several advantages over regenerators. On one hand, regenerators are specific to the bit rate and modulation format used by the communication system. On the other hand, optical amplifiers are insensitive to the bit rate or signal formats. Thus a system using optical amplifiers can be more easily upgraded. Thus a system using optical amplifiers can be more easily upgraded, for example, to a higher bit rate, without replacing the amplifiers. In contrast, in a system using regenerators, such an upgrade would require all the regenerators to be replaced. Furthermore, optical amplifiers have fairly large gain bandwidths. Thus optical amplifiers have become essential components in high-performance optical communication systems [14].

7. *Interferometers*

An interferometer is a device that makes use of two interfering paths of different lengths to resolve different wavelengths. Mach interferometers are typically constructed in integrated optics and consist of two 3 dB directional couplers interconnected through two paths of differing lengths. Interferometers are useful as both filters and de-multiplexers. Even though there are better technologies for making narrow band filters, for example, dielectric multi-cavity thin-film filters, MZI are still useful in realizing wide band filters. Narrow band interferometers filters are fabricated by cascading a number of stages.

C. *Rayleigh Parameters*

Rayleigh crosstalk is induced by the thrashing between upstream signal and the in band backscattering noise towards OLT. Two types of backscattering exist: the carrier RB and signal RB. The carrier RB arises from the CW carrier delivered to the ONU, whereas signal RB is the back reflection of the upstream signal, which is further amplified and modulated at ONU before transmitting to the OLT, along with the upstream signal. By calculating the power ratio between two types of RB, we can find out their different contributions in upstream Rayleigh noise. We first calculate power of carrier backscattering at port 2 of OLT optical circulator. The signal RB is generated in both feeder and distribution fiber [15].

Algorithm: Proposed Rayleigh Scattering Parameters

- *S=0.0016*
- α_p*=0.046*
- *Read Length L1 and L2.*
- *Calculate Parameters for L1=L2, L1>L2 and L1<L2.*
- *Step 1: For (carrier RB)*
- *Calculate* $(R1=2/S\,(1-e^{-2\alpha pL1})$ *and* $R2=2/S\,(1-e^{-2\alpha pL2})$.
- *Calculate* $\alpha_1=e^{\alpha pL1}$ *and* $\alpha_2=e^{\alpha pL2}$
- *Then calculate Mean intensity of carrier RB in feeder fiber* $Pcb\_1=Pc/R1$ *and Mean intensity of carrier RB in distribution fiber* $Pcb\_2=Pc/(\alpha_1.\alpha_A)^{2\cdot}R2$
- *Step 2: for (signal RB)*
- *Read L1and L2.*
- *Calculate* $(R1=2/S\,(1-e^{-2\alpha pL}$ *and* $R2=2/S\,(1-e^{-2\alpha pL2})$
- *Calculate* $\alpha_1=e^{\alpha pL1}$ *and* $\alpha_2=e^{\alpha pL2}$
- *Then calculate Mean intensity of signal RB in feeder fiber* $Psb\_1=P{\cdot}G^2{}_{ONU}/R_1.\alpha_1{}^2(\alpha_{A.}\alpha_2)^4$ *and (Mean intensity of signal RB in distribution fiber* $Psb\_2=P_c.G^2{}_{ONU}/R_2(\alpha_{1.}\alpha_{A.}\alpha_2)^2$
- *Step 3: Calculate power ratio between two types of RB:*$P_{cb}/P_{sb}=[(\alpha_{1.}\alpha_A)^{2\cdot}R_2+R1].\alpha_2{}^4\alpha_A{}^2/G^2{}_{ONU}[(\alpha_{2.}\alpha_A)^2.R_1+R_2]$
- *Step 5: Estimate BER, Blocking probability, delay and channel load.*
- *Step 6: Assign different wavelengths and check effect on various parameters.*
- *Step 7: find the graph relations between various parameters.*
- *end*

We first calculate the power of carrier RB. The mean intensity of the carrier RB produced in the feeder fiber is given by [12]:

$$Pcb1=\frac{Pc}{R1} \tag{1}$$

Where Pc is power of optical carrier incident to the feeder fiber, and R1is RB-induced return loss of the feeder fiber that is given by equation(2):

$$R1=\frac{2}{S(1-e^{-2\alpha pL\,1})} \tag{2}$$

With S, αp being recapture factor, and fiber attenuation factor in units of km respectively. Now, mean intensity of the carrier backscattering generated in distribution fiber is given by equation (3):

$$Pcb2=\frac{Pc}{(\alpha 1\alpha A)^2R2} \tag{3}$$

Where α1,αA are insertion loss of feeder fiber and the AWG at RN in linear scale, respectively, and is RB induced return loss of the distribution fiber. Now, α1 and R2 are given by equation (4)& (5):

$$\alpha 1=e^{\alpha pL\,1} \tag{4}$$

$$R2=\frac{2}{S(1-e^{-2\alpha pL\,2})} \tag{5}$$

Similarly, we can calculate power of signal RB at port 2 of the OLT optical circulator. The mean intensity of the signal RB generated in the feeder fiber is given by equation (6):

$$Psb1=\frac{Pc*Gonu^{\,2}}{R1*\alpha 1^2(\alpha A*\alpha 2)^4} \tag{6}$$

With *α2* and *Gonu* being the insertion loss of the distribution fiber and the ONU gain, respectively. The ONU gain is defined as the power ratio between the output and the input signals at ONU. $\alpha 2$is further given by equation (7):

$$\alpha 2 = e^{\alpha pL\,2} \qquad (7)$$

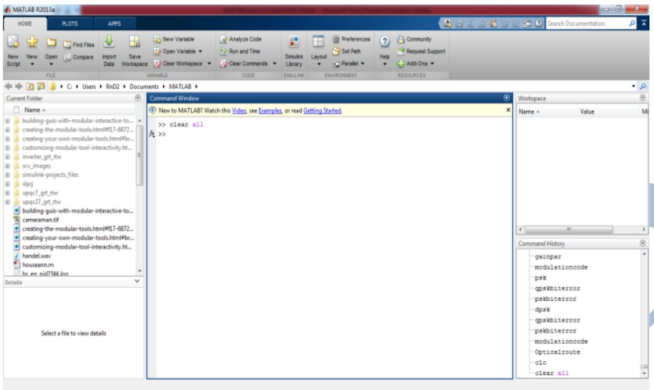
The mean intensity of signal RB generated in the distribution fiber is given by equation (8):

$$Psb2 = \frac{Pc*Gonu^{\,2}}{R2*(\alpha 1*\alpha A*\alpha 2)^2} \qquad (8)$$

V. RESULT

A. Simulation Environment Tool

MATLAB is one of a number of commercially available, sophisticated mathematical computation tools, which also include Maple, Mathematica, and MathCAD. Despite what proponents may claim, no single one of these tools is “the best.” Each has strengths and weaknesses. Each allows you to perform basic mathematical computations. They differ in the way they handle symbolic calculations and more complicated mathematical processes, such as matrix manipulation. For example, MATLAB (short for Matrix Laboratory) excels at computations involving matrices, whereas Maple excels at symbolic calculations. It is shown in fig 2.



New to MATLAB? Watch this Video, see Examples, or read Getting Started.

```
>> clear all
>>
```

```
gainpar
modulationcode
psk
qpskbiterror
pskbiterror
dpsk
qpskbiterror
pskbiterror
modulationcode
Opticalroute
clc
clear all
```

Figure 2: MATLAB Tool

B. Graphical User Interface

Figure 3: Graphical User Interface

MATLAB apps are self-reliant MATLAB programs with GUI front ends that systematize a task or calculation. The GUI typically comprises controls such as menus, toolbars, buttons, and sliders.

C. Input Optical Parameters

Table 1 show the various input parameters used by this proposed network.

Table 1: Input Optical Parameters

Input Parameters	**Value**
Wavelength	100 µm
a	.45
b	.42
Line Width	10 DB
Delay	1 DB
Incident power	100 DB
Recapture Factor	0.5
Attenuation	0.1 dB
Feeder fiber length	40 km
Distribution fiber length	60 km
Insertion Loss	10 DB
System Margin	8 DB
Energy	100 DB
Noise Power	10 DB
Min Received Power	10 DB
No. of Servers	6
No. of Signals	5
Expected Blockage	1

D. Output Parameters

The output parameters are important in every network. Because their value decide whether network holds good or not. There are various calculated parameters shown below:

```
17
```

Figure 4: Extinction Ratio

```
0970330390819.5803
```

Figure 5: Optical Gain Output

```
00.85714    0.68182    0.50805    0.34181    0.19592
```

Figure 6: Blocking Probability Output

```
0151.4888    110.0196    76.58292    50.31889    29.66335
```

Figure 7: Delay Output

E. *Graphical Analysis*

1. Power Relations

The power ratio between Pcb and Psb can be derived via dividing Pcb/Psb. The power ratio between Pcb and Psb can be derived. Note that Fig. 8 is independent of ONU gain and all types of RB powers are calculated at port 2 of the OLT optical circulator. An interesting opinion is that while carrier backscattering generated in the feeder fiber is dominant, signal RB generated in a short distribution fiber may be comparable with or even larger than that produced in a long feeder fiber.

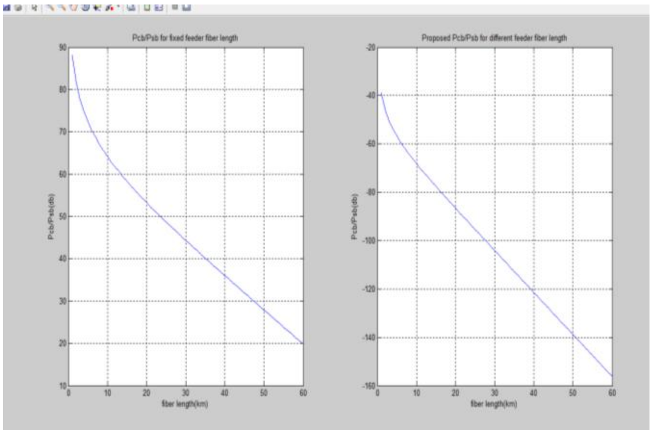


Figure 8: Power Relation

2. BER-Noise Relation

As an alternative approach to directly measuring the BER, it is common to extrapolate the BER from a few data points that require less time to measure. It is important to note that due to the random nature of the noise, the noise levels of the base line link and the noise generator are not simply added together when determining the overall link noise level.The fig 9 shows the relation between BER with noise power. As power increases, BER decreases and vice-versa.

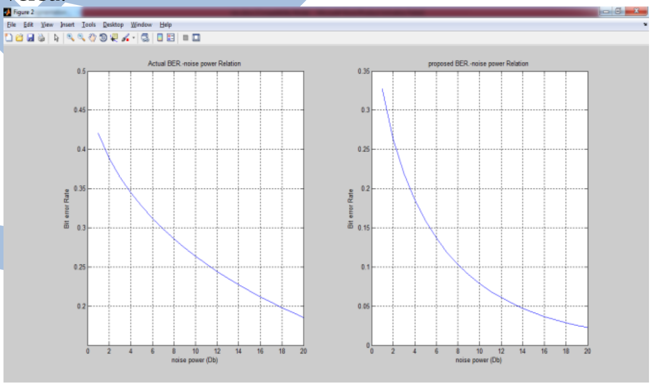


Figure 9: BER-Noise Relation

F. *Output Using Wavelength Assignment*

Table 2 shows that effect of wavelength assignment on various parameters.
Enter the wavelength of signal: 100
No. of Wavelengths 5

Table 2: Wavelength Assignment (I) Output

Blocking Probability	0.9091	0.7843	0.6295	0.4387
BER	0.2181	0.2348	0.2585	0.2943
Delay	175.8901	148.0708	116.2607	80.7032

V. CONCLUSION

This paper reviewed the wavelength assignment and their effect in WDM network with optical carrier regeneration. The wavelength transfer problem was transformed into the vertex colouring problem. An optical delay interferometer at central office tailors the chirp of the converted upstream signal to improve the system bandwidth and the dispersion tolerance. The bandwidth of system can be increased by increasing the capacity of the system. The capacity of system can be increased by increasing the number of users without disturbing the working of another user. The various performance parameters has been studied and numerically investigated. Their graphical analysis is also plotted and examined. The results showed that as it increases the wavelength of channel, delay is also increases. The graphical analysis shows that as system contains noise, BER is also high. So, to decrease BER, system must use filters to reduce noise.

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