K. Nishanth Rao et al. Int. Journal of Engineering Research and Applications www.ijera.com
ISSN: 2248-9622, Vol. 5, Issue 8, (Part - 5) August 2015, pp.141-148

RESEARCH ARTICLE OPEN ACCESS

Single Mode Optical Fiber in Rof System Using DWDM

K. Nishanth Rao, B. Kalpana, S.V.S Prasad
Assistant Professor, Dept of ECE, MLR Institute of Technology, Hyderabad
M. Tech Student, Dept of ECE, MLR Institute of Technology, Hyderabad
Associate Professor, HOD of ECE, MLR Institute of Technology, Hyderabad.

Abstract

Performance analysis was carried out to find the effect of crosstalk in a WDM system. Firstly, analysis of BER was carried out without crosstalk. Then analysis of BER with crosstalk was done. Using equation for crosstalk, number of channels was plotted using matlab. System parameters were optimized for a particular crosstalk.

***Objective* of the thesis work**

Performance Analysis is carried out to find the effect of crosstalk due to optical cross connect in a DWDM system considering a WDM based optical cross connect (OXC). An analysis is carried out to find the amount of crosstalk due to OXC. The bit error rate performance degradation due to crosstalk is evaluated for OXC parameter and number of wavelengths per fiber. The optimum parameters such as optimum number of channels and hops are determined.

I. INTRODUCTION

OPTICAL wavelength division multiplexing (WDM) networks are very promising due to their large bandwidth, their large flexibility and the possibility to upgrade the existing optical fiber networks to WDM networks. WDM has already been introduced in commercial systems. All-optical cross connects (OXC), however, have not yet been used for the routing of the signals in any of these commercial systems. Several OXC topologies have been introduced, but their use has so far been limited to field trials, usually with a small number of input–outputfibers and wavelength channels. The fact, that in practical systems many signals and wavelength channels could influence each other and cause significant crosstalk in the optical cross connect, has probably prevented the use of OXC's in commercial systems. The crosstalk levels in OXC configurations presented so far are generally so high that they give rise to a significant signal degradation and to an increased bit error probability. Because of the complexity of an OXC, different sources of crosstalk exist, which makes it difficult to optimize the component parameters for minimum total crosstalk. In this paper, the crosstalk with the bit error rate and without bit error rate is calculated and compared with each other, and the influence of the component crosstalk on the total crosstalk is identified. We present an analytical approximation for the total crosstalk level in a WDM system, which makes the component parameter optimization considerably easier.

II. OPTICAL MULTIPLEXING SCHEMES

A. *Orthogonal frequency-division multiplexing (OFDM):*

Orthogonal frequency-division multiplexing (OFDM) — essentially identical to Coded OFDM (COFDM) and Discrete multi-tone modulation (DMT) — is a frequency-division multiplexing (FDM) scheme utilized as a digital multi-carrier modulation method. A large number of closely-spaced orthogonal sub-carriers are used to carry data. The data is divided into several parallel data streams or channels, one for each sub-carrier. Each sub-carrier is modulated with a conventional modulation scheme (such as quadrature amplitude modulation or phase-shift keying) at a low symbol rate, maintaining total data rates similar to conventional single-carrier modulation schemes in the same bandwidth.OFDM has developed into a popular scheme for wideband digital communication, whether wireless or over copper wires, used in applications such as digital television and audio broadcasting, wireless networking and broadband internet access.

The primary advantage of OFDM over single-carrier schemes is its ability to cope with severe channel conditions — for example, attenuation of high frequencies in a long copper wire, narrowband interference and frequency-selective fading due to multipath — without complex equalization filters. Channel equalization is simplified because OFDM may be viewed as using many slowly-modulated narrowband signals rather than one rapidly-modulated wideband signal. The low symbol rate makes the use of a guard interval between symbols affordable, making it possible to handle time-spreading and eliminate intersymbol interference

(ISI). This mechanism also facilitates the design of Single Frequency Networks (SFNs), where several adjacent transmitters send the same signal simultaneously at the same frequency, as the signals from multiple distant transmitters may be combined constructively, rather than interfering as would typically occur in a traditional single-carrier system.

B. Wavelength-Division Multiplexing (WDM):

In fiber optic communications, wavelength-division multiplexing (WDM) is a technology which multiplexes multiple optical carrier signals on a single optical fiber by using different wavelengths (colours) of laser light to carry different signals. This allows for a multiplication in capacity, in addition to enabling bidirectional communications over one strand of fiber. This is a form of frequency division multiplexing (FDM) but is commonly called wavelength division multiplexing.

The term wavelength-division multiplexing is commonly applied to an optical carrier (which is typically described by its wavelength), whereas frequency-division multiplexing typically applies to a radio carrier (which is more often described by frequency). However, since wavelength and frequency are inversely proportional, and since radio are both forms of electromagnetic radiation, the two terms are equivalent in this context.

A WDM system uses a multiplexer at the transmitter to join the signals together, and a demultiplexer at the receiver to split them apart. With the right type of fiber it is possible to have a device that does both simultaneously, and can function as an optical add-drop multiplexer. The optical filtering devices used have traditionally been etalons, stable solid-state single-frequency Fabry-Perot interferometers in the form of thin-film-coated optical glass.

As explained before, WDM enables the utilization of a significant portion of the available fiber bandwidth by allowing many independent signals to be transmitted simultaneously on one fiber, with each signal located at a different wavelength. Routing and detection of these signals can be accomplished independently, with the wavelength determining the communication path by acting as the signature address of the origin, destination or routing. Components are therefore required that are wavelength selective, allowing for the transmission, recovery, or routing of specific wavelengths.

In a simple WDM system each laser must emit light at a different wavelength, with all the lasers light multiplexed together onto a single optical fiber. After being transmitted through a high-bandwidth optical fiber, the combined optical signals must be demultiplexed at the receiving end by distributing the total optical power to each output port and then requiring that each receiver selectively recover only one wavelength by using a tunable optical filter. Each laser is modulated at a given speed, and the total aggregate capacity being transmitted along the high-bandwidth fiber is the sum total of the bit rates of the individual lasers. An example of the system capacity enhancement is the situation in which ten 2.5-Gbps signals can be transmitted on one fiber, producing a system capacity of 25 Gbps. This wavelength-parallelism circumvents the problem of typical optoelectronic devices, which do not have bandwidths exceeding a few gigahertz unless they are exotic and expensive. The speed requirements for the individual optoelectronic components are, therefore, relaxed, even though a significant amount of total fiber bandwidth is still being utilized.

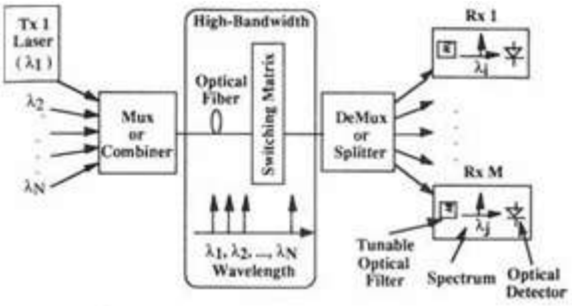


Figure .1: Diagram Of A Simple WDM System

C. DWDM System

Dense wavelength division multiplexing, or DWDM for short, refers originally to optical signals multiplexed within the 1550 nm band so as to leverage the capabilities (and cost) of erbium doped fiber amplifiers (EDFAs), which are effective for wavelengths between approximately 1525-1565 nm (C band), or 1570-1610 nm (L band). EDFAs were originally developed to replace SONET/SDH optical-electrical-optical (OEO) regenerators, which they have made practically obsolete. EDFAs can amplify any optical signal in their operating range, regardless of the modulated bit rate. In terms of multi-wavelength signals, so long as the EDFA has enough pump energy available to it, it can amplify as many optical signals as can be multiplexed into its amplification band (though signal densities are limited by choice of modulation format). EDFAs therefore allow a single-channel optical link to be upgraded in bit rate by replacing only equipment at the ends of the link, while retaining the existing EDFA or series of EDFAs through a long haul route. Furthermore, single-wavelength links using EDFAs can similarly be upgraded to WDM links at reasonable cost. The EDFAs cost is thus leveraged across as many channels as can be multiplexed into the 1550 nm band.

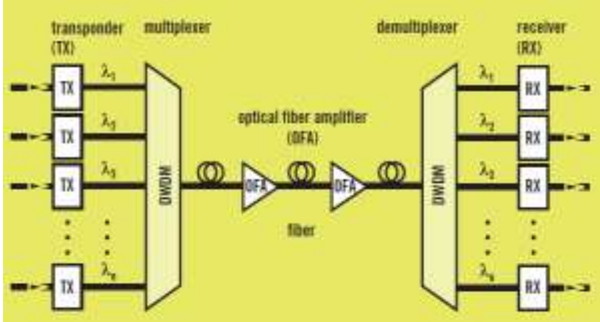


Figure.2: Multichannel DWDM transmission system

D. *Transponder*

Transponders receive optical signals and send them out carrying digital information at predefined wavelengths in accordance with the ITU-T guidelines (see reference table on pages 75 to 79) . A single channel transmitter typically consists of a high power distributed feedback (DFB) laser followed by a modulator and power amplifier (also referred to as a post-amplifier or booster). Direct modulation of the laser is only possible up to 2.5 Gbps. For higher transmission rates as a result of laser chirp, an external modulator must be used. DFB lasers offer greater precision than Fabry-Perot (FP) lasers, the latter of which emits harmonics close to the main peak rendering them unsuitable for DWDM systems. In DWDM systems both fixed and uneable laser sources can be utilized. In networks with dense channel spacing, transponder temperature must be stabilized. This can be enabled with the use of thermo-electric coolers.

E. *Multiplexer (MUX)*

MUX are deployed in DWDM systems to combine the signals at different wavelengths onto a single fiber through which they then travel simultaneously. Each wavelength carries its own information and represents a channel. An ideal MUX requires uniformly high transmission across the passband with a very high drop at the edge.

F. *Fiber*

The fiber is one of the most critical components of a DWDM system as it provides the physical transportation medium. Optical fibers consist of both core and cladding. The core is the inner, light-guiding section and is surrounded by the cladding. As the refractive index of the core is higher than that of the cladding, light entering it at an angle – or numerical aperture – is fully reflected (almost 100 percent) off the core/cladding boundary and propagates down the length of the fiber. Optical fibers can be divided into multimode and singlemode fibers, each approximately the size of a human hair, with an outer diameter of 125 μm. Core size however differs. The diameter of multimode fibers range from between 50 μm and 62.5 μm, whilst for singlemode fibers it is between 7 and 10 μm. Light propagates down the fiber core in a stable path known as a mode. In multimode fibers, multiple paths arise making them unsuitable for use in long haul DWDM transmission. In DWDM systems the fibers can be used either unidirectionally (signals transmitted in one direction only per fiber) or bi-directionally (signals traveling in both directions).

G. *Amplifier*

Amplifiers boost signals traveling down a fiber so they can cover longer spans. In the early stages of fiber optic telecommunications, lasers emitted relatively low power which led to the signal having to be frequently electrically regenerated (figure 7). These amplifiers receive the optical signal and convert it into an electrical signal (O/E conversion) which is then reshaped, retimed and amplified again. This is the so called 3R regenerator. Finally, the signal is converted back to an optical signal (E/O conversion). Optical fiber amplifiers (OFAs) can be used to provide a more economical solution. These can work solely in the optical domain, performing a 1R (optical reamplification only) regeneration. OFAs simultaneously amplify each wavelength of the DWDM signal without the need for demultiplexing and remultiplexing. One major advantage of OFAs is their transparency to signal speed and data type. Three types of OFAs are deployed in DWDM systems: erbium doped fiber amplifier (EDFA), semiconductor optical amplifiers (SOA) and Raman fiber amplifiers (RFA). In DWDM systems, the multiplexed signal has to be demultiplexed before each channel is regenerated, emitted by a laser and then multiplexed again. This is a process which is both complex and expensive.

H. *Demultiplexer (DEMUX)*

DEMUXs unscramble multiplexed channels before they are fed into their corresponding receivers. They work similarly to MUXs but operate in the reverse direction. It is common to preamplify optical signals before they are separated by the optical filters of the demultiplexer. The performance of a MUX or DEMUX is related to its capability to filter each incoming signal. The Bragg grating is currently the most popular technique used in DWDM systems.

I. *Receiver*

Receivers are used to convert optical signals into electrical signals. The light pulses transmitted over the optical fiber are received by a light sensitive device known as a photo diode which is made of semi-conductor material.

J. *Limitations of WDM*

Crosstalk will be one of the major limitations for the introduction of OXC in all optical networks. In this paper the influence of the components on the total OXC crosstalk is investigated.

K. Crosstalk

Crosstalk occurs in devices that filter and separate wavelengths. A small proportion of the optical power that should have ended up in a particular channel(on a particular filter output) actually ends up in an adjacent (or another) channel.Crosstalk is critically important in WDM systems. When signals from one channel arrive in another they become noise in the other channel. This can have serious effects on the signal-to-noise ratio and hence on the error rate of the system. Crosstalk is usually quoted as the “worst case” condition. This is where the signal in one channel is right at the edge of its allowed band. Crosstalk is quoted as the loss in dB between the input level of the signal and its (unwanted) signal strength in the adjacent channel. A figure of 30 dB is widely considered to be an acceptable level for most systems.

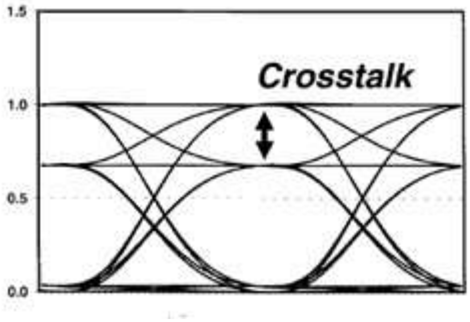


Figure. 3:Defination of Cross talk

L. Types of crosstalk

Different kinds of crosstalk exist, depending on their source. First one has to make a distinction between interband crosstalk and intraband crosstalk.

Interband crosstalk: Interband crosstalk is the crosstalk situated in wavelengths outside the channel slot (wavelengths outside the optical bandwidth). This crosstalk can be removed with narrow-band filters and it produces no beating during detection, so it is less harmful. In a WDM networks, interband crosstalk appears from channels of different wavelengths.

Intraband Crosstalk: The crosstalk within the same wavelength slot is called intraband crosstalk.(fig 1.2). It cannot be removed by an optical filter and therefore accumulates through the network. Since it cannot be removed, one has to prevent the crosstalk. In this paper intraband crosstalk is studied since the network performance will be limited by this kind of crosstalk. Intraband crosstalk occurs when the signal and the interferer has the closely-valued wavelengths. Intraband however, can be coherent or incoherent crosstalk. If the signal crosstalk mixing takes place within the laser coherence length, then intraband crosstalk is defined as coherent. Otherwise incoherent crosstalk will appear.

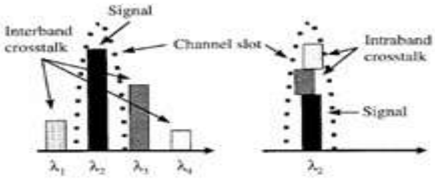


Figure.5: Interband and Intraband Crosstalk

Moreover, within the intraband crosstalk, a distinction between incoherent and coherent crosstalk has to be made. These types of crosstalk are not well defined in literature and therefore a definition is given here. To make a distinction between both types of intraband crosstalk one has to look at the consequences. The interference of the signal channel and the crosstalk channel at the detector results in a beat term.

III. ANALYSIS OF CROSSTALK IN WDM SYSTEM

Firstly the block diagrams representing the system block diagram and WDM system with Hops. Secondly, analysis of Bit Error Rate without Crosstalk, which is in ideal case, is given. Then analysis of Bit Error Rate with Cross talk using equations in both the cases is given.

A. WDM system block diagram

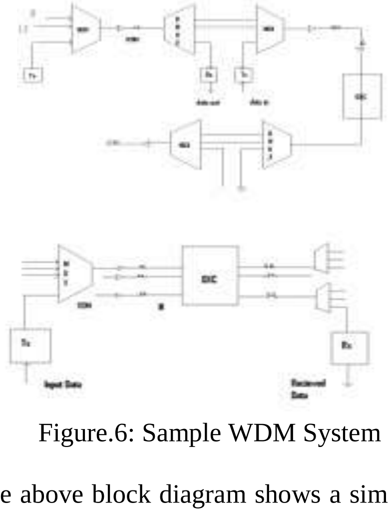


Figure.6: Sample WDM System

The above block diagram shows a simple WDM system. Here L numbers of signals are multiplexed in a channel in a multiplexer from transmitters. N number of channels are going through Optical Cross connect and each channel are demultiplexed using a demultiplexer and the receiver receives the desired signal.

IV. SYSTEM BLOCK DIAGRAM WITH HOPS

The above diagram shows a WDM system block diagram with hops. Here three hops are shown. L number of signals are multiplexed and passed through a optical fiber. Which is demultiplexed to get the desired signal and a new signal is multiplexed by the transmitter. The signal passes through optical fiber again. This way hops are used.

A. Block diagram of optical cross connect

Figure.7: Schematic illustration of conventional OXC node

The above diagram shows an optical cross connect where M input fibers are coming. The cross connect switches the signal to the desired location to pass on the other side to be demultiplexed.

B. Block diagram of oxc crosstalk

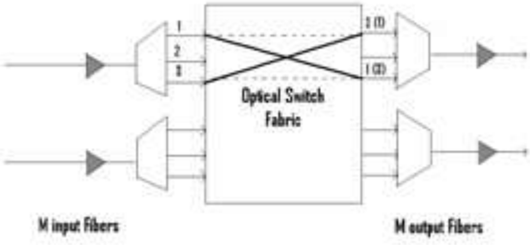


Figure.8: Schematic illustration of conventional OXC node

The above diagram shows the crosstalk in the Optical switch. In the switch, signal from input 1 is connected with output 3. And signal from input 3 is connected to output 1. But it can be seen that in output 3, a little portion of input 3 has entered along with the signal 1. Similarly at output 1 a little portion of input 1 has entered along with the signal 3. this unwanted portion of signal that enters in the output of the Optical Cross connect is the crosstalk due to OXC.

*C. **Analysis** of Bit Error Rate without Crosstalk*

Bit Error Rate can be calculated with and without Crosstalk using some equations. In this section the ideal case is shown. So Crosstalk is taken to be zero. Equation for crosstalk is given is the next section. Bit Error Rate: The number of bit errors that occur within the space of one second. This measurement is one of the prime considerations in determining signal quality. The higher the data transmission rate the greater the standard.

The BER is an indication of how often data has to be retransmitted because of an error. Too high a BER may indicate that a slower data rate would actually improve overall transmission time for a given amount of transmitted data since the BER might be reduced, lowering the number of packets that had to be resent.

For most practical WDM networks, this requirement of BER is 10^{-12} (~ 10^{-9} to 10^{-12}), which means that a maximum one out of every 10^{12} bits can be corrupted during transmission. Therefore, BER is considered an important figure of merit for WDM networks; all designs are based to adhere to that quality.

BER in WDM system is calculated by the equation:
BER =. 5 erfc (Q/√2) (eq. 1) Here Q is a function proportional to the receiver signal-to-noise ratio (SNR).

D. Analysis of Bit Error Rate with Crosstalk

In practical case zero crosstalk is not possible. So BER is calculated with equation 1 taking in the value of σc
BER =. 5 erfc (Q/√2) (eq. 1)
Here Q is a function proportional to the receiver signal-to-noise ratio (SNR).
It is expressed as:
Q = (Rd * Ps) ^2/√(σase^2 + σc^2)

V. RESULTS AND DISCUSSION

BER or Bit Error Rate is plotted as a function of input power (Pin) in dbm in Figure: 1 Here the value of Rb(bit rate) is 10GHz. The Pin is taken from range -8 dbm to 100 dbm. The resulting graph of BER VS Pin is plotted bellow. It is seen that without crosstalk the BER increase with increase in Pin.

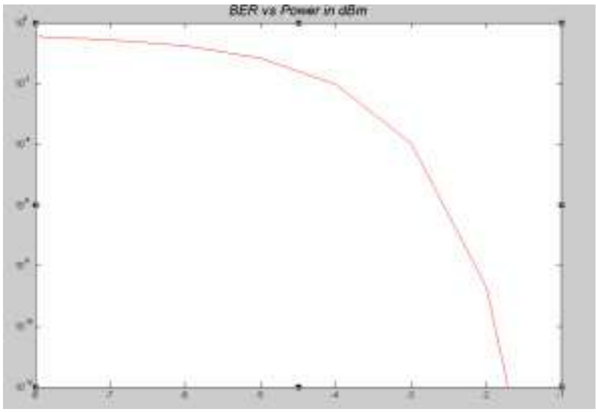


Figure 9

This is the plot of BER vs power in dbm for different bandwidths. Here for without crosstalk different values of bandwidth(B) is taken and has been shown in graph. The input power is taken from range -8 dbm to -1 dbm. Then the corresponding values of BER are plotted against Pin for the corresponding different values of B.

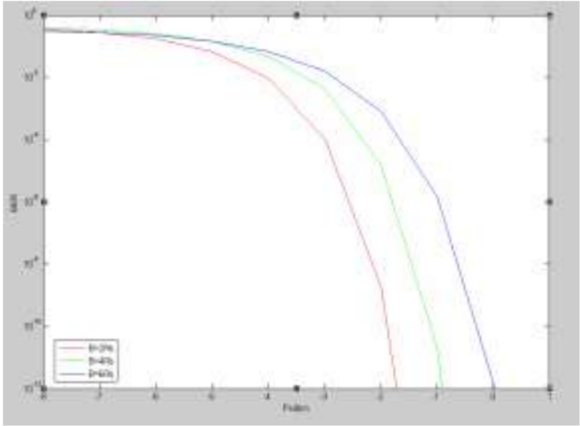


Figure.10: BER vs input power for different Bandwidth.

The resulting graph of BER VS Pin is plotted above. We have plotted this graph for three different bandwidths. It is seen that the BER increases with increase in Pin. It is also shown that to use more bandwidth we need more input power. For example, when we use 4*Rb as our bandwidth, we need -1.2dbm power where we need 0.1 dbm input power to use 6*Rb as bandwidth. At the same time BER also increase with increase in bandwidth.

A. *BER with Crosstalk*

BER or bit error rate is plotted as a function of input power (Pin) in dbm in Figure: 3.

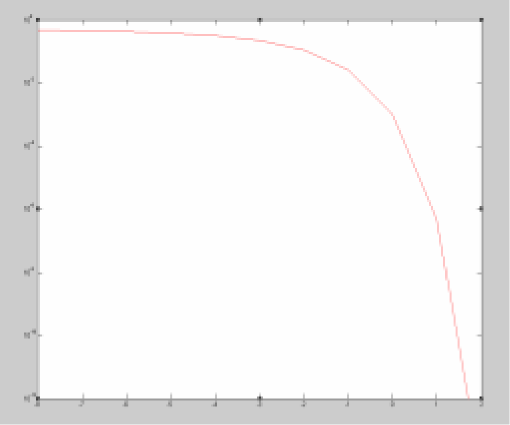


Figure.11: BER vs Input power in dbm

In this graph we have plotted BER against Input power in dbm when crosstalk is available. Now we have plotted the graph of BER against input power in dbm for different crosstalk. Different values of crosstalk have been taken here for a fixed bandwidth and analysis the graphs for different crosstalk. The input power is taken from range -5dbm to 20dbm.

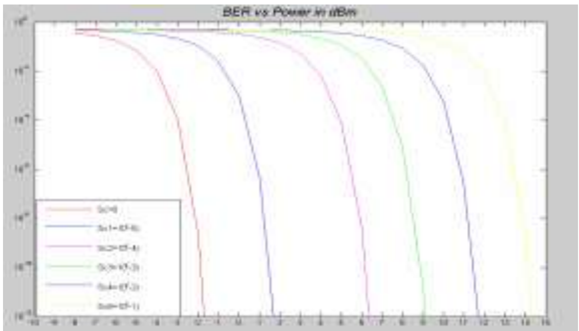


Figure 12: BER vs input power in dbm for different crosstalk.

Here we show that BER increase for increasing crosstalk. For using more input power we get more crosstalk. For example, when 1.8 dbm is used as input power, the crosstalk is and for 9.1dbm input power, crosstalk is. At the same time BER is also increasing.

Figure below shows Crosstalk plotted against number of channel using in WDM system. The input power is taken from the range -8dbm to 20 dbm. Effective adjacent and non adjacent both are taken 0.5. We have plotted this graph for 2 hoops and 10 channels.

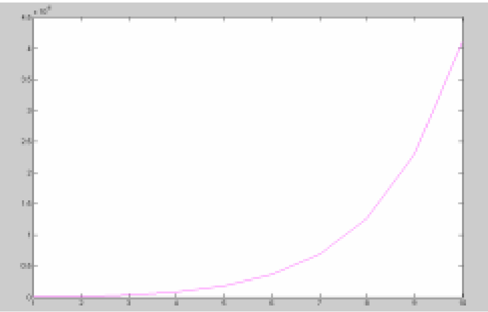


Figure 13: crosstalk vs number of channel

From this graph it can be said that crosstalk increase if we use more channels. The graph of crosstalk vs number of channel is plotted for different number of hops. In this graph we have changed the value of M for the same input power, which is -8dbm to 20 dbm and for 10 channels.

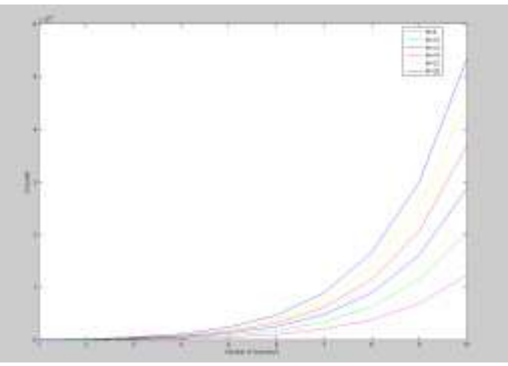


Figure 14: crosstalk vs number of channels

It can be said that if we increase the number of hop then crosstalk also increases. Another way it can be analyzed that for a fixed number of crosstalk if we use more hops, the number of channel decrease and in another way we can use more channels for less hops. Now from the figure 4, for one bit error rate we can find the power penalty from the input power. Power penalty is the difference between two powers. So for calculating power penalty we need to calculate the difference of input power with crosstalk from the power without crosstalk.Power penalty vs crosstalk is plotted here.

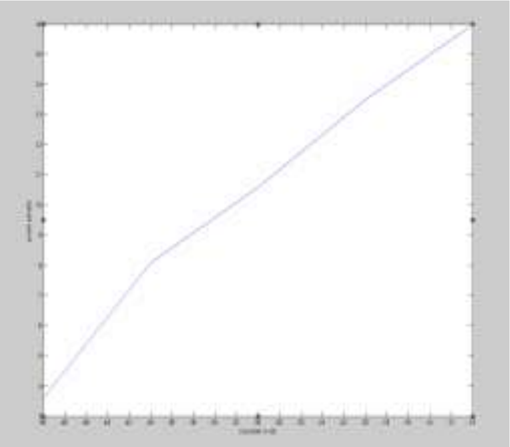


Figure 15: power penalty vs crosstalk

From this graph we can be able to find out the crosstalk for different power penalty.

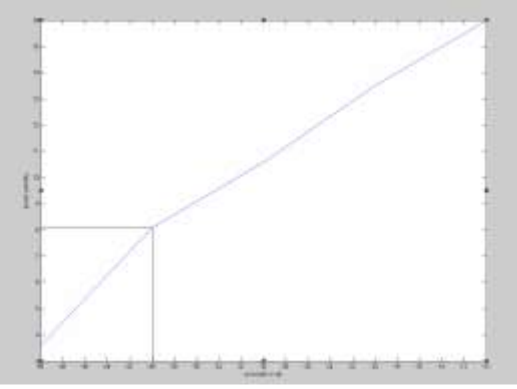
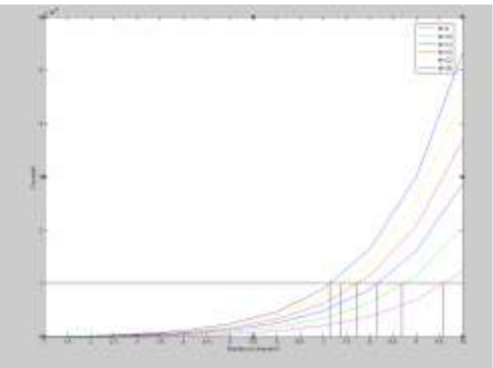


Figure 16: power penalty vs crosstalk.

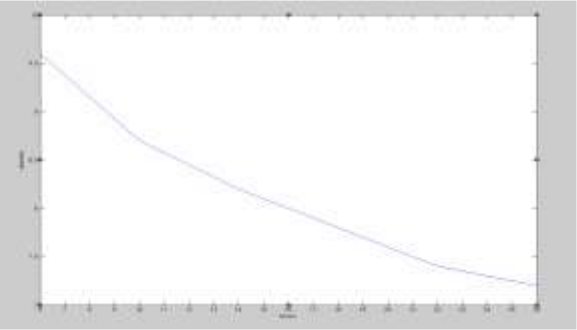
For example, it can be said that for 8.1 power penalty relative crosstalk is -40 db, which is 0.0004. in this way we can find crosstalk for a given power penalty. After finding the amount of crosstalk we can find the number of channels and number of hops can be used for that particular crosstalk from figure 6 which is crosstalk vs number of channels.



For this graph we are able to find out the number of channels and hops for related crosstalk. For example for power penalty 8.1db we got the corresponding crosstalk to be -40db which is 10^(-4). From the above graph, we can find combinations of hops and channels. Here, the combinations are :

Hoops	Channels
6	9.6 = 10(approx.)
10	8.7 = 9 (approx.)
14	8.2 = 8 (approx.)
18	7.8 = 8 (approx.)
22	7.4 = 7 (approx.)
26	7.2 = 7 (approx.)

Numbers of channel are plotted against number of hops.



This graph can be plotted manually too. Which is given below. This graph shows different combinations of hops and channels for a crosstalk 10 ^ (-4) which we got for power penalty 8.1 db. From this graph any combination can be used for this power penalty. Similarly, we can plot a graph for hops and channels for any power penalty and corresponding crosstalk. Therefore a relationship between hops and channels is established using this graph.

VI. CONCLUSION

In this thesis paper, we have used some basic equations to optimize the relation between hoops and channels. No new equation were derived or used to form this relationship. The graph was plotted manually using the graphs plotted with the basic equations of BER and Crosstalk in matlab software. At first a graph for BER vs. Pin was plotted using BER equation. Then a graph of crosstalk vs. number of channels was plotted for different number of hops. From this graph power penalty was found out. This power penalty was used to plot a graph of power penalty vs. crosstalk. From this graph we have taken a particular crosstalk. And from the graph of crosstalk vs. channel, the combination of hoops and channels were found out. Which were plot manually to get the final graph. The graphs are shown in the Result section.

In this final graph, we have shown that for a particular Power Penalty, combination of hoops and channels can be plotted. The user can use any combination as required by the system. Hence, we can conclude that by this process we can find number of hoops and channels for a given Power penalty.

FUTURE WORK

Further research can be carried out to evaluate the performance of a WDM network with OXC using different topologies of the OXC and to find a topology with optimum system performance. Work can be carried out to evaluate the performance of a WDM system with bi-directional OXC and find the limitations due to crosstalk and optimum system parameters. Work can be carried out with precoding techniques to minimize the effect of Bit noise due to crosstalk and signal in a WDM system.

REFERENCES

[1]. ‘Performance Limitations of Optical Cross Connect without Wavelength Converter due to Crosstalk’ by M. S, Islam, S.P. Majumder, Ngee Thiam Sim
[2]. ‘Crosstalk in WDM Communication’ by Idelfonso Tafur Monry, EdwardbTangdiongga
[3]. ‘Analysis of Signal Distortion and Crosstalk Penalties Induced By Optical Filters in Optical Networks.’ By John D. Downie, A. Boh Ruffin
[4]. ‘Optical Crosstalk in Fiber Radio WDM Networks’ by David Castleford, Ampalavanapillai Nirmalathas, Dalama Nobak, Rodney S. Tucke.