OPTICAL POWER DEBUGGING IN DWDM SYSTEM HAVING FIXED GAIN AMPLIFIERS

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Abstract

This article covers optical power measurement of light signal in DWDM network and debugging of optical power as per the specifications of DWDM system with fix gain amplifier. The measurement and calculations of each component of DWDM system is discussed individually. Optical power of individual optical channel, aggregate optical power of multiplexed signals, relation with amplifier gain, insertion loss and attenuation on signal are the key factors involved in design and operation of DWDM system. From transmitter to receiver, the working performance of the DWDM system depends on the optical strength of input light signal should be as per specifications of its components. A description of input and output optical power of light signal of each DWDM component and its relationship is discussed. If there is any deviation as per specifications is observed, process to calculate deviation and debug is given with working example in this article.

Keywords: *Dense wavelength division multiplexing (DWDM), Optical MUX/DEMUX, Optical transmitters/receivers, Optical amplifiers, Optical Fiber, Optical power, Attenuation, Optical Power Debugging*

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1. INTRODUCTION

DWDM stands for 'Dense Wavelength Division Multiplexing'. DWDM is an extension over traditional optical network with idea of WDM. DWDM is a technology to transmit multiple light signals through a single optical fiber cable simultaneously. This idea is based on the property of light which says that light rays with different wavelength can travel with each other without distorting each other. In DWDM system, multiple light signals (which may have same wavelength) from traditional optical networking devices comes to DWDM system at input. Here they are tuned with the help of transponder to specific wavelengths as per requirement of DWDM system i.e. on C-Band. For this tuning input optical signal is first convert to electrical and then again regenerated to optical signal with tuned λ. As this optical signal is regenerated in transponder hence optical strength of output of light signal of each transponder is expected to be same or nearby. These light signals with tuned wavelength will then multiplexed with the help of Optical Multiplex Unit (MUX). This MUX is a passive device and only has capability to multiplex multiple light signals and not to strengthen it. There is always a big insertion loss of optical strength of light signal during this multiplexing. As light signal has to travel over long distance and should have enough strength, hence this multiplexed signal with low strength pass through an amplifier (normally refer as booster amplifier or output amplifier at transmit end). We are considering amplifiers with fixed gain in our article. After gaining strength in amplifier, signal will be transmitted over line fiber where it will travel to destination. Vice-versa will happen at receiver end. Receive signal is amplified by amplifier (refer as pre amplifier or input amplifier) and de-multiplexing is done by Optical Demux Unit (DEMUX). During this operation of DWDM system, multiple times it happens when the components of DWDM get the input signal which does not match their defined specifications and hence unable to give desired output. For efficient and proper working of these components and also DWDM system it is highly required that the input light signal of each component should match the defined specification and if not so we have to debug them to desired level.

2. PURPOSE OF OPTICAL POWER DEBUGGING

Optical power debugging is a very important task for smooth functioning of DWDM network. It will ensure that all components of DWDM system will function as per requirement and specification.

There are three basic purpose of optical power debugging:

1. Each optical channel would have same optical power during the transmission.

   During DWDM transmission, multiplexed optical signal or channel lose their strength during travelling long distance and need to amplify multiple times using optical amplifier. We need to ensure that they should have same optical strength at the receiver end or should have minimum difference. We need to control the difference between any two waves to less than 3 dB.

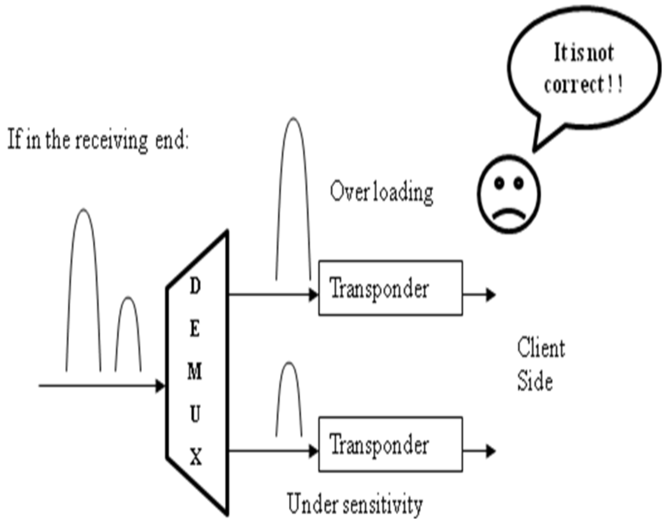


Fig -1: Effect of non uniform strength of signals

2. Optical Amplifier should work in saturated state.

As mentioned above, optical channels need to amplify multiple times using optical amplifier during transmission. These optical amplifiers should work in saturated state. If not so, they will cause amplification discrepancy and will give different amplification to different channels or will not able to work as per requirement of network.

There are 3 working states of Optical amplifier –

a. Oversaturated state **-** will amplify more than the requirement of network. This can damage hardware at receiver end.
b. Saturated state – will amplify as per requirement. This is the best working state.
c. Under saturated state – will amplify less than the requirement of network. In this case signal at receiver end is either destroyed or have errors. It will affect the traffic.

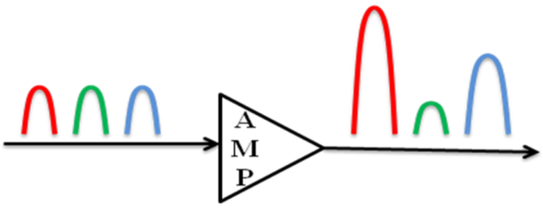


Fig -2: Malfunctioning of optical amplifier

Here red wave will cause hardware failure of Rx port and green wave not detect at Rx and cause signal failure. It is not a good working of optical amplifier.

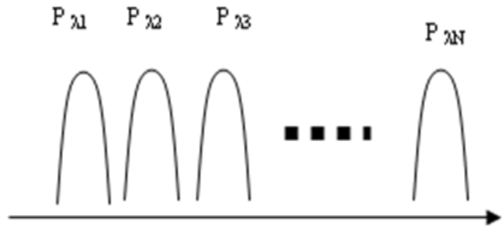
3. Make OTU-Rx in best working state.

If there is discrepancy in the increment of optical power between the light channels during amplification then some of the light channel will have more optical power and some will have less optical power than specifications. It will either cause hardware fault of OUT or signal outage.

3. BASIC FORMULAS

There are 3 basic formulas we will use for our calculations.

3.1 Formula-1



$P_N = P_{\lambda1}+P_{\lambda2}+P_{\lambda3}+\ldots+P_{\lambda N}$ **(mW)**

$P_N = P_1+P_1+P_1+\ldots+P_1$ **(mW)** as $P_{\lambda1}=P_{\lambda2}=\ldots=P_{\lambda N} = P_1$

$P_N = N\times P_1$ **(mW)**

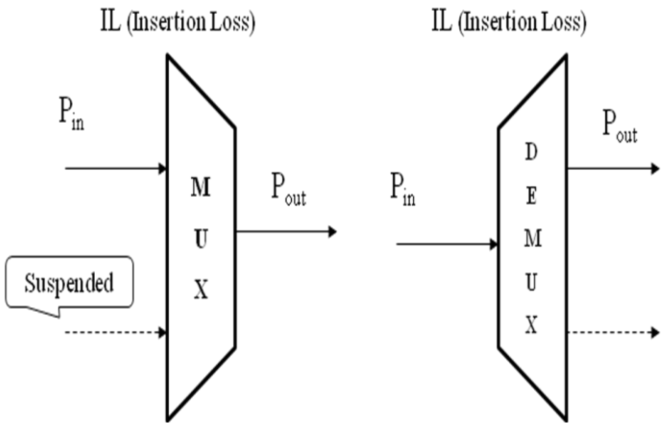
$10\lg P_N = 10 \lg (N\times P_1)$

$10\lg P_N = 10 \lg N+10\lg P_1$ since 10lgP (mW) = P (dBm)

$P_N = 10 \lg N+P_1$ (dBm)

$P_N = 10 \lg N + P_1$ (dBm)

3.2 Formula-2



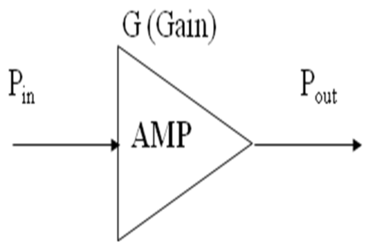
$P_{out} = P_{in}/IL$ (mw)

$10\lg P_{out} = 10\lg P_{in} - 10\lg IL$ since 10lgP (mw) = P (dBm)

$P_{out} = P_{in} - IL$ (dBm)

$P_{out}=P_{in}-IL$ (dBm)

3.3 Formula-3



$P_{out} = P_{in} \times G$ (mw)

$10lgP_{out} = 10lgP_{in} + 10lgG$ since $10lgP(mw) = P$ (dBm)

$P_{out} = P_{in} + G$ (dBm)

$P_{out} = P_{in} + G$ (dBm)

4. WORKING MODEL

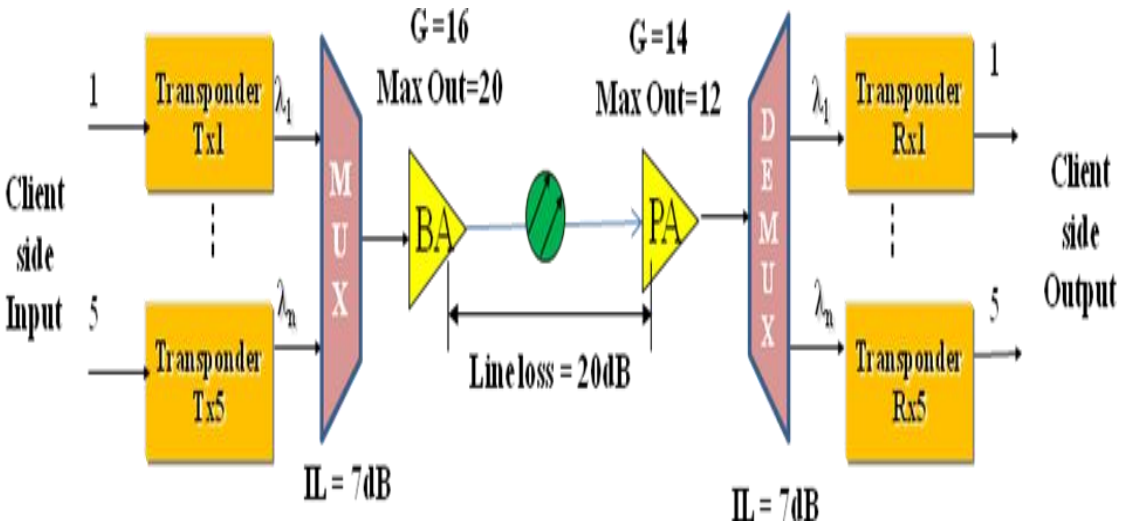


Fig -3: Working model of DWDM system having fixed gain amplifiers

Diagram shown above is DWDM system. In this we have a DWDM system having capacity to support up to 32 channels. Presently only five optical channels are used for this system. Each optical channel is coming from Tx side transponder with optical power of 3 dBm. Now they will undergo DWDM multiplexing under MUX, where insertion loss of each channel is 7dB. Now aggregate output of this MUX module will be amplify at output amplifier having fixed gain of 16 dB and maximum output of 20 dBm, when all 32 channel are in use and then send to line side fiber where it will carry out to receiver end. During this there will be fiber line loss of 20 dB on each channel. At receiver end there is input amplifier having fixed gain of 14 dB and maximum output of 12 dBm. Amplified signal from input amplifier will go to DEMUX for de-multiplexing, where each channel will be separated. During this there will be insertion loss of 7 dB. Now these separated light signals will be received by transponder. During optical power debugging we have to calculate the power level at each input and output point. Also we have to found out when and what attenuation should be added in the system to function in optimum way.

5. METHOD OF DEBUGGING AND CALCULATIONS

In our working model each components has its optical specifications. On the basis of these specifications we can calculate ideal input optical power. Every component will work in its best state when it will get ideal value as input. Also we can calculate output optical power of each component that can be identified as actual input optical power for next component. Output optical power of transponder will be actual input for MUX. Output optical power of MUX will be actual input for booster amplifier. Similarly output of line fiber will be actual input for pre amplifier and output of pre amplifier will be actual input of DEMUX. So we can calculate ideal and actual values of input optical power and debug the deviation.

i. Output power of MUX (Actual input for Booster AMP)

$P_{1out} = P_{1in} - IL$ (Formula 2)
$P_{1out} = -3-7 = -10$(dBm)

ii. Output power of Booster AMP

$P_{32out}=P_{1out}+10lg32$ (Formula 1)
$P_{1out}=P_{32out}-10lg32$
$P_{1out}=20-15=5(dBm)$

iii. Ideal input power of Booster AMP

$P_{1out}=P_{1in}+G$ (Formula 3)
$P_{1in}=P_{1out}-G$
$P_{1in}=5-16=-11(dBm)$

iv. Output optical power of Line fiber (Actual input for Pre AMP)

$P_{After\ Line}=P_{1outOBA}$-Line Loss
$P_{After\ Line}=5-20=-15(dBm)$

v. Output power of Pre AMP (Actual input of DEMUX)

$P_{32out}=P_{1out}+10lg32$ (Formula 1)
$P_{1out}=P_{32out}-10lg32=12-15=-3(dBm)$

vi. Ideal input power of Pre AMP

$P_{1out}=P_{1in}+G$ (Formula 3)
$P_{1in}=P_{1out}-G=-3-14=-17(dBm)$

vii. Ideal input power of DEMUX

$P_{1out}=P_{1in}-IL$ (Formula 2)
$P_{1in}=P_{1out}+IL=-14+7=-7(dBm)$

6. RESULTS

In our article, we have calculated ideal and actual optical power of light signal at input of DWDM components. In case of MUX there is no ideal value so debugging is not applicable. For Booster Amplifier input at transmitter ideal optical power is -11 dBm while actual optical power is -10 dBm. There is a difference of 1 dB between ideal and actual value. To make Booster amplifier to work in saturated state, it is require adding 1 dB attenuation at input of Booster Amplifier. For Pre Amplifier at receiver ideal value is -17 dBm while actual value is -15 dBm. It is required to add 2 dB of attenuation to make pre amplifier to work in saturated state. Similarly ideal input power at DEMUX input is -7 dBm while actual value is -3 dBm. Here 4 dB of attenuation is need to add to make DEMUX work as per network design.

Table -1: Results with required attenuation

Network Points	Ideal Value	Actual Value	Attenuation required
MUX Input	NA	-3 dBm	NA
Booster Amp Input	-11 dBm	-10 dBm	1 dB
Pre Amp Input	-17 dBm	-15 dBm	2 dB
DEMUX Input	-7 dBm	-3 dBm	4 dB

Below figure shows DWDM system after debugging.

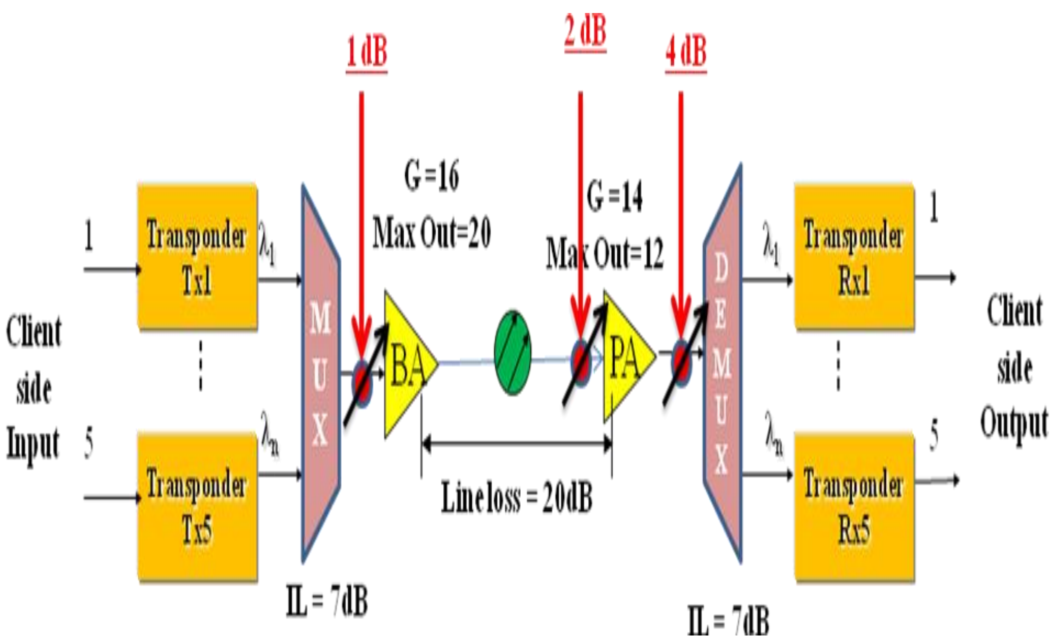


Fig -4: Working model of DWDM system after optical power debugging

7. CONCLUSION

Optical Power debugging plays an important role for smooth and efficient functioning of DWDM system. In this paper, we have studied relationship and calculations between different parameters related optical strength of light signal. Then we evaluated ideal and actual optical power of light signal at input points of DWDM components. Experimental results show that at many points actual value of optical power of light signal differs from ideal value, which is causing failure of network design and may lead to traffic outage and hardware fault of DWDM components. We have also described to debug this difference between ideal and actual value with the help of attenuation. Therefore we can conclude the importance of optical power debugging for better performance of DWDM system having fixed gain amplifiers.

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BIOGRAPHIES

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