

Effect of Modulation Techniques on Power Budgeting in Optical Fiber System

Yankho Alexander Chitungu
(m.tech student)

Electronics and communication engineering department
PDM university
Bahadurgarh, India

Gurmeet Singh
(Assistant Professor)

Electronics and communication engineering department
PDM university
Bahadurgarh, India

Dinesh Kumar Verma
(Assistant Professor)

Electronics and communication engineering department
PDM university
Bahadurgarh, India

Abstract— In this paper the power budgeting of the different modulation techniques is investigated in order to determine which one has the best performance in terms of transmitting power. The modulation techniques researched on are carrier-suppressed return-to-zero (CSRZ), duobinary return-to-zero (DRZ) and modified duobinary return-to-zero (MDRZ). The simulations for the modulation techniques performance were carried out in OptiSystem 17 software.

Keywords—Carrier suppressed return to zero, duobinary return to zero, modified duobinary return to zero

I. INTRODUCTION

In optical fiber communication systems, it is essential to study power budgeting as it helps maintain reliable performance of the system. Power budget can be defined as the maximum amount of power that an optical link is able to transmit. The worst-case analysis is usually used to provide the margin of error. In the paper I shall discuss why power budgeting is important as it helps us to make sure the link will always have enough power to transmit information. This will be demonstrated by calculating the power budget of a given system taking into account the losses and gains the signal will pass through. For the purpose of this study I will take a carrier-suppressed return-to-zero (CSRZ), duobinary return-to-zero (DRZ) and modified duobinary return-to-zero (MDRZ) modulation systems and calculate their respective power budget.

II. REVIEW OF LITERATURE

Optical fiber systems have become the backbone of communication in the 21st century, this is so since fiber optical cables can carry information for long distances with minimal attenuation when compared to other transmission media. The fact that it is immune to electrical interference plays a huge role in this. The other benefit of optical fiber that has made it a backbone of communication is the capacity of the links, fiber links have a transmission capacity which is high so much that the only limit is the receiving and sending equipment capacity.

A. OPTICAL FIBER

Optical fiber is a medium of transmission which sends data in form of light pulses, optical fiber is advantageous due to the fact that it has a high bandwidth capacity, it can transfer of data for longer distances without a need for a booster when compared to the normal copper methods and it is also faster in terms of transmission.

The optical fiber communication basic principle is that the transmitter which can be a laser or an LED emits light pulses which are carried through the optical fiber cable up to the receiving end. If the link is very long repeaters are used to boost up the signal along the way so that when it reaches the receiver the original information can still be detected. When it reaches the receiver, this is where a detector, for example a photodiode is used to detect the received signal and convert it back into electrical signal.

The optical fiber cable is composed of a core and cladding. The core is made up of either glass or plastic which has a higher index of refraction than compared to the cladding. The cladding is made up of a material with a lower index of refraction when compared with the core and is also made using plastic. There are two types of fiber which are single mode fiber and multimode fiber. In Single-mode fiber the core diameter is usually smaller (around 10 microns) compared to the multimode fiber since it only gets to transmit a single mode through the center of the core. Multimode fiber has a core diameter which is bigger than the single mode fiber (around 50 microns or bigger) which allows it to carry multiple modes at the same time.

The multimode fiber can be divided into two different groups which are a step index fiber and graded index fiber. The step index fiber has a problem of modal dispersion which is where some modes take longer to pass through the core as they get to travel a longer distance than others. The graded index fiber is there to solve the problem of the step index fiber, it does this by having a core with varying density which make the modes which travel further to also move faster than the modes which move closer to the core resulting into an almost uniform speed of transmission of all the modes. Nowadays

graded index fiber is the more commonly used compare to the step index fiber because of the reduced modal dispersion and also due to the fact that the graded index has a bandwidth which is higher when compared to the step index.

B. DISPERSION

Dispersion which is the spreading out of light pulse as it travels through the fiber is one of the big issues in optical fiber, dispersion in optical fiber can be divided into three different types which are modal dispersion, polarization mode dispersion and chromatic dispersion. Modal dispersion as explained happens because different modes through the fiber take different amounts of time to pass through, and this has been reduced by using the graded index fiber in place of step index fiber. Chromatic dispersion is caused by the fact that different wavelengths have different velocities, this can occur in both single mode and multi-mode fiber. Finally, the polarization mode dispersion which works on the principle that light with different polarization in the fiber tends to travel at different speed, this type off dispersion can be caused by imperfect circular geometry or stress on the cable.

C. ATTENUATION

Attenuation is the loss of optical power over a certain amount of distance in the optical fiber cable, this means that a fiber cable with lower attenuation will allow a higher amount of power to reach the receiver compared to a fiber cable with higher attenuation which will reduce the amount of power received at the end. Attenuation of a signal in a fiber optic cable is directly proportional to the length of the cable. Attenuation is the ratio of optical output power to the input power in the optical fiber. Attenuation coefficient (α) is calculated using the below equations:

$$Y(\text{dB}) = 10 \log_{10} (P_x/P_y) \quad (1)$$

Where P_x is the input power and P_y is the output power

$$\alpha = A/L \quad (2)$$

where L is the distance between input and output

D. OPTICAL FIBER COMPONENTS

- Fiber Connector: this is used to terminate the end of the fiber cable and enables quicker connection and disconnection.
- Broadband Light Source (BBS): this is a light source that is capable of emitting light over a large wavelength range, good example is super luminescent diodes(SLED).
- Fiber Coupler: this is used to combine or split power in optical fiber cable.
- Circulator: defined a three-port device that couples light from different ports for example port 1 to port 2 and port 2 to port 3 and also has a high isolation in other directions.
- Mode Scrambler: this is a device that is used to mix the optical power in the cable so as to achieve equal power distribution in all modes.

- Index Matching Fluid: this is a liquid which has a similar reflection index to glass which is used to match the materials at the ends of two fibers in order to reduce loss and back reflection.
- Wavelength Division Multiplexer: this a used to either split or combine lights with different wavelengths.

E. DESIGNING OPTICAL LINK

During the designing phase of an optical system there are a number of different things that have to be taken into consideration in order to make the final system cost efficient, durable and most of all perform efficiently at all times. So primarily the things that are considered during design are the dispersion limitation and attenuation limitation, the other criteria that are also taken into consideration include modulation format this can be whether its analog or digital, system fidelity which includes things like bit error rate(BER) and signal to noise ratio(SNR), cost of components during initial system installation and also during maintenance of the system, upgradeability of the system is also considered and its easier if WDM system is used compared to a TDM system. Below is fig 2.1 showing the different criteria considered:

TABLE here

F. POWER BUDGETING

To ensure good performance of the optical system link power budgeting is one of the most important things that is looked into. The equation for calculating link power budget is a shown below

$$P_{TX} (\text{dBm}) = P_{RX} (\text{dBm}) + CL (\text{dBm}) + MS (\text{dBm}) \quad (3)$$

From the above equation P_{TX} is the power of the transmitter itself , P_{RX} is the valuable representing the power of the receiver or in short sensitivity of the receiver, CL is the added sum of all the loses in the transmission link of the system which include the splices and also the connectors, MS is just used as a safety margin of the given system.

For any given optical link, power is lost through the different components being used on that particular link. some of the components are the ones shown below for example the fiber itself, connectors and in splices.

III. SIMULATIONS

In the experiment conducted three different modulation techniques are used, and these are carrier-suppressed return-to-zero (CSRZ), duobinary return-to-zero (DRZ) and modified duobinary return-to-zero (MDRZ). The simulations were done using the aid of OptiSystem 17 software.

A. COMPONENTS

Pseudo Random Bit Sequence Generator which is used to produce a binary sequence of bits which act as a test signal for the simulation. CW Laser is a continuous wave laser as in it produces a continuous output wave which can carry the signal in the optical fiber. LiNb Mach-Zehnder Modulator which is used as a tool to control the amplitude of the given optical wave. It has a Y-slitter junction, one- or two-phase modulators, two waveguides and a Y-combiner junction. Sine

Generator is used as a tool for generation of sine wave signal. Single Mode Fiber (SMF) which is a fiber cable with the core smaller in size and carries the light directly down the fiber core, this type of fiber has a higher transmission distance when compared to the multi-mode fiber. Erbium-Doped Fiber Amplifier (EDFA) which is useful in optical systems as it can amplify the optical signal without the need to convert it to electrical signal. Double-Clad Fiber (DCF) is a three-layered optical fiber cable and is capable of both single mode and multimode transmission. Photo Detector PIN is used to detect the optical signal and convert it back to electrical signal. Low Pass Bessel Filter is a filter which allows only low frequency signals. RZ Pulse Generator is used to generate pulses which return to zero. NOT binary inverter is used to flip the binary bit, if it was 1 it becomes 0 and if it was 0 it becomes 1. Precoder Delay is an exclusive-or gate with a delayed feedback path. NRZ Pulse Generator is a generator which creates non return to zero pulses. Duobinary Pulse Generator. Electrical time delay is used to cause a delay in the bits. Electrical subtractor is used to sum the current and delayed bit. Fork is used to split the signal to two different paths. Electrical gain is used to increase the transmitting power of a signal

B. CARRIER-SUPRESSED RETURN-TO-ZERO

Carrier suppressed return to zero is one of the advanced modulation techniques which is used in optical fiber communication systems, this type of modulation techniques is similar the normal return-to-zero (RZ) technique with the only difference in that there is a 180-degree phase alternation of the pulses in CSRZ. Fig 3.1 below shows a simulation of the optical communication link using the OptiSystem 17 software.

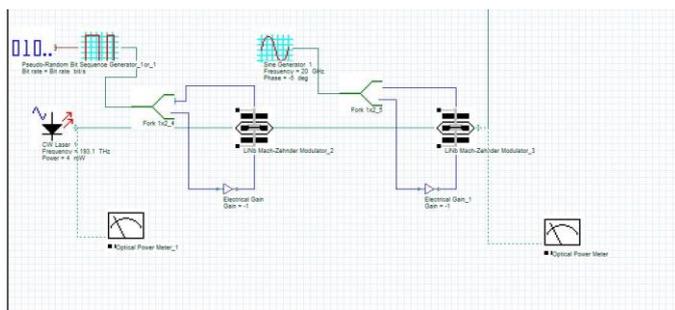


Fig III.1 CSRZ advanced modulation scheme

DUOBINARY RETURN-TO-ZERO

In duobinary return-to-zero coding there are three different types of values used, these are +, - and 0. The duobinary levels are used to represent power in three different power levels which are frequency, phases and polarization states. In the phases case of which there are three of them, the phases symbols may represent a phase shift of -90, 0, +90 degrees therefore making it correspond to phase shift keying. Duobinary modulation is known to minimize the high frequency components of the signal so that it results into a higher tolerance to chromatic dispersion therefore enabling it to reach longer distances. It merges two binary pulses which are successive in the digital stream to give a multilevel electrical signal. For example at the transmitting end if the bit stream is X_k , the output of the encoder is

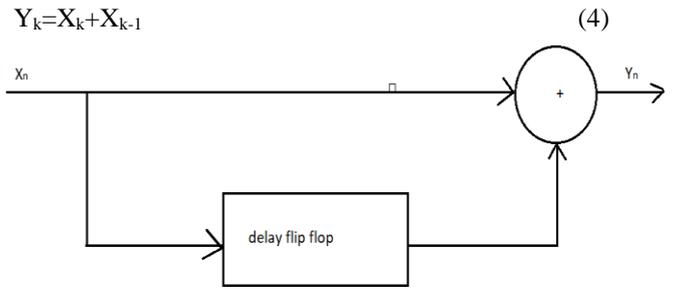


Fig III.2 duobinary precoder

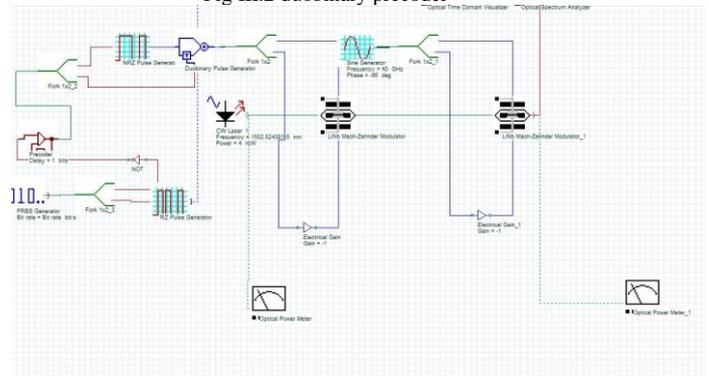


Fig III.3 DRZ circuit with power meters connected

C. MODIFIED DUOBINARY RETURN-TO-ZERO

This is a modified version of the duobinary return-to-zero modulation, compared to the normal duobinary return-to-zero it has a narrower optical bandwidth which results to a greater dispersion tolerance. The circuit for modified duobinary comprises of components including a duobinary precoder and an electrical subtractor among others.

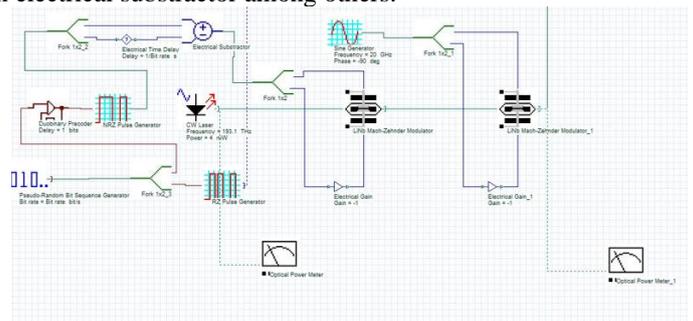


Fig III.4 MDRZ circuit in OptiSystem 17

D. METHODOLOGY

To obtain the final results the setups shown above where made in OptiSystem 17, two optical power meters are used. One is placed where the CW laser is located in order to check the optical power being sent to the system, the other is placed right after the second LiNB Mach-Zehnder Modulator. The second one is placed on that particular position since this is where the power is propelled into the optical fiber cable, so from here up to the receiving end all the three different modulation techniques have the same setup so the components can be neglected. By checking the power at this point we can observe how the different modulation setups affect power of the signal in the optical fiber system.

IV. RESULTS

After running the simulations in OptiSystem 17 for the different advanced modulation formats which are carrier suppressed return-to-zero, Duobinary return-to-zero and modified Duobinary return-to zero-the results obtained are shown below

A. CARRIER SUPRESSED RETURN-TO-ZERO



Fig IV.1 input power for the CSRZ



Fig IV.2 output power for the CSRZ

Fig 4.1 shows the input power and the fig 4.2 shows output power after the second LiNB Mach- Zehnder Modulator where the signal is about to be sent into the optical fiber. From the experiment conducted it shows that for carrier suppressed return-to-zero with input power of 6.021dBm, the output power will be 0.945dBm.

B. DUOBINARY RETURN-TO-ZERO



Fig IV.3 input power for the DRZ



Fig IV.4 output power for the MDRZ

Fig 4.3 shows the power at the input of the duobinary return-to-zero system and fig 4.4 shows the power at the output of the modulation which is just after the second LiNB Mach- Zehnder Modulator. From the experiment it was observed that when the input power was 6.021dBm then the output power was -0.138 dBm.

C. MODIFIED DUOBINARY RETURN-TO-ZERO



Fig IV.5 input power of MDRZ



Fig IV.6 output power of MDRZ

Fig 4.5 shows the power of the signal at the input which is right before the modulation and fig 4.6 shows the power of the signal after the second LiNB Mach- Zehnder Modulator. The results obtained from the experiment show that when given an input power of 6,021dBm then the output power will be -1.713 dBm.

TABLE I. INPUT/OUTPUT COMPARISON OF POWER

| INPUT/OUTPUT POWER COMPARISON | | |
|-----------------------------------|-------------|--------------|
| MODULATION TECHNIQUE | INPUT POWER | OUTPUT POWER |
| Carrier suppressed return-to-zero | 6.021 | 0.945 |
| Duobinary return-to-zero | 6.021 | -0.138 |
| Modified duobinary return-to-zero | 6.021 | -1.713 |

V. CONCLUSION

The results obtained in the above experiment show that the carrier suppressed return-to-zero feed more power into the actual fiber compared to duobinary return-to-zero and modified duobinary return-to-zero. Modified duobinary return-to-zero is the one which sends the least power into the fiber optical when compared to the other two advanced modulation formats.

ACKNOWLEDGMENT

I would like to thank Mr. Dinesh Kumar Verma who is an assistant professor for the electronics and communication engineering department and Mr Gurmeet Singh who is the head of electronics and communication engineering at PDM university for the continuous support in my studies.

REFERENCES

- [1] Sharan et al.(2016). Design and simulation of modified duobinary modulated 40 Gbps 32 channel DWDM optical link for improved non-linear performance. Cogent Engineering. 3: 1256562
- [2] Kumar Ajay (2014). Power Budget for Single Mode Optical Fiber. International Journal of Soft Computing and Engineering (IJSCE). Volume-3, Issue-6. 2231-2307.
- [3] John C. Mauro · Srikanth Raghavan(2008). Advanced modulation formats for fiber optic communication systems. Sci Model Simul, Volume 15, Nos 1–3, 283–312
- [4] Prof. R.K. Shevgaonkar (n.d). Fiber Optic Link Design [WWW page]. URL https://nptel.ac.in/content/storage2/courses/117101002/downloads/Lec2_5.pdf
- [5] Optiwave (2020). System Design – Power Budget [WWW page]. URL <https://optiwave.com/category/resources/>