# Bit Error Rate Optimization in Fiber Optic Communication

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*Abstract*— The Bit Error Rate (BER) is indicates how often data has to be retransmitted because of an error in telecommunication. We have different modulation techniques scheme for improvement of BER in fiber optic communications. Optical fiber systems operating with a non-return-to-zero (NRZ) format at transmission rates of up to 10Gbps can be obtained by the developed scheme. Performance of improved detected signals has been evaluated by the analysis of quality factor and computed BER. Noticeable improvement can be seen in the Numerical simulations of the system BER after implementation of the suggested processing operation on the detected electrical signals at central wavelengths in the region of 1310 nm.

***Key words:*** BER improvement, Modulation Techniques, Noise, Optimization, NRZ

## I. INTRODUCTION

Fiber optic communications transmits over longer distances and at higher bandwidths and better than other forms of communication. Wavelength division multiplexing (WDM) architecture is the basis of optical transmission networks with bit rates exceeding several terabit per second rates to serve the ever increasing demand of Internet Protocol (IP) networks. Some of the main TCP/IP networking functions such as routing, add-drop multiplexing and demultiplexing and wavelength conversion, need to be functional to encapsulate the IP packet requirements into the optical layer. It is necessary to develop approaches to improve regeneration of transmitted data as both linear and nonlinear characteristics of the optical fiber at higher bit rates, seriously limit the data transmission performance. Experimental investigations have shown a considerable progress in this direction. These were based on compensation techniques, filtering, developing optimized line coding, and further dispensation of received signal. In a communication system, the receiver side BER may be affected by transmission channel noise, interference, distortion, bit synchronization problems, attenuation, wireless multipath fading, etc. The BER can be considered as an approximate estimate of the bit error probability which is the expectation value of the BER.The approximation is accurate for a long studied time interval and a high number of bit errors.

## II. BIT ERROR RATE AND SIGNAL-TO-NOISE RATIO

### *A. Bit Error Rate*

The bit error rate (BER) is the percentage of bits that have errors relative to the total number of bits received in a transmission. Out of 1,000,000 bits transmitted, one bit was in error BER is $10^{-6}$. 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 present. by choosing a strong signal strength the BER may be improved (unless this causes cross-talk and more bit errors), by choosing a slow and robust modulation scheme or line coding scheme, and by applying channel coding schemes such as redundant forward error correction codes [1]. The transmission BER is the number of detected bits that are incorrect before error correction, divided by the total number of transferred bits (including redundant error codes). Normally information BER is less than the transmission BER. The information BER is affected by the strength of the forward error correction code.

### *B. Signal-To-Noise Ratio*

Signal-to-noise ratio is a measure to quantify how much a signal has been corrupted by noise. It is the ratio of signal power to the noise power corrupting the signal. A ratio higher than 1:1 indicates more signal than noise. While SNR is commonly quoted for electrical signals, it can be applied to any form of signal (such as isotope levels in an ice core or biochemical signaling between cells). Level of a desired signal (such as music) to the level of background noise give the signal ratio. The less obtrusive the background noise indicates the higher the ratio. Signal-to-noise ratio is sometimes used informally to refer to the ratio of useful information to false or irrelevant data in a conversation or exchange. The concepts of dynamic range and signal-to-noise ratio are closely related. The ratio between the greatest undistorted signal on a channel and the smallest detectable signal is Dynamic range, which for most purposes is the noise level. Signal-to-noise ratio measures the ratio between an arbitrary

### *C. Digital Signal*

The maximum possible signal-to-noise ratio is determined by the number of bits used to represent the measurement. This is because the minimum possible noise level is the error caused by the quantization of the signal (quantization noise). This noise level is nonlinear and signal-dependent; different calculations exist for different signal models. Quantization noise is modeled as an analog error signal summed with the signal before quantization [4]. This theoretical maximum SNR assumes a perfect input signal. If the input signal is noisy, the measurement noise may be larger than the quantization noise. Real analog-to-digital converters also have other sources of noise that further decrease the SNR compared to the theoretical maximum from the idealized quantization noise. Although noise levels in a digital system can be expressed using SNR, it is more common to use $E_b/N_o$ the energy per bit per noise power spectral density. The modulation error ratio (MER) is a measure of the SNR in a digitally modulated signal

## III. NOISE SOURCES, MODULATION AND CODING

### *A. Noise Sources*

In communication system Noise is a significant issue. In the optical world (especially in WDM) there are many sources of noise. The noise sources are so small that can be ignored. In other cases the action can take to mitigate one form of noise also mitigates many others. Amplifier noise (ASE) and thermal noise in the receivers are the dominant noise sources in WDM systems are. However, in the design of any system it is very important to be aware of all the potential sources of noise so that they can be avoided or mitigated.

### *B. Modulation*

Modulation is used for conveying a message signal it can be digital or analog, inside another signal that can be physically transmitted. Modulation of a sine waveform is used to transform a base band message signal to a pass band signal, for example, a radio frequency (RF) signal. In radio communications, cable TV systems or the public switched telephone network for instance, electrical signals can only be transferred over a limited pass band frequency spectrum, with specific (non-zero) lower and upper cutoff frequencies . In optical communication, Electro-Absorption modulator and Mach-Zehnder modulator. Are two major modulation techniques. *Electro- Absorption Modulator (EAM).* Electro - Absorption modulator is a semiconductor device which is used for modulating the intensity of a laser beam with help of an electric voltage. A change in the absorption spectrum caused by an applied electric field, which changes the band gap energy (thus the photon energy of an absorption edge) but usually, does not involve the excitation of carriers by the electric field. External modulation links in telecommunications is one of the application EAM . These devices are useful for optical fiber communication as they can be operated at very high speed; a modulation bandwidth of tens of gigahertz can be achieved. EAM can be integrated with distributed feedback laser diode on a single chip to form a data transmitter in the form of a photonic integrated circuit. Compared with direct modulation of the laser diode, a higher bandwidth and reduced chirp can be obtained.

*Mach-Zehnde Modulator*. Here Mach-Zehnder modulator is *used* for intensity modulating signal light, using a simple drive circuit for the modulating voltage. The modulator includes two waveguides with respective multiple quantum well (MQW) structures. Well layers of the MQW structures of the two optical waveguides have different thicknesses or are made from different materials so the phase of light propagating through one waveguide advances and through the other waveguide is delayed in response to the same applied voltage. The phase changed light signals are combined as an output light signal that is intensity modulated [3].

### *C. Coding*

Non-Return-to- Zero (NRZ), Return-to-Zero (RZ), Alternate Mark Inversion (AMI), Manchester, Differential Manchester and Multi-state Coding are different types of coding.

*1)* NRZ Coding.

If the bit stream is to be sent as simply the presence or absence of light on the fiber (or as changes of voltage on a wire) then the simplest NRZ coding is possible. In this method a one bit is represented as the presence of light and a zero bit is represented as the absence of light. This method of coding is used for some very slow speed optical links but has been replaced by other methods for most purposes.

*2) RZ Coding.*

In RZ coding the signal returns to the zero state every bit time such as, a “1” bit is represented by an “ON” laser state for only half a bit time. In a restricted bandwidth environment (such as in most electronic communications) there are two different line states required to represent a bit (at least for a “1” bit) and this type of coding is not desired.

*3) AMI Coding.*

It is a synchronous clock encoding technique which uses bipolar pulses to represent logical 1 value. The alternating coding prevents the buildup of a D.C voltage level down the cable. This is considered an advantage since the cable may be used to carry a small D.C. current to power intermediate equipment such as line repeaters [5].

*4) Manchester Coding.*

It is a type of digital encoding that is used in data transmission. Within the structure for Manchester encoding, the data bits in the transmission are represented by a series of states that occur in a logical sequence. This approach to data transmission is somewhat different, as many encoding methods tend to assign a high or low state of voltage to each bit and use that information as the criteria for affecting the transfer of bit

*5) Differential Manchester Coding.*

It is a method of encoding data in which data and clock signals are combined to form a single self synchronizing data stream. It is a differential encoding, using the presence or absence of transitions to indicate logical value. This gives it several advantages over standard Manchester encoding [8].

*6) Multi-state Coding.*

It is a method in the electronic systems where both signal amplitude and phase are used to create unique line states representing particular bit combinations.

## IV. ERROR DETECTION AND CORRECTION METHODOLOGY

By adding redundancy we detect and correct the errors, which receivers can use to verify correct order of the delivered message and decode it successfully. The process of error detection can be either systematic or nonsystematic. In case of systematic scheme, the transmitter transmits the original data, and attaches a particular number of parity bits, which are derived from the data bits by some deterministic algorithm. If only error detection is necessary, a receiver can simply implement the same algorithm to the received data bits and compare its output with the received check bits; if the values do not match, an error has occurred at some point during the transmission. In a system that employs the nonsystematic code, the original message is made into an encoded message that has at least as many bits as the original message. If the capacity of the channel cannot be determined or is highly time varying, various error detection scheme may be combined within a system for retransmissions of data which is erroneous. This is called as (or termed) as automatic repeat request (ARQ) and is mostly used in the Internet. An alternate implementation for error control is hybrid automatic repeat request (HARQ) which is a combination of both.

### *A. Error Identification Scheme*

The detection of error is most commonly realized using a suitable checksum algorithm. A checksum algorithm adds a specified length of tag, which enables receiving unit to verify the delivered message by re computing the tag and comparing it with the one available. There exists a wide variety of different checksum algorithm designs. Some are of widespread use because of either their simplicity or their suitability for detecting certain kinds of errors (e.g., the cyclic redundancy check's performance in detecting burst errors). Random error correcting codes based on minimum distance coding can provide a suitable alternatives to checksum algorithm when a strict guarantee on the minimum number of errors to be detected is desired.

### *B. Error Correction Scheme*

Error correction schemes are mainly of three kinds: Automatic repeat request (ARQ), Error correcting code (ECC) or forward error correction (FEC) and Hybrid schemes.

*1) Automatic Repeat Request (ARQ).*

ARQ method uses specific codes in error detection mechanism, acknowledgment and/or negative acknowledgment messages, and timeouts to achieve reliable and successful data transmission. An acknowledgment is a message sent to the sender by receiver stating that it has received the message successfully and it is ready to receive the next data. Usually, in case of ARQ if the sender doesn't receive the acknowledgement in prescribed timeout (particular period of time) it starts to resend the frame thinking that the data was lost or corrupted. Automatic repeat request is appropriate if the communication channel has varying or unknown capacity, such as is the case on the Internet. ARQ requires the availability of a backup channel, results in possibly increased latency due to retransmissions, and requires the maintenance of buffers and timers for retransmissions, which in the case of network congestion can put a strain on the server and overall network capacity.

*2) Error Correcting Code (ECC) .*

An forward error correction (FEC) code is a method(or process) of adding redundant data, or parity data, to a message, such that it can be recovered by a receiver even when a number of errors (up to the capacity of the code being used) were introduced, either during the period of transmission, or on storage. Since the receiver does not have to ask the sender for retransmission of the data, a back channel is not required in forward error correction, and it is therefore suitable for simplex communication such as broadcasting. Error correcting codes are frequently used in lower layer communication, as well as for reliable storage in media such as CDs, DVDs, hard disks, and RAM. Error correcting codes are usually distinguished between convolution codes and block codes: Convolution codes are processed bit by bit where ass block codes are processed block by block.

*3) Hybrid Schemes.*

It is a combination of ARQ and forward error correction. There are two basic methodologies: Messages are always transmitted with FEC parity data (and error detection redundancy). A receiver decodes a message using the parity information, and requests retransmission using ARQ only if the parity data was not sufficient for successful decoding (identified through a failed integrity check). Messages are transmitted without parity data (only with error detection information) . If a receiver detects an error, it requests FEC information from the transmitter using ARQ, and uses it to reform the original message. The latter approach is particularly attractive on an erasure channel when using a rate less erasure code.

## V. OPTICAL FIBER

An optical fiber is a thin and transparent fiber which acts as a waveguide, or light pipe, to transmit light from one point to other. Optical fibers are mostly used in fiber optic communication which favor long distance transmission without undergoing transmission losses and dispersions. There are two basic types of fiber: Single mode and Multi-mode optical fiber.

### *A. Single Mode Optical Fiber*

It is an optical fiber in which only the lowest order bound mode can propagate at the wavelength of 1300 to 1320nm. Single mode optical fiber is used in many applications where data is sent at varying frequency, so only one cable is needed - (single mode on one single fiber) single mode fiber gives higher transmission rate and 50 times more distance than multimode

### *B. Multi-Mode Optical Fiber*

They gives high bandwidth at high speeds (10 to 100MBS - Gigabit to 275m to 2km) over medium distances. Multi-mode cable has a slightly bit bigger diameter, with a common diameters in the 50-to-100 micron range for the light carry component.

## VI. OPTICAL SIGNAL LOSS AND BIT ERROR RATE ANALYSIS

The digital data bits generated are made into codes using familiar line coding techniques such as non-return to zero (NRZ) and return to zero(RZ) line coding techniques. The code generated in this method is coupled with laser light which is used as a carrier in our case and modulated using modulation techniques like EAM and MZ modulation schemes. At the receiver part the message is received using a photo diode and on the received signal BER analysis is performed. BER defined as the no of times the data needs to be retransmitted in case of error. A fiber optic communication is termed as a successful one when it has minimum BER. The eye pattern is used to measure the ISI (inter symbol interference) the broadened eye diagram implies a low ISI where as a closer eye represents higher ISI. Therefore by using the fiber optic cables when can minimize BER to some extent.

*1) Analysis of the Bit Error Rate*

The BER may be analyzed using computer simulations. If a simple transmission channel model and data source model is assumed, the BER may also be calculated analytically. OptiSystem 9.0 was used for analyzing the BER. The circuit diagram of Fig. 2 has been used to do this analysis

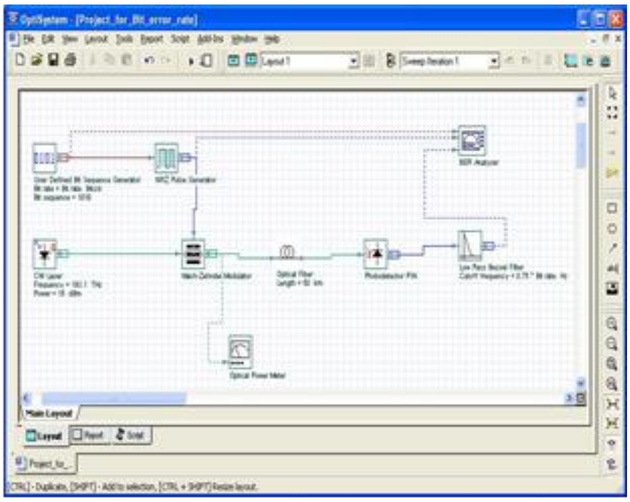

Fig. 2: The Circuit Diagram Of Analyzed BER

### *2) The Components of the Bit Error Rate Diagram*

Input bit sequence, Signal pulse generator: RZ pulse generator and NRZ Pulse generator, Modulation Technique: Mach-Zehnder and Electro-Absorption, Optical input power: 20 dB and 15 dB, cable 50 km, A low pass filter, BER analyzer. The following components of the BER diagram vary the result: Signal pulse generator, Modulation technique, Input optical Power. The results are shown in Table II and Table III and in Fig. 3.

Bit sequence length=4

| Input Bits | Signal Generator | Modulation techniques | Optical Power (dBm) | Min BER |
|---|---|---|---|---|
| 1010 | RZ | MZ | 15 | 0 |
| 1010 | RZ | EAM | 15 | 0 |
| 1010 | NRZ | MZ | 15 | 0 |
| 1010 | NRZ | EAM | 15 | 0 |
| 1010 | RZ | MZ | 20 | 0 |
| 1010 | RZ | EAM | 20 | 6.4xe-224 |
| 1010 | NRZ | MZ | 20 | 1.737xe-160 |
| 1010 | NRZ | EAM | 20 | 6.7xe-322 |

Table II: 4 Bits Result From Ber Analysis

Bit sequence length=8

| Input Bits | Signal Generator | Modulation techniques | Optical Power (dBm) | Min BER |
|---|---|---|---|---|
| 10101100 | RZ | MZ | 20 | 8.61xe-15 |
| 10101100 | RZ | EAM | 20 | 4.5xe-124 |
| 10101100 | NRZ | MZ | 20 | 3.8xe-29 |
| 10101100 | NRZ | EAM | 20 | 5.9xe-30 |
| 10101100 | RZ | MZ | 15 | 1.62xe-42 |
| 10101100 | RZ | EAM | 15 | 1.92xe-195 |
| 10101100 | NRZ | MZ | 15 | 2.8xe-36 |
| 10101100 | NRZ | EAM | 15 | 2.3xe-53 |

Table 3: 8 Bits Result From Ber Analysis

The BER decreases with the decrease in optical power level. Hence it is always preferred to use the optical fiber at the lowest possible power level. Input bit sequence, Signal pulse generator: RZ pulse generator and NRZ Pulse generator, Modulation Technique:Mach-Zehnder and Electro-Absorption, Optical input power:20 dB and 15 dB, cable 50 km, A low pass filter, BER analyzer. The following components of the BER diagram vary the result: Signal pulse generator, Modulation technique, Input optical Power. The results are shown in the following tables

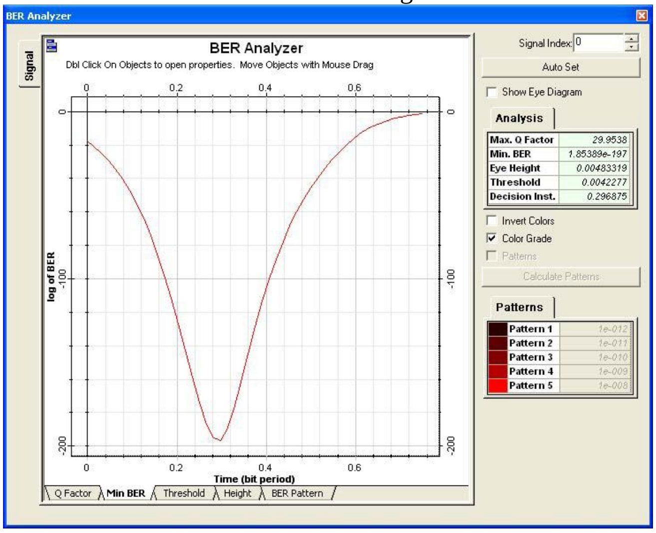


Fig. 3: Input Bits: 1010, Signal Generator: RZ, Modulation Technique: Mach Zehnder, Optical Power: 20 Db, Min BER: 1.85389×E-197

## VII. CONCLUSIONS AND FUTURE EXTENSIONS

The methods proposed to calculate the true average signal loss in the fiber optic communication; the single ended measurement offers a huge advantage in terms of time, logistics, and result in reliability and processing effort. Numerical simulation shows a noticeable improvement of the system BER after optimization of the suggested processing operation on the detected electrical signals at central wavelengths in the region of 1310 nm. The optimum solution reduces the bit error rate by using RZ signal generator through Electro-Absorption modulation techniques. The operation of optical transmission networks will be most important features in the near future to serve the ever increasing demand of Internet Protocol (IP) networks. However, a lot of research works needs to be carried out to improve the increasing effective data transmission through these systems.

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