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Review Paper on Design of Bit Error Rate Tool for Optical Communication

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Abstract: In this paper, the simulation tool for analyzing the bit error rate has been reviewed. The paper discussed the basic concepts and existing work that has been competed in this field. The BER tool in real-time is very much expansive need a lot of efforts to design it. This review paper will discussed all pros and cons of existing BER available in the research. Apart of that paper also discussed the roadmap to design the BER in more efficient manner comparison to existing work.

Keywords: Bit Error Rate; Q-factor, Optical Communication.

1. Introduction

The primary objective of optical fiber communication system is to transfer the signal containing information from the source to the destination [1]. The general block diagram of optical fiber communication system is shown in the Fig. 1. The source provides information in the form of electrical signal to the transmitter. The electrical stage of the transmitter drives an optical source to produce modulated light wave carrier. Semiconductor LASERs or LEDs are usually used as optical source here [2]. The information carrying light wave then passes through the transmission medium example optical fiber cables in this system. When the signal reaches the receiver stage where the optical detector demodulates the optical carrier and gives an electrical output signal to the electrical stage [3]. The common types of optical detectors used are photodiodes. Finally the electrical stage gets the real information back and distribute to the concerned destination [4]. It is notable that the optical carrier may be modulated by either analog or digital information signal. In digital optical fiber communication system the information is suitably encoded prior to the drive circuit stage of optical source. Similarly at the receiver end a decoder is used after amplifier and equalizer stage [5].

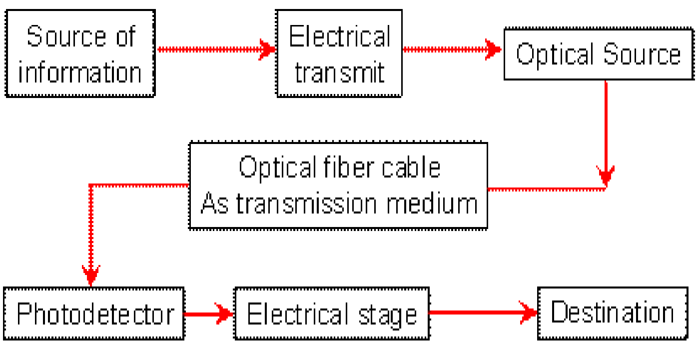

Fig. 1 - Basic Flows of Optical System Modulation [6]

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In telecommunication, modulation is the process of conveying a message signal, for example a digital bit stream or an analog audio signal, inside another signal that can be physically transmitted. Modulation of a sine waveform is used in view to transform a baseband message signal to a passband signal, for example a radio-frequency signal (RF signal). In radio communications, cable TV systems or the PSTN (public switching telephone network) for instance, electrical signals can only be transferred over a limited passband frequency spectrum, with specific (non-zero) lower and upper cutoff frequencies. Modulating a sine wave carrier makes it possible to keep the frequency content of the transferred signal as close as possible to the centre frequency (typically the carrier frequency) of the passband [7].

2. Purpose of modulation

The purpose of modulation is to take a message bearing signal and superimpose it upon a carrier signal for transmission [8]n. For ease, the transmission carrier signals are generally high frequency for severable reasons:

So that they may be simultaneously transmitted without interference from other signals

- It easy (low loss, low dispersion) propagation as electromagnetic waves
- So as to enable the construction of small antennas (a fraction, usually a quarter of the wavelength)
- So as to be able to multiplex that is to combine multiple signals for transmission at the same time.

Modulation is the process of conveying a message signal, for example a digital bit stream or an analog audio signal, inside another signal that can be physically transmitted. Modulation of a sine waveform is used in view to transform a baseband message signal to a passband signal [9].

2.1 Type of modulation

2.1.1 Baseband

A signal at baseband is often used to modulate a higher frequency carrier wave in order that it may be transmitted via radio. Modulation results in shifting the signal up to much higher frequencies (radio frequencies, or RF) than it originally spanned [10]. A key consequence of the usual double-sideband amplitude modulation (AM) is that, usually, the range of frequencies the signal spans (its spectral bandwidth) is doubled. Thus, the RF bandwidth of a signal (measured from the lowest frequency as opposed to 0 Hz) is usually twice its baseband bandwidth. Steps may be taken to reduce this effect, such as single-sideband modulation; the highest frequency of such signals greatly exceeds the baseband bandwidth. Some signals can be treated as baseband or not, depending on the situation [2]. For example, a switched analog connection in the telephone network has energy below 300 Hz and above 3400 Hz removed by bandpass filtering; since the signal has no energy very close to zero frequency, it may not be considered a baseband signal, but in the telephone systems frequency-division multiplexing hierarchy, it is usually treated as a baseband signal, by comparison with the modulated signals used for long-distance transmission. The 300 Hz lower band edge in this case is treated as "near zero", being a small fraction of the upper band edge [3].

2.1.2 Return-to-zero (RZ)

Return-to-zero (RZ) describes a line code used in telecommunications signals in which the signal drops (returns) to zero between each pulse [11]. This takes place even if a number of consecutive 0's or 1's occur in the signal. The signal is self-clocking. This means that a separate clock does not need to be sent alongside the signal, but suffers from using twice the bandwidth to achieve the same data-rate as compared to non-return-to-zero format. The "zero" between each bit is a neutral or rest condition, such as a zero amplitude in pulse amplitude modulation (PAM), zero phase shift in phase-shift keying (PSK), or mid-frequency in frequency-shift keying (FSK). That "zero" condition is typically halfway between the significant condition representing a 1 bit and the other significant condition representing a 0 bit.

Although return-to-zero (RZ) contains a provision for synchronization, it still has a DC component resulting in "baseline wander" during long strings of 0 or 1 bits, just like the line code non-return-to-zero [17].

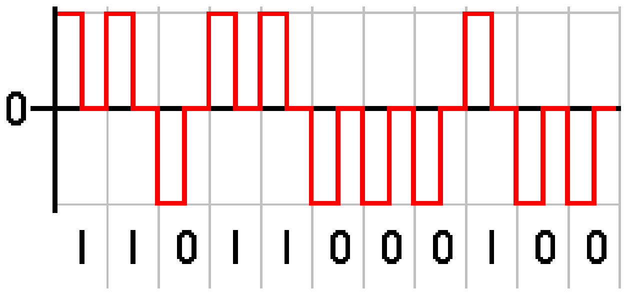

Fig. 2 - RZ sequence signals [11].

Fig. 2 shows that, the binary signal is encoded using rectangular pulse amplitude modulation with polar return-to-zero code.

2.1.3 Non-return-to-zero (NRZ)

In telecommunication, a non-return-to-zero (NRZ) line code is a binary code in which 1's are represented by one significant condition (usually a positive voltage) and 0's are represented by some other significant condition (usually a negative voltage), with no other neutral or rest condition [12]. The pulses have more energy than a RZ code. Unlike RZ, NRZ does not have a rest state. NRZ is not inherently a self-synchronizing code, so some additional synchronization technique (for example a run length limited constraint or a parallel synchronization signal) must be used to avoid bit slip. For a given data signaling rate bit rate, the NRZ code requires only half the bandwidth required by the Manchester code. When used to represent data in an asynchronous communication scheme, the absence of a neutral state requires other mechanisms for data recovery, to replace methods used for error detection when using synchronization information when a separate clock signal is available [12].

NRZ-Level itself is not a synchronous system but rather an encoding that can be used in either a synchronous or asynchronous transmission environment, that is, with or without an explicit clock signal involved. Because of this, it is not strictly necessary to discuss how the NRZ-Level encoding acts "on a clock edge" or "during a clock cycle" since all transitions happen in the given amount of time representing the actual or implied integral clock cycle. The real question is that of sampling--the high or low state will be received correctly provided the transmission line has stabilized for that bit when the physical line level is sampled at the receiving end [12].

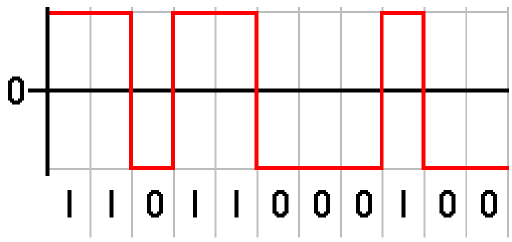

Fig. 3- NRZ sequence signals [16].

Fig. 3 shows that, the binary signal is encoded using rectangular pulse amplitude modulation with polar non-return-to-zero code.

2.1.4 Pulse-amplitude modulation (PAM)

Pulse-amplitude modulation, acronym PAM, is a form of signal modulation where the message information is encoded in the amplitude of a series of signal pulses. Pulse-amplitude modulation is widely used in baseband transmission of digital data, with non-baseband applications having been largely superseded by pulse-code modulation, and, more recently, by pulse-position modulation. In particular, all telephone modems faster than 300 bit/s use quadrature amplitude modulation (QAM). (QAM uses a two-dimensional constellation) [13].

2.1.5 On-off keying(OOK)

On-off keying (OOK) the simplest form of amplitude-shift keying (ASK) modulation that represents digital data as the presence or absence of a carrier wave. In its simplest form, the presence of a carrier for a specific duration represents a binary one, while its absence for the same duration represents a binary zero. Some more sophisticated schemes vary these durations to convey additional information. It is analogous to unipolar encoding line code. On-off keying is most commonly used to transmit Morse code over radio frequencies (referred to as CW (continuous wave) operation), although in principle any digital encoding scheme may be used. OOK is more spectrally efficient than FSK, but more sensitive to noise. In addition to RF carrier waves, OOK is also used in optical communication system [14].

2.1.6 Amplitude-shift keying (ASK)

Amplitude-shift keying (ASK) is a form of modulation that represents digital data as variations in the amplitude of a carrier wave. The amplitude of an analog carrier signal varies in accordance with the bit stream (modulating signal), keeping frequency and phase constant. The level of amplitude can be used to represent binary logic 0s and 1s. We can think of a carrier signal as an ON or OFF switch. In the modulated signal, logic 0 is represented by the absence of a carrier, thus giving OFF/ON keying operation and hence the name given [14]. AM and ASK is also linear and sensitive to atmospheric noise, distortions, propagation conditions on different routes in PSTN, etc. Both ASK modulation and demodulation processes are relatively inexpensive. The ASK technique is also commonly used to transmit digital data over optical fiber. For LED transmitters, binary 1 is represented by a short pulse of light and binary 0 by the absence of light. Laser transmitters normally have a fixed "bias" current that causes the device to emit a low light level. This low level represents binary 0, while a higher-amplitude lightwave represents binary 1.

2.1.7 Phase-shift keying (PSK)

Phase-shift keying (PSK) is a digital modulation scheme that conveys data by changing, or modulating, the phase of a reference signal (the carrier wave).Any digital modulation scheme uses a finite number of distinct signals to represent digital data. PSK uses a finite number of phases, each assigned a unique pattern of binary digits. Usually, each phase encodes an equal number of bits. Each pattern of bits forms the symbol that is represented by the particular phase. The demodulator, which is designed specifically for the symbol-set used by the modulator, determines the phase of the received signal and maps it back to the symbol it represents, thus recovering the original data. This requires the receiver to be able to compare the phase of the received signal to a reference signal [14].

Alternatively, instead of using the bit patterns to set the phase of the wave, it can instead be used to change it by a specified amount. The demodulator then determines the changes in the phase of the received signal rather than the phase itself. Since this scheme depends on the difference between successive phases, it is termed differential phase-shift keying (DPSK). DPSK can be significantly simpler to implement than ordinary PSK since there is no need for the demodulator to have a copy of the reference signal to determine the exact phase of the received signal (it is a non-coherent scheme). In exchange, it produces more erroneous demodulations. The exact requirements of the particular scenario under consideration determine which scheme is used [14].

2.1.8 Quadrature amplitude modulation (QAM)

QAM is both an analog and a digital modulation scheme. It conveys two analog message signals, or two digital bit streams, by changing (modulating) the amplitudes of two carrier waves, using the amplitude-shift keying (ASK) digital modulation scheme or amplitude modulation (AM) analog modulation scheme. These two waves, usually sinusoids, are out of phase with each other by 90° and are thus called quadrature carriers or quadrature components. In the digital QAM case, a finite number of at least two phases and at least two amplitudes are used. PSK modulators are often designed using the QAM principle, but are not considered as QAM since the amplitude of the modulated carrier signal is constant [14].

3. Bit error rate (BER)

In digital transmission, the bit error rate or bit error ratio (BER) is the number of received binary bits that have been altered due to noise and interference, divided by the total number of transferred bits during a studied time interval

In a communication system, the receiver side BER may be affected by transmission channel noise, interference, distortion, bit synchronization problems, attenuation, wireless multipath fading and others. The BER may be improved by choosing a strong signal strength, 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. The transmission BER is the number of detected bits that are incorrect before error correction, divided by the total number of transferred bits. The information BER, approximately equal to the decoding error probability, is the number of decoded bits that remain incorrect after the error correction, divided by the total number of decoded bits. Normally the transmission BER is larger than the information BER. The information BER is affected by the strength of the forward error correction.

3.1 Noise

In communication systems, the noise is an error or undesired disturbance of a useful information signal, introduced before or after the detector and decoder. The noise is a summation of unwanted or disturbing energy from man-made and natural sources. Noise is, however, often distinguished from interference.

3.2 Attenuation

Attenuation in fiber optics, also known as transmission loss, is the reduction in intensity of the light beam (or signal) with respect to distance traveled through a transmission medium. Attenuation coefficients in fiber optics usually use units of dB/km through the medium due to the relatively high quality of transparency of modern optical transmission media. The medium is typically a fiber of silica glass that confines the incident light beam to the inside. Attenuation is an important factor limiting the transmission of a digital signal across large distances. Thus, much research has gone into both limiting the attenuation and maximizing the amplification of the optical signal. Empirical research has shown that attenuation in optical fiber is caused primarily by both scattering and absorption.

3.3 Gaussian Noise (Gaussian Probability Density Function)

Gaussian noise is a statistical noise that has its probability density function equal to that of the normal distribution, which is also known as the Gaussian distribution. In other words, the values that the noise can take on are Gaussian-distributed. A special case is white Gaussian noise, in which the values at any pairs of times are statistically independent (and uncorrelated). In applications, Gaussian noise is commonly used as additive white noise to yield additive white Gaussian noise. Gaussian noise is properly defined as the noise with a Gaussian amplitude distribution. Labeling Gaussian noise as 'white' describes the correlation of the noise. It is necessary to use the term "white Gaussian noise" to be precise. Gaussian noise is sometimes misunderstood to be white Gaussian noise, but this is not the case.

4. Existing Work related to Design of Bit error rate (BER)

In this section, the techniques related to design of BER are discussed in details as shown in Table 1

Table 1- Existing BER design techniques

Years	Title	Description
2016	Soft output detection for MIMO systems using binary polar codes	This paper introduces a method that computes an estimation of the bit error rate (BER) based on the RAKE receiver soft output only. For this method no knowledge is required about the channel characteristics or the precise external conditions. Simulations show that the mean error of the estimation is below 2%, with only a small variance. Implementation issues for a practical use of the method are discussed[9].
2003	Probability Of Error For Trained Unitary Space-Time Modulation Over A Gauss-Innovations Rician Channel	The pair wise probability of error for trained unitary space-time modulation over channels with a constant specula component and time-varying diffuse fading is derived in this paper. The derive pair wise probability of error expressions using these effective SNR values, which are shown by simulation to accurately describe performance[12].
2004	Performance Of Nonuniform PAM Constellations For Gaussian Channel	The Gaussian source quantization is done by using three different quantization methods. They analyzed Pulse Amplitude Modulation (PAM) signal constellation obtained by means of different quantization methods for Gaussian channel[11].
2006	Accurate BER Estimation Of Optical DPSK System Using Sum Of Gaussian Approximation	An efficient of Gaussian algorithm(GA).assisted bit error rate (BER) estimated using sum of Gaussian approximation(SGA) for all single channel optical direct detection DPSK system effected by non linear phase noise is present[10]
2008	Bit error rate approximations using Poisson and negative binomial sampling Distributions	A recently discovered link between Poisson random variables and the standard Marcum Q-function is applied to the estimation of bit error rates (BERs) in digital communications. This results in simple probabilistic representations for BERs, and consequently Monte Carlo estimators are constructed[13].
2009	Bit Error Rate Estimation For Turbo Decoding	A method for on-line estimation of Bit Error Rate during turbo decoding. The two Gaussian random variables and derive estimators for the mean and variance of these distributions based on a Maximum-Likelihood approach. The parameter estimates are then employed to calculate the cross-over area of the Gaussian tails to estimate BER at each decoder iteration. The performance of the BER estimator is analyzed and compared[8].
2009	Estimation of the Bit Error Rate for Direct-Detected OFDM Signals with Optically Preamplifier Receivers	A numerical bit error rate (BER) estimation approach for direct-detected orthogonal frequency division multiplexing (OFDM) signals in the presence of optical preamplifier receivers. The calculated BER is verified by the conventional error-counting approach with high precision and is still accurate with higher quadratic-amplitude modulation (QAM) formats, even under the influences of the optical filtering and polarization mode dispersion (PMD) effects [9].

2010	Simulating the Multipath Channel With a Reverberation Chamber: Application to Bit Error Rate Measurements	These effects have a strong impact on the quality of the wireless channel and the ability of a receiver to decode a digitally modulated signal. Different channel characteristics such as power delay profile and RMS delay spread are varied inside the chamber by incorporating various amounts of absorbing material. In order to illustrate the impact of the chamber configuration on the quality of a wireless communication channel, bit error rate measurements are performed inside the reverberation chamber for different loadings, symbol rates, and paddle speeds; the results are discussed. Measured results acquired inside a chamber are compared with those obtained both in an actual industrial environment and in an office [14].
2010	Bit Error Rate Analysis for BPSK Modulation in Presence of Noise and Two Co-channel Interferers	In this paper the bit error rate (BER) analysis of binary phase shift keying (BPSK) modulated signal detection in presence of two BPSK modulated co-channel interfering signals and additive white Gaussian noise is presented. The detection of a desired signal with minimum achievable BER in co-channel interfering environment with two interferers was analyzed. The minimum achievable BER was obtained at interferers gain less than -10dB. Noise effect of AWGN channel can be observed using scatter plot rather than BER values [15].
2011	Evaluation of Bit Error Rate (BER) in WLAN IEEE 802.11a with radio over fiber (RoF) downlink system	In this paper, the system suggested for improvement of Bit Error Rate (BER) in WLAN IEEE 802.11a with Radio over Fiber (RoF) technology in downlink system to increase reliability of the system and to make it flexible and satisfy the future requirements. The downlink blocks operating at 1550 nm using 50 Km bidirectional Single Mode Fiber (SMF) with 64 QAM modulations using RF modulated frequency 5.8 GHz (UNII) and 54 Mbps data rate. The improvement of BER of 802.11a is done by using QAM modulation and components of RoF likes using SMF and Bessel filter. The evaluation of performance of BER is done by using OPTISYSTEM for simulation results [16].
2012	Characterization of semiconductor-laser phase noise and estimation of bit-error rate performance with low-speed offline digital coherent receivers	The field spectrum, the FM-noise spectrum, and the phase-error variance measured with such a receiver can completely describe phase-noise characteristics of lasers under test. The sampling rate of the digital coherent receiver should be much higher than the phase-fluctuation speed. However, 1 GS/s is large enough for most of the single-mode semiconductor lasers. In addition to such phase-noise characterization, interpolating the taken data at 1.25 GS/s to form a data stream at 10 GS/s, we can predict the bit-error rate (BER) performance of multi-level modulated optical signals at 10 Gsymbol/s. The BER degradation due to the phase noise is well explained by the result of the phase-noise measurements [17].
2013	Bit Error Rate Performance Of Cascaded Optical Amplifiers Using Matlab Computation Software	This paper gives a detailed presentation of the bit error rate (BER) performance of cascaded optical amplifiers with variation of amplified spontaneous emission noise in an optical network using Matlab files that models the transmission of an on-off keyed non-return to zero (NRZ) optical signal through a cascade of optical amplifiers (typically Erbium Doped Fibre Amplifiers (EDFAs) separated by optical loss (i.e. fibre) and calculate the amplified spontaneous emission (ASE) noise, optical-signal-to-noise ratio (OSNR), Q factor and BER at the amplifier input and output, fibre dispersion was accounted for by a penalty on Q [18]
2014	Improvement of Bit Error Rate in Fiber Optic Communications	The bit error rate (BER) is the percentage of bits that have errors relative to the total number of bits received in a transmission. The different modulation techniques scheme is suggested for improvement of BER in fiber optic communications. The developed scheme has been tested on optical fiber systems operating with a non-return-to-zero (NRZ) format at transmission rates of up to 10Gbps. Numerical simulations have shown 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 [19].
2015	Bit Error Rate (BER) Comparison of AWGN Channels for Different Type's Digital Modulation Using MATLAB Simulink	he MATLAB software with relevant Toolboxes for developing Simulink model is used for the simulation of system. In this paper, three basic types of digital modulation techniques are discussed then the bit error rate performance characteristics of receiver are evaluated by using MATLAB Simulink model for FSK, PSK and QAM modulation techniques. There are various kinds of channel used in wireless communication. In this paper, the AWGN channel is used between transmitter and receiver. This paper focuses on the characterization and the design of analog signal waveforms that carry digital information and compares their performance on an AWGN channel [20].
2016	Modeling the Bit-Error-Rate Performance of Nonlinear Fiber-Optic Systems	We demonstrate an efficient method of calculating second-order statistics of the NLIN coefficients, particularly their temporal autocorrelation and cross correlation. The model is highly accurate in predicting system performance metrics such as bit-error-rate and signal-to-noise ratio, and is shown to provide better accuracy with respect to models that use the NLIN variance alone, particularly when accounting for the adaptive filtering of realistic receivers [21].
2017	Bit Error Rate (BER) Performance Enhancement for Wireless Communication System Using Modified Turbo Codes	his work revisits the FEC using conventional turbo codes and proposes few modifications in them to obtain modified turbo codes. Trivial alterations in the frame length of the codes have been implemented along with puncturing scheme. The decoding complexity of the system is alleviated with the use of Viterbi algorithm for punctured codes. A comparative study between the performance of the system using turbo and modified turbo codes is presented in terms of their BER. Simulation results show that there is significant enhancement in the performance of the system when modified turbo codes are employed [22].
2018	Bit error rate analysis of different digital modulation schemes in orthogonal frequency division multiplexing systems	The OFDM system was modelled and different modulation schemes: M-ary phase shift keying (M-PSK) and M-ary quadrature amplitude modulation (M-QAM) were employed over two different channels: additive white Gaussian noise (AWGN), and Rayleigh multipath fading channels. Bit error rate (BER) analysis was carried out for the different digital modulation schemes over the two channels, and the number of fast Fourier transform (FFT) points used during the transmission was examined. Generally, results showed that over both AWGN and Rayleigh fading channels, lower order modulation schemes perform better than the higher order schemes. This comes at the detriment of the data rate, as lower order schemes have lower data rates compared with their higher order counterparts. In addition, it was observed that the system performed better over AWGN channel than Rayleigh fading channel for all modulation schemes used. On the number of FFT points used during the transmission, findings revealed that the performance of the system is more or less not really affected by the number of FFT points employed during transmission [23].

5. Road Map for Design of Better BER Tool

Currently BER estimation tool is developed using various methods such numerically, in simulation, real-time and etc. This educational software interface tool in the future can be developed using OPTISYSTEM. The MATLAB GUI system for measuring BER is design using Gaussian probability errors approximation method. The future BER estimation tool simulation, will be able to plot the eye diagram, BER diagram, Q-factor value, threshold value, and the most important function to analysis the BER value for two levels, four levels and eight levels of a PAM optical communication systems.

Conclusion

In this paper, the existing BER tool development design and techniques are discussed up to year 2018. After that road map of better BER system is discussed to provide better guidance to reader for future work.

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