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Secured and Efficient Fiber Optic Based Data Signal Transmission

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ABSTRACT: In this paper, secured and efficient fiber optic based Data Signal Transmission architecture is designed which enables high efficiency in terms of throughput and area. In addition, dedicated circuit architecture has been described for sending digitally encoded signals from remote sensors to measurement systems over fiber optics, which is a very reliable communication medium. For a given number of simultaneous users, the suggested code optimization method looks for code sets with the lowest Bit Error Rate (BER) among all codes. The delta encoder reduced bit rate, combined with the inherent advantages of optical fibre, particularly their resilience to electric perturbations resulted in a compelling implementation option. This approach is essential for preventing unanticipated security breaches induced by crosstalk. Most importantly, while having an acceptable bit error rate, only a small percentage have proven that the available code sets are not affected by crosstalk i.e, 0.5 percent in the W-H32 with four simultaneous users. In addition, the fibre optic encoder and transmission system can be used in didactical laboratories to teach advanced communication techniques have analyzed.

KEYWORDS: Fiber Optics, Bit Error Rate (BER), Crosstalk, Data Signal Transmission, power.

I. INTRODUCTION

There have an increase in demand for high-speed transmission systems in recent years [1]. Because of the transmission bandwidth, there is a growing interest in signal transmission via optical fibre [2]. Developing new optical transmission paths can be both time-consuming and expensive. As a result, more efficient methods of meeting increased customer demand are emerging [3]. Increased transmission capacity can be achieved by employing new advanced signal processing techniques in both the electric and optical domains. Implementing such solutions is simple. Negative impacts on transmitted optical signals grow as modulation rates rise which there are more bit errors in information flows [4]. As a result, designing and analysing the effectiveness of modern signal processing algorithms employed in optical transmission media in respect to environmental factors is crucial [5]. New optical transmission systems are designed using advanced optical components and fiber. As a result, advanced signal processing methods use simulations to estimate future gains in data rates and transmission distances for optic fiber transmission systems.

Especially, the system is installed in a noisy industrial environment by adjusting short-amplitude signals from analog sensors to transmit measurement data over long distances requires special design and high-performance circuitry. In this situation, the signal processing based method and tolerance to external electrical perturbations are required to improve the sensor signal resilience.

Spectral phase encoding is important for accessing optical code-based systems, such as: Optical secure communication and optical code division multiple access (OCDMA) system [6]. To achieve spectral phase encoding, a phase modulator can be used along with a pair of dispersive components. The broadband optical signal is first sent to the first dispersing component, which temporarily or spatially amplifies the signal depending on scattering characteristics. Different wavelengths have different time periods and physical positions. In order to encode a signal with a specific optical code, a phase modulator is used to introduce a phase change between adjacent wavelength components using a second dispersing component with diametrically opposed amplitude characteristics, the amplified and encoded optical signal is compressed back to its original form. There are various methods for capturing spectral phase-encoding.

Data and optical codes are hidden in encrypted signals. By inserting the sequence of conjugated phase shifts generated by the optical code into the coded signal in the spectral region, only those with the same optical code can restore the coded signal to the original optical signal on the receiving side. The transmitted data can be extracted after decoding. Encoded signals without a matching code are not restored to the original optical signal and the transmitted data is immersed in the encoded signal for security reasons.

Security is the most important issue in optical encoding systems. Because it allows the encryption of confidential information in the optical layer using optical encoding, Optical Code Division Multiple Access (OCDMA) is a commonly prescribed technology to improve data security [7]. However, the OCDMA system has security flaws because efficient evaporators can extract optical code (OC) from an encoded waveform or directly demodulate or detect block data [8]. The spectrum is reduced by phase shift. Eavesdroppers may easily identify the optical code and extract information from the encoded signal since the phase change during encoding was shown by the shape of the encoded spectrum. Because phase change is intrinsically linked to the optical code, Eavesdropper can easily capture the optical code and extract information from the encoded signal.

II. LITERATURE SURVEY

Haoyu Du et. al. [9] presents a Sub-Optimal relay selection in audio frequency (AF) relaying networks for physical-layer security. Flexibility and physical-layer security issues in communication networks with multiple relays and multiple evaporators are discussed in this study. As a result, on AF relay networks, the Fairness-Aware sub-optimal relay option for physical-layer security is displayed. The fairness of the proposed approach is proved by computing the answer to each relay chosen probability. Also obtained is the equation for the probability of interruption. Sub-optimal selection has some advantages, according to the simulation results. In the meantime, the expression for the probability of interruption is displayed.

Ben Wu et. al. [10] presents Data encryption and key generation can be done at the speed of data transmission in optical fibre using signal processing algorithms based on fibre components. As private and confidential communication as possible without compromising optical network capacity or bandwidth. By using an optical stealth transmission, the signal can be hidden from view. Optical stealth transmission provides a high degree of privacy, as eavesdropper cannot read data or detect the presence of a transmitted signal. When it comes to blocking traffic analysis, a hybrid system that uses both public and stealth channels to provide anonymous communication is extremely effective.

G. P. Temporao et. al. [11] describes There are several solutions to adapt Optical Time Domain Reflectometer (OTDR) to a passive optical network (PON). They are based on standard OTDRs and backscatter signals used for Fresnel reflections and back-link transfers rather than point-to-point PMP links. Each branch of the Point-to-multi point (PMP) network is partially covered by the other branches. In Tree-Architecture PON, the Central Office (CO) Network Manager had a problem discriminating between events. At the remote node (RN), an adjustable OTDR is used in conjunction with the wavelength-selective isolator to separate each branch. Furthermore, due to their small network size and high system complexity, these solutions are impossible.

Zhensen Gao et. al. [12] the security of the stealth channel is experimentally proved by combining a time-domain spectral phase n decoding (SPE/D) optical code division multiple access (OCDMA) system with mass velocity dispersion. The public wavelength division-multiplexing network transmits the time-domain spectral phase encoded OCDMA signal invisibly. With pulse amplification provided by a simply pulses fiberglass grading and high-speed phase modulator. Error-rate free transmission (less than 1% bit-error rate for public and stealth channels using the 32-chip 40-Gchip/s gold code).

Wei Jiang et. al. [13] presents Game Theoretical method for determining and analyzing the Right active defense strategy. Several recent studies have proposed game theory as a theoretical framework for analyzing network security. The ADG and Cost Sensitive models were used to develop the Optimal Active Defense Strategy Decision (OADSD) technique. Low-cost optimum defense solutions are used to protect against attacks and to harden the network in advance. Finally, experiments show that our achromatic doublet on glass (ADG) model and OADSD algorithm are effective for reducing overall defense system costs and preventing future attacks.

Taher M. Bazan et. al. [14] presents two methods for reducing beat noise effects are described for two-dimensional time-wavelength optical code-division multiple access systems. The first method is to use the optical hard limiter (OHL) before the optical correlator on the receiver. For OHL-based systems, a general formula for crosstalk level functional error probability is fixed and branches of OHL non-ideal transfer characteristics are analysed. Pulse position modulation is used in the second method and comparing with on-off keying to monitor the system performance.

S. Etemad et. al. [15] It describes 16-bit phase lock laser lines as frequency bins and a spectral phase encoder/decoder with ultra-high frequency resolution to prove the capability of an efficient wavelength division multiplexing (WDM) compatible with an optical code division multiple access system. Encoding and decoding of four users at 2.5 Gb/s has been proved using a binary [0,1] phase chip to produce a single encoded signal from four propagation signals simultaneously with an error bit rate of 10^9.

III. FIBER OPTIC BASED DATA SIGNAL TRANSMISSION ARCHITECTURE

The architecture of secured and efficient Fiber Optic based data signal transmission is represented in below Fig. 1.

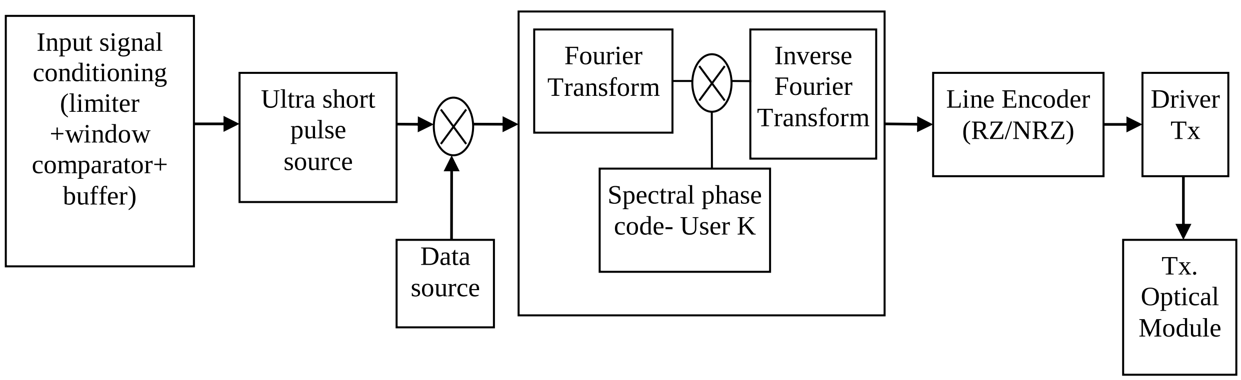

Fig. 1: ARCHITECTURE OF FIBER OPTIC BASED DATA SIGNAL TRANSMISSION

The solution proposed in this paper uses a bidirectional optical module to transmit delta encode signals received from an analog sensor. To create bidirectional communication between the two measuring systems, such optical modules must be paired. Transfer transistor level (TTL) circuits are used in the transmitting module, which requires a 5V power source (transistor-transistor-logic). A regular multimode RLS001Z optical fibre has a maximum communication distance of about 120 metres. To obtain transmission rates with appropriate Tx/Rx modules are approximately 40 kb/s due to cost constraints. However, this parameter can be improved significantly by using high-performance at transmitters and receivers, as well as low-attenuation in optical fiber.

The transmitter is made up of three parts: a spectral encoder (SE), a data source, and an ultra short light pulse source. When the source generates a bit "1," an ultra short pulse is delivered to the SE in the ON–OFF keying (OOK) scheme utilised here. Based on the user code, the SE then applies a specified phase shift to each spectral component. The SE uses two Fourier transforms to obtain the pulse spectrum: Fourier Transform and Inverse Fourier Transform. Current research will access the effect of multiple access interference (MAI) on target users. To improve clock recovery at the receiver, the data transmitted via fiber optics is further encoded using the basic line code return to zero (RZ).

The Walsh–Hadamard (W-H) codes are a set of orthogonal codes generated recursively in this system from the following relation:

$$H(k+1) = \begin{bmatrix} H(k) & H(k) \\ H(k) & -H(k) \end{bmatrix} \ldots. (1)$$

Where, k= 0, 1, 2, 3, … and $H(k)$. Each user codes in this W-H matrix is defined as a row vector, with "1" and "-1" denoting phase shifts of "0" and "π", respectively.

For proper signal adjusting, the remaining blocks in the optical module diagram shown in Fig. 1 are required. Furthermore, the modules can communicate bidirectional between two computers via an RS 232 serial port. It presents an ultrafast pulse source with a maximum power of 500 fs and a pulse width of 176 mW (average power of 0 dBm) at a repetition rate of 10 GHz, achieving a bit time slot of 100 ps. A 100ps calculation frame and Fourier discrete points are taken into account. The lossless splitter encoding / decoding method uses W-H code on chips 32 and 64. The code is applied to the pulse's spectral region, limiting the pulse edge component to at least 1% of the maximum spectral power and reducing the spectral width to 17nm. W-H32 and W-H 64 can obtain 0.5nm/chip and 0.25nm/chip, respectively.

The paper shows how poor code selection can cause enough crosstalk between active users for data from the user of interest to be detected by other users. It also show you how effective code set selection can overcome a previously unresolved security flaw. A code set is a group of codes that are sized according to the number of concurrent users in your system. The WH code is used in this study because it produces an orthogonal signal when synchronized. Furthermore, the multiple access interface generated (MAI) by these codes does not exactly correspond to the decoded signal. It is shifted before or after the reconstructed pulse to improve visibility.

Some users receive nearly the same amount of energy as the user-based. When user #5(#6) is transferred, W-H 32(64) for users #29(#53) and #30(#54) occurs. When user #53 transmits, the energy received by user #5 is the same as when user #53 transmits for W-H 64 because this interference is symmetric. Three factors influence this commutative property: 1) the combination of these codes (used in the decoding process) is the same as that used in the encoding process because the phase change is "0" and "1") Since the phase change is "0" and "1", there is no step change in the modulation data format used here. In addition, the transmission penalty between the encoder and the decoder is ignored (the system is considered back-to-back here).

IV. RESULT ANALYSIS

Each active user interacts differently with other active users in the system as mentioned previous; each requires a unique bit error rate value. It is reasonable to assume that there exists an optimal code set that minimises the bit error rates of all code set users.

The mathematical formalism used to calculate the bit error rate (BER) and multiple access interface (MAI) is described. These parameters are used as a criterion for selecting the best code in this case. The mean and variance of MAI interference per interfering user are given by:

$$\mu MAI_m = \frac{1}{N-1}\sum_{k=1}^{N} E_{k,m}, \quad m \neq k \text{....(2)}$$

$$\sigma MAI_m^2 = \frac{1}{N-1}\sum_{k=1}^{N}(E_{k,m} - \mu MAI_m)^2, m \neq k \text{ ... (3)}$$

$E_{k,m}$ is the energy received by user when user has transmitted. μ is Mean and σ is Variance. MAI_m is the MAI noise. Finally, after accounting for the contributions of the dominant effects to system performance and assuming a Gaussian distribution for the BER_m, one obtains:

$$BER_m = \frac{1}{2}\left[1 - \text{erf}\left(\sqrt{\frac{SNR_m}{2}}\right)\right] \text{.... (4)}$$

Where, SNR_m is the signal-to-noise ratio. To begin, we use the optimization algorithm to obtain extremely useful data. For example, the percentage of code sets that meet a given BER. This task describes W-H 32 analysis using the number of users as a parameter.

Therefore, found 384 (or about 7.74 %) of 4960 possible combinations that satisfy BER< (10^{-12}) for three simultaneous users (error-free). If BER 10-9 is required, the number of valid code sets increases to 448 (or approximately 9.03 percent). When four users are online and receive 192 (or approximately 0.53 percent) BER < 10^{-12} code sets from a universe of 35960 possible combinations BER <10^{-9}. However, the same code-set combinations can be obtained for up to four simultaneous users. In other words, there is a 99.5% chance BER< 10^{-9} will be generated by random selection of codes. The W-H 32 supports only a maximum of four simultaneous users with satisfactory y bit error rate values and there is no security loss due to crosstalk.

For W-H 64, a similar analysis can be performed. The percentages of code sets that satisfy a predefined bit error rate are discussed in relation to the number of concurrent users. With BER < 10^{-12}, found 74, 528 (or around 0.1 percent) of the nearly 75 million possible combinations for six simultaneous users. If BER<10^{-9} is required, the number of optimal code sets increases to 135264 (or about 0.18 percent). With seven concurrent users, the total number of users is 23, 936. (or approximately 3.9 x 10^{-3} percent) and 58, 112 (or approximately 9.4 x 10^{-3} %) code sets were found with BER < 10^{-12} and BER < 10^{-9} respectively. There are over 621 million different code-set combinations to choose from. None of the code sets are obtained acceptable bit error rate values for more than eight concurrent users. This research also demonstrates that choosing code sets at random will statistically impact not only overall system performance but also security.

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The bit error rate (BER) drops from approximately 4.55x10-1 to nearly 3.21x10-1 for W-H 32(64) with 5(9) simultaneous users (Fig. 2). It also does not work with Reed-Solomon Forward Error Correction (RSFEC) (255, 223).

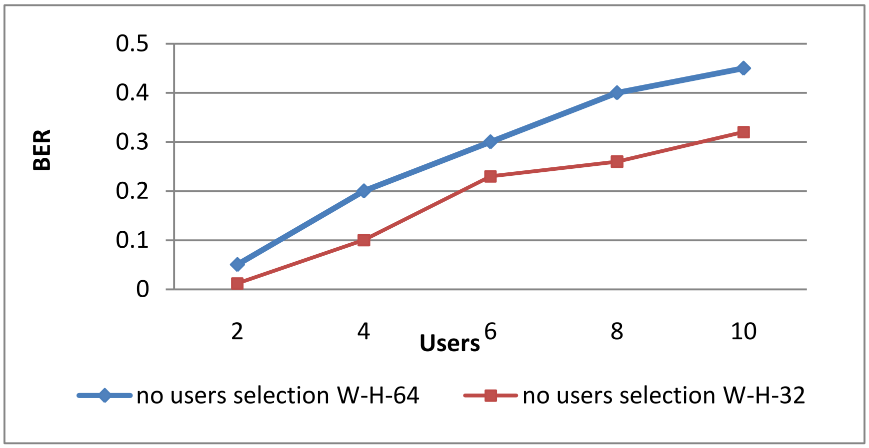

Fig. 2: BER FOR W-H 32 AND 64 CODES

As a result, the W-H 32 and 64-based systems described here can only support four and eight users at the same time, respectively.

V. CONCLUSION

In this study, we analyzed a Fiber Optic-based data signal transmission system based on W-H codes, with the purpose of analyzing security loss due to crosstalk and determining appropriate code-set selections. Each user has his or her own performance in terms of the BER value for the set of code assigned to him or her on the system. By combining high power optical transmitters and receivers with less fibre optics, the system performance parameters can be improved even further. Most importantly, despite having an acceptable BER, only a small portion of the available code set proved to be unaffected by crosstalk 0.5% for W-H32 with 4 simultaneous users and about 1 x 10^4 % for W-H 64 with 8 simultaneous users.

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