Different Types of Coding Input Data In Optical Transmission Systems

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***Abstract*— Optical fiber transmission systems are currently the most widely used transmission media. Their development in time had improved their characteristics to such an extent that they gradually replaced very popular copper cable connections. Inspite of that optical fibers still have not reached perfection and constant improvement is needed. Apart from notable advantages such as large data transfer, few numbers of repeaters required on the transmission path or higher safety of transmitted data, optical fiber has also drawbacks that include not sufficient purity optical fibers, fiber fragility and also higher proclivity to nonlinear effects. Weaknesses of optical systems can be depressed by e.g. a selection of an appropriate laser, a proper combination of materials used for fiber production during the manufacture process, or even by using an encryption of transmitted data. This article is focused on the comparison of optical signal properties in various source encoding types of input data.**

Keywords— coding, nonlinear phenomena, optical fiber, stimulated brillouin scattering, wavelength division multiplex

I. INTRODUCTION

The transmitted signal in optical fiber is influenced by many aspects. These include primarily two main categories, namely: linear and nonlinear effects. The linear effects that are considered as deficiencies of optical fiber transfer are caused by improper environment in which a particular optical cable or fiber is allocated or by material used in production process, etc. The nonlinear effects require a different approach to their solution compared to linear effects. Protection against signal degradation by nonlinear phenomena can be accomplished via signal modulation and also via the proper selection of transmitted data encryption.

For the transfer and storage of data it is necessary to encode the data in the appropriate manner. In data processing and data transfer data tend to be most often expressed by a code, usually in binary or hexadecimal form. The task of encoding at the physical layer is to assign a suitable numerical representation to physical representation. In computation technique the most frequently used signal has the form of an appropriately modulated electric or electromagnetic quantities.

II. STIMULATED BRILLOUIN SCATTERING

One of nonlinear effects in optical fiber is Stimulated Brillouin Scattering (SBS). For the first time, SBS was observed in the 1964 and is shown through the Stokes light. Its wave frequency relative to the incident light down, the frequency shift is determined by the nonlinear medium. Because of the threshold of inherent power is low, the narrow line-width gain and high conversion efficiency characteristics of SBS, fiber amplifier (FBA) and lasers (FBL) based on SBS are important in many applications. Optical fiber are able to carry the signal for long haul if a high pulse light input power is used. However, high pump power could cause SBS resulting in to most of input power transfer to backward Stokes [1].

The current transmission systems are regularly used in optical amplifiers to compensate for losses in the fiber. Each amplifier typically comprises an optical isolator which prevents the passage of growth and backward spread by the Stokes wave. Despite this action, SBS between two successive amplifiers could still worsen system performance, in the case where the signal strength is above the threshold SBS.

Another of the main dangers of SBS is associated with the channel crosstalk in WDM (Wavelength Division Multiplex) systems. Crosstalk occurs only in cases where the fiber supports dissemination channels in the opposite direction and where the spacing between channels is approximately equal to the Brillouin shift (around 11 GHz). In fact, the problem caused by crosstalk-induced SBS can be seen in two-way transmission systems at power levels far below the threshold SBS. But this kind of crosstalk can be easily printed with mild pitch changing channels. In WDM systems to SBS absence if any broadcast signal, that is, if each output channel is less than the threshold [1][2][3].

III. CODING TECHNIQUES

It should be noted that all of the techniques deal with how the message signal was impressed onto a carrier. Modulation did not address how the message signal was created from the data to be sent. Coding defines how we accurately, efficiently, and robustly construct a message signal from the data we desire to communicate. Just like modulation, there are a vast number of ways to code data, each having unique qualities and attributes and each can be chosen to optimize certain aspects in the desired system. We will briefly cover a few coding methods, NRZ and BiPhase [4].

A. Non Return Zero

NRZ is one of the most basic of coding schemes. In this method the message signal does Not Return to Zero after each bit frame. This means that the message exactly follows the digital data structure. For example, a long data string of "1"s will produce a long high period in the message signal. Transitions only occur in the message when there is a logical bit change.

B. BiPhase

BiPhase adds a level of complexity to the coding process but in return includes a way to transfer the bit frame data clock that can be used in the decoding to increase accuracy. BiPhase coding says that there will be a state transition in the message signal at the end of every bit frame. In addition, a logical "1" will have an additional transition at the mid-bit. This allows the demodulation system to recover the data rate and also synchronize to the bit edge periods. With this clock information, the data stream can be recreated. This is similar to the method we will describe next [4].

C. Manchester Coding

Manchester coding is one of the most common data coding methods used today. Similar to BiPhase, Manchester coding provides a means of adding the data rate clock to the message to be used on the receiving end. Also Manchester provides the added benefit of always yielding an average DC level of 50%. This has positive implications in the demodulator's circuit design as well as managing transmitted RF spectrum after modulation. This means that in modulation types where the power output is a function of the message such as AM, the average power is constant and independent of the data stream being encoded. Manchester coding (see Fig.1.) states that there will always be a transition of the message signal at the mid-point of the data bit frame. What occurs at the bit edges depends on the state of the previous bit frame and does not always produce a transition. A logical "1" is defined as a mid-point transition from low to high and a "0" is a mid-point transition from high to low. Methods of encoding and decoding data will be shown in the next sections [5].

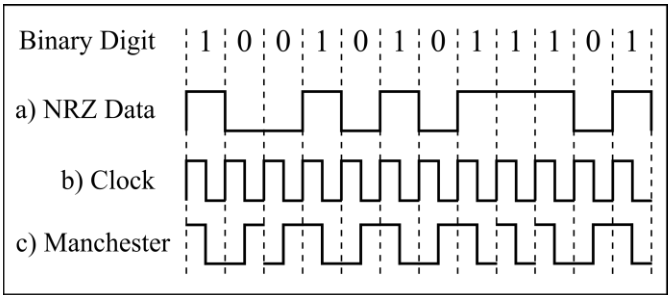

Fig. 1. Manchester coding.

D. Coded Mark Inversion

The present invention relates to digital transmission, and more particularly to decoding a binary signal which is encoded by alternate mark inversion. CMI (Coded Mark Inversion) (see Fig.2.) is a bi-phase two level transmission code known in full as: "Binary coded alternate mark inversion".

This provides a signal having no DC component, and which is transparent to a clock rate signal recoverable from the 1 to 0 transitions which always occur at the end of a bit. Further, since it is easy to implement both for coding and for decoding, it is well adapted for data transmission between equipments operating at a very high binary rate. It is described in particular in contribution No. 14 of the CCITT's special commission D in February 1974 together with a coder and a decoder for its implementation [6][7].

The decoding method used in the decoder described in the above article consists in spotting absences of a transition in the received signal by comparing the received signal in an "exclusive nor" logic gate with a version thereof that has been delayed by one-half of a bit period. This method provides a signal in which the binary data is only valid during the second half-period of each bit. This signal is transformed into non return to zero binary data (N.R.Z.-L) by means of a D-type bi-stable synchronized on the recovered clock rate. This has the drawback, as will be seen below, of requiring special synchronization conditions between the transitions in the received signals and those in the recovered clock rate signals. Meeting these synchronization conditions requires the phase position of the clock rate signal to be rigorously determined during regeneration and greatly limits the maximum tolerable amplitude the jitter in the received signal.

Preferred embodiments of the present invention mitigate the above-mentioned drawback and, consequently, to provide a considerable increase in the maximum amplitude of jitter which can be tolerated in the signal to be decoded.

The present invention provides a method of decoding a CMI encoded binary signal, the method comprising the steps of: detecting the 0 to 1 transitions in the CMI encoded binary signal; in detecting the 1 to 0 transitions in the same signal; in eliminating from the detected 0 to 1 transitions those transitions which appear one binary bit period after the immediately preceding 1 to 0 transitions; and in using the remaining 0 to 1 transitions to synchronize pulses of a duration equal to one bit period thereby obtaining, after inversion, a signal in NRZ-L code corresponding to the binary data contained in the CMI encoded signal [7].

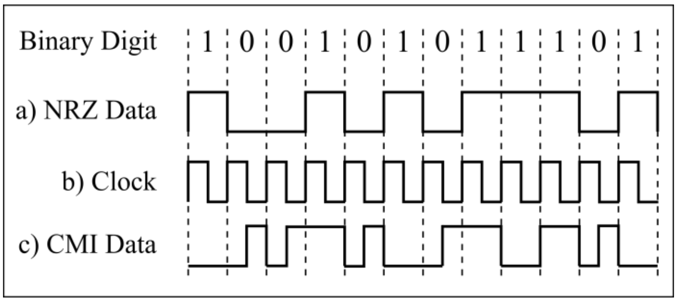

Fig. 2. CMI coding.

IV. EXPERIMENTAL SCHEME OF TRANSMISSION PATH

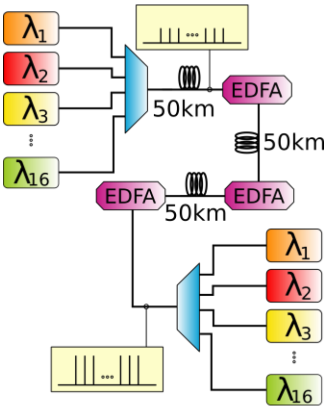

Fig. 3. Block diagram of experimental model optical transmission path.

Objective of the proposal of optical communication system is achieved by multichannel transfer over a distance of metropolitan network. Transmission speed per channel was adjusted to 10 Gb/s, it means that total transmission speed in optical fiber reaches 160 Gb/s at maximum. Influence of stimulated Brillouin scattering was observed on transmission path with distance of 150 km and measurement points were located on each 50th km. Fig.3 shows block diagram of experimental model.

DWDM (ITU-T G.694.1) technology with 16 channels was selected for transmission, wide band per channel was 50 GHz (0.4 nm).

V. RESULTS

The influence of Manchester coding could improve BER in the individual transmission channels at the same SNR level, based on the theory mentioned in the previous chapter. The different spectrum using NRZ and Manchester coding is shown in Fig.4. The red curve represents the spectrum using Manchester coding and the green line represents NRZ coding. The spectra are shown in detail for the first three transmission channels because of better spectrum readability.

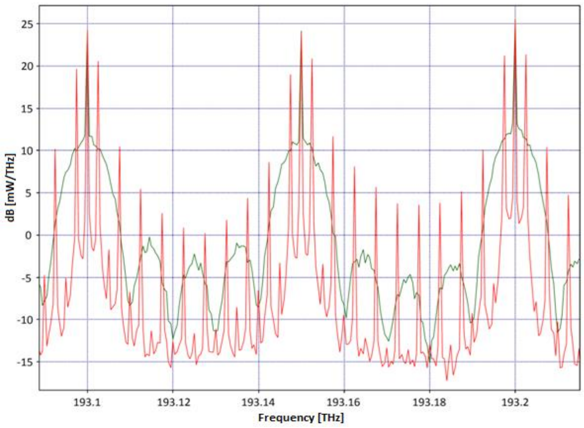

Fig. 4. Spectrum at the end of the communication system with SBS gain $3*10^{-11}$, NRZ modulator (green curve) and by using Manchester coding (red curve).

TABLE I. COMPARISON OF BER VALUE WITH SBS GAIN $3*10^{-11}$ AND 3 $3*10^{-9}$

Channel	BER	
	SBS $3*10^{-11}$	***SBS $3*10^{-9}$***
5	$1.006 * 10^{-12}$	$1.323 * 10^{-6}$
12	$4.475 * 10^{-14}$	$3.407 * 10^{-7}$
8 (100km)	$2.514 * 10^{-24}$	$4.494 * 10^{-15}$
15 (50km)	$4.882 * 10^{-34}$	$4.362 * 10^{-23}$

TABLE II. COMPARISON OF BER VALUE BY USING MANCHESTER CODING WITH SBS GAIN $3*10^{-11}$ AND $3*10^{-9}$

Channel	BER	
	SBS $3*10^{-11}$	***SBS $3*10^{-9}$***
5	$2.147 * 10^{-23}$	$5.358 * 10^{-10}$
12	$3.05 * 10^{-23}$	$3.159 * 10^{-10}$
8 (100km)	$4.362 * 10^{-35}$	$8.418 * 10^{-22}$
15 (50km)	$1.0 * 10^{-39}$	$2.721 * 10^{-37}$

As well as Table I, Table II also compares the values of SBS gain but Table II shows the results after applying of Manchester encoding. Compared to Table I, Manchester coding has improved BER values of each channel by about 10 numeric orders for SBS gain $3 * 10^{-11}$. It is also improving BER value for SBS gain $3 * 10^{-9}$, but only by 3 numeric orders. Ultimately, it meets the standard and we could transmit communication by optical fiber with SBS gain $3 * 10^{-9}$. It is also necessary to mention that SBS phenomenon is eliminated more by NRZ Manchester coding. Thus it is recommended to use Manchester coding to obtain better performance, it means less errors in the transmission channel. Channels 5 and 13 are measured at the end of transmission paths. The eye diagrams (see Fig. 5 and 6) show information from channel 5.

Next experiment includes CMI coding. There is used the same scheme as in previous measurement. Table III shows experimental result by using CMI code.

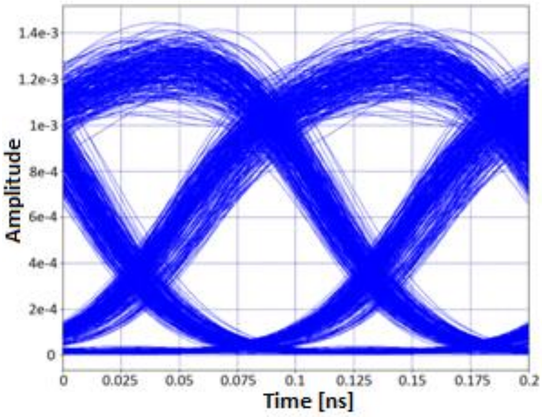

Fig. 5. Eye diagram for Manchester coding with SBS gain $3*10^{-11}$ in transmission channel 5.

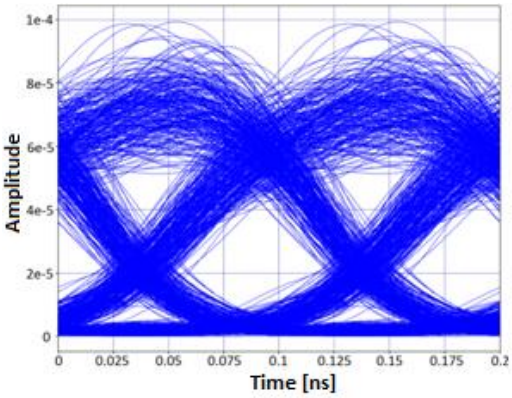

Fig. 6. Eye diagram for Manchester coding with SBS gain 3*10^{-9} in transmission channel 5.

TABLE III. COMPARISON OF BER VALUE BY USING CMI WITH SBS GAIN 3 $*10^{-11}$ AND 3 3$*10^{-9}$

Channel	BER	
	SBS 3*10^{-11}	***SBS 3*10^{-9}***
5	1.236 * 10^{-21}	4.758 * 10^{-9}
12	1.005 * 10^{-21}	2.291 * 10^{-9}
8 (100km)	5.054 * 10^{-36}	7.983 * 10^{-24}
15 (50km)	1.050 * 10^{-40}	3.021 * 10^{-37}

VI. CONCLUSION

This article was focused on the optical signal properties affected by SBS phenomenon. The main idea was to present the improvement of the signal quality via change of the encoding on the level of input data. Manchester encoding and CMI were chosen for experimental verification of the impact of changing the encoding. Experiments have shown that encoding change of the input data has a positive impact on the quality of the signal. The tables of measured values show that CMI encoding results in slightly better values at shorter distances by 2 numeric orders. For the selected transmission channels it can be seen that Manchester encoding has better results for longer distances.

We have described two different coding approaches. At this moment the decision of what approach is more suitable to apply is up to the user. This decision must be made based on the functions and limits of supporting system and the level of priority this task has in the overall system. Each approach has benefits and drawbacks associated. The intent of this article is to provide real examples of coding that can be applied.

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References

[1] F. M. Ferreira, “Nonlinear Effects in Optical Fibers,” John Wiley and Sons, Inc., Hoboken, New Jersey, 2011, ISBN: 978-0-470-46466-3.

[2] X. Li and H. Gong and S. Li and J. Wang, “Experimental investigation on pulse light stimulated Brillouin scattering in the optical fiber,” IEEE, 2011, ISBN: 978-0-8194-8961-6.

[3] M. A. Shaik and V. V. Achuth and D. Venkitesh and B. Srinivasan, “Investigation of stimulated Brillouin scattering spectra of an optical fiber with use of a frequency modulated laser,” IEEE, 2011, ISBN: 978-0-8194-8961-6.

[4] Atmel, “Manchester Coding Basics. Atmel Corporation,” Rev.: 9164BAUTO07/15 http://www.atmel.com/Images/Atmel-9164-Manchester-Coding-Basics_Application-Note.pdf.

[5] S. A. Hassan, “Manchester coder/decoder,” Google Patents, 1997, US Patent 5,687,193. https://www.google.ch/patents/US5687193.

[6] VECTRON a KNOWLES COMPANY: “Code Mark Inversion (CMI) Input Data,” 267 Lowell Road, Hudson, NH 03051, http://www.vectron.com/products/literature_library/CD700_TRU050_CMI.pdf.

[7] P. L. Brozec and F. Ferret and P. Doussoux, “Method and a circuit for decoding a CMI encoded binary signal,” Google Patents, 1982, US Patent 4,325,053. http://www.google.com/patents/US4325053

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