INTENSITY MODULATION FORMATS IN OPTICAL COMMUNICATION SYSTEM

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Abstract— In this paper,we review different modulation formats for intensity modulation,and optical modulation techniques. The performance of non-return to zero ON-OFF keying, return to zero ON-OFF keying,carrier suppressed return to zero and duo-binary intensity modulation format for the optical communication system is analyzed.

Index Terms— Non-return to zero(NRZ), return-to zero(RZ), ON-OFF keying(OOK), carrier suppressed(CS), duo-binary(DB), mach-zehnder modulator(MZM), Electroabsorption modulator(EAM), modulator(MOD), phase shaped binary transmission(PSBT), phase amplitude -shift signaling(PASS).

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1 INTRODUCTION

THE rapid growth of capacity requirement for long distance transmission, fiber-optic communication system form the high data rate transport infrastructure. To maximize the capacity of system and to minimize the performance degradation,system engineering and optimization are important. There are many benefits of using fiber in telecommunication. It has very loss, allows long distance between repeaters and has high data carrying capacity. Generally, fiber cables experience no crosstalk as in electrical transmission lines. Modern optical networks are now based on 2.5Gb/s and 10Gb/s channels. 40Gb/s channels have begun to be implemented in new product offering.[1]

In fiber-optic communication system signal modulation format is key issue which determines transmission quality. The optical signal modulation formats affects the other parameters of system such as optical spectral bandwidth, resistance to nonlinear crosstalk, tolerance to chromatic dispersion, susceptibility to accumulated noise and other system performance measures are directly related to the optical modulation format. In recent research advanced optical modulation formats was motivated for high transmission capacity and better system reliability. A exact selection of an advanced optical modulation format does improve the system performance. The choice of optimum optical modulation format depends on various factors such as data rate, fiber types, wavelength spacing and so on. In this paper , we will present our theoretical evaluation on optical intensity modulation formats and data rate preferences.

2 MODULATORS

Modulation is a process of imposing information onto a light-wave. In this process the base-band signal uses high frequency carrier signal to become more suitable for transmission over long distances. There are two types of modulation technique we generally used, are direct modulation and external modulation.

2.1 Directly Modulated Lasers (DMLs)

In the direct modulation information is imposed on a laser emitted light stream. This process directly varying the laser drive current electrically formatted information stream to produce a correspondingly varying optical output power. This direct modulation technique is used for data rates of less than approximately 10Gb/s. For higher data rates external modulator is used.

2.2 Electro-absorption Modulator

The external modulator temporally modify a steady optical power level emitted by the laser. The electrical driving signal dynamically changes the optical power level instead of varying the amplitude of the light.

The EAM is a semiconductor device whose laser beam intensity can be modulated by applying an electric voltage which changes the device's absorption properties. EAM's typically feature relatively low drive voltages and are cost effective in volume production. They are available for high speed modulation rates up to 40Gb/s , with some research demonstration up to 80Gb/s.[2]. However, similar to DMLs they gives some residual chirp. The absorption characteristic of EAM's are wavelength dependent and dynamic extinction ratios does not exceed than 10db and have limited optical power handling capabilities.

The EAM have insertion losses of about 10db , On Chirp integration can avoid the losses at input interface. By integrating with semiconductor optical amplifiers(SOAs),high insertion losses of EAMs can be eliminated.[3]

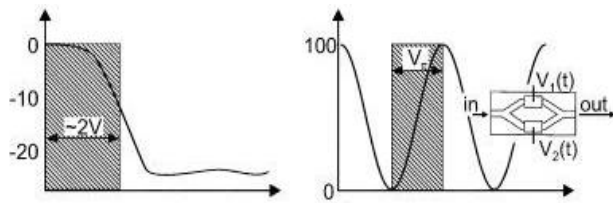Figure[1] shows the exponential transmission characteristic of an EAM as a function of drive voltage.[3]

Figure 1.Functions of Transmission for: (a) EAMs and (b)MZMs

2.3 Mach-Zehnder Modulator

The EAM and MZM both have different principle of operation, as EAM works on the principle of absorption and MZM works on the principle of interference. The device of MZM consists Y junctions which gives an equal division of the incoming light. At the input interface incoming light splits into two paths. One path is controlled by the applied voltage and this path modulates the phase of the incoming light. These two split-ted light-wave recombines with each other at the output interface. The recombination of light gives constructive and destructive interference at the output interface and hence converts phase modulation into intensity modulation. To make the device off phase difference between two light-waves should be of п.
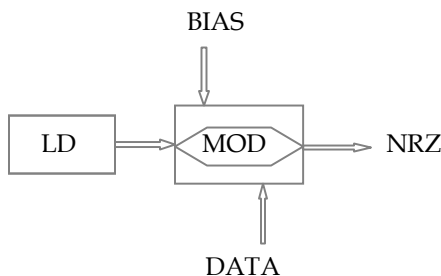
3   INTENSITY MODULATION FORMATS

3.1 Non-Return To Zero On-Off Keying(NRZ-OOK)

This is easiest to generate NRZ-OOK. There are various benefits of using NRZ-OOK in early days of fiber-optic communication, such as it needs a low electric bandwidth for transmission and receiving of the signal. It is also less sensitive to the laser phase noise and very simple configuration.

If we consider the recent technologies in optical communication field for high capacity of system then this modulation format may not give the best results. Thus because of its simplicity,it can be used for the comparison purpose. The schematic diagram of NRZ-OOK transmitter is shown in figure(2) with an external modulator which can either be a electro-absorption type modulator or a mach-zehndertype modulator. The intensity modulator converts the electric signal into an optical signal with same data rate. When using MZM type of modulator, it is biased by its quadrature point and is driven from minimum value of transmission to maximum value of transmission. To detect a NRZ signal of optical form, a simple photodiode is used at the receiving point. Generally, NRZ modulated signal gives much compact spectrum compared to other modulation formats.

Although NRZ gives compact spectrum but NRZ optical signal does not have greater resistance to residual chromatic dispersion in an amplified fiber system with dispersion compensation.[4].If comparing NRZ optical signal to RZ optical signal then we get to know that NRZ is less resistive to group velocity dispersion- single phase modulation(GVD-SPM). The different types of input data stream needs different optimum residual dispersion for the best eye opening.

Figure[2]. Block Diagram of NRZ transmission.
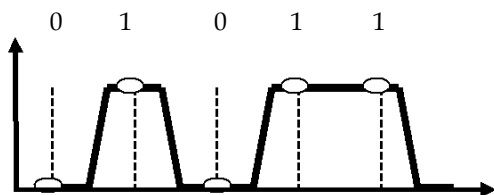
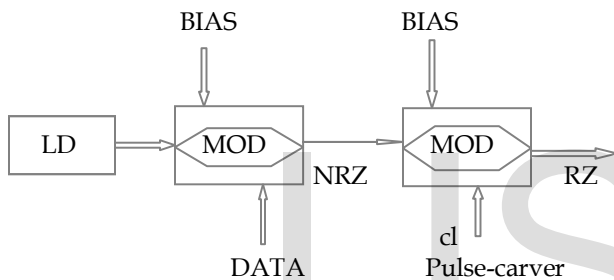Figure[3]. Waveform of Intensity for NRZ transmission.

For example a continuous digital level '1's generates less self phase modulation effect than an individual digital level'1'. A continuous digital level '1's and an individual digital level'1' have a difference of optimum dispersion compensation which make it impossible to optimize the residual dispersion in the system. It makes the system performance vulnerable to the data patent -dependent fiber non-linear effect.[4]

3.2 Return To Zero On-Off Keying(RZ-OOK)

RZ-OOK waveforms can be generated electronically and then modulate onto an optical carrier. We can also generate RZ wave-forms by carving pulses out of an NRZ-OOK signal using an another intensity modulator in cascade. The width of RZ optical signal is smaller than its bit period so a clock signal is used as a electrical signal with the same data rate to carve RZ optical signal.

The NRZ optical signal is modulated by a synchronized pulse train with the same data rate as the electrical signal. If RZ pulse have a duty cycle of 50% then optical NRZ pulse will have twice of the peak power. The optical amplifiers works in saturation region so there will be a increase in which results in gain. The photo current of photo diode is proportional to optical power thereby the received electrical power is also proportional to the square of the optical power of the photo diode as we use square law detector.

Therefore, the electric power of an RZ pulse with a 50% duty cycle will be twice that of an NRZ pulse.[4]
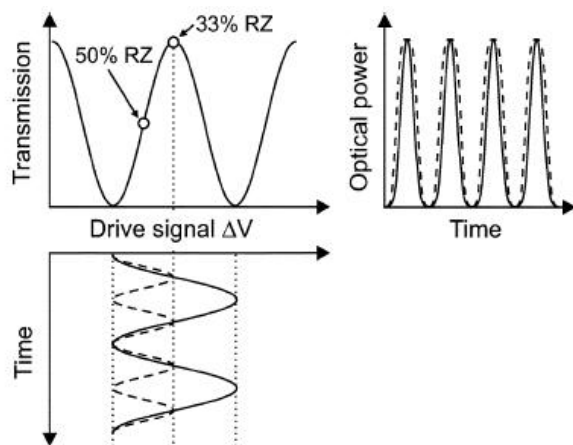
Figure[4]. Block Diagram of RZ transmission.
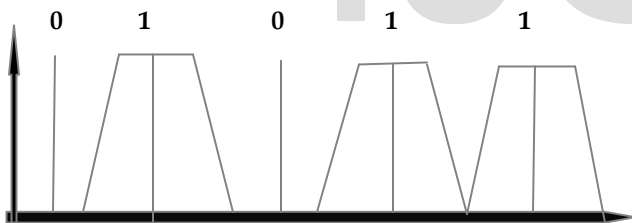
Figure[5]. Waveform of Intensity for RZ transmission.

To produce a 50% duty cycle RZ pulse, carver modulator should drive at data rate between the maximum and minimum value of transmission.
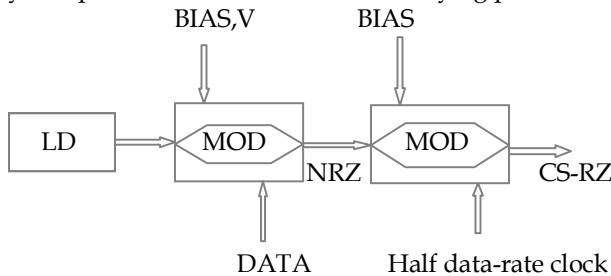
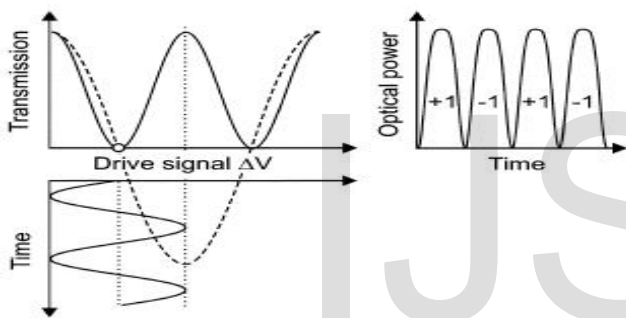**Figure[6].Bias setting of pulse carver for RZ transmission.**

In the RZ optical signal transition s of pulse stay temporarily on the zero voltage level and also indicates that the pulse of the light is narrower than the bit period, so for the best eye opening, the optimal dispersion compensation would require same amount for an individual digital bit '1' and continuous '1's. So RZ format gives more optimal dispersion compensation in the system than NRZ format and also exhibits better tolerance.

3.3 Carrier-Suppressed Return To Zero (CSRZ)

CSRZ [5] is pseudo-multilevel modulation format. It is characterized by reversing the sign of the optical field at each bit transition. In contrast to the correlative coding formats like duo binary, the sign reversals occur at every bit transition and are completely independent of the information carrying part of the signal.

**Figure[7].Block Diagram for CS-RZ transmission**

Figure[8].Bias setting of pulse carver for CS-RZ.

To generate a CSRZ pulse, a intensity modulator pulse carver is drives at half the data rate. So the optical field of one bit has its one half of positive sign and another half of negative sign resulting in a zero-mean optical field envelope.[6].The optical phase in a CSRZ signal is periodic at half the data rate.

3.4 Duo-Binary

Optical duo-binary scheme is related to a class of correlative coding formats. It has also been named as phase shaped binary transmission(PSBT) and phased amplitude-shift signaling(PASS).[7]. In this DB scheme using less than N/2 Hz of bandwidth to transmit N bits/s. DB gives high dispersion tolerance and narrow band optical filtering, these are the main advantages of using DB.

Differential Precoder   **Duo-Binary Encoder**
$Y_k = \overline{Z_y} \text{ xor } Y_{n-1}$ $X_k = Y_k + Y_{k-1}$
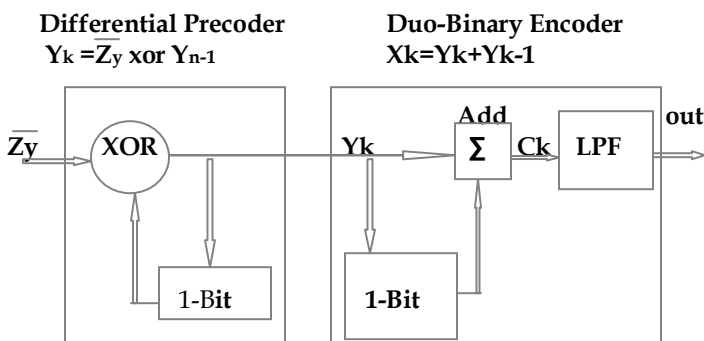

Figure[9].Block diagram of Duobinary Precoder &Encoder

By using a low pass filter, this precoded signal is converted to three level electric signal and this type of low pass filter en-

hance CD tolerance.

The quarter of the bit rate is equal to the cut-off frequency. The LPF works as an analog converter and converts the signals from binary signal to duo binary signal. In this we use MZM type of modulator which is biased at its null point.
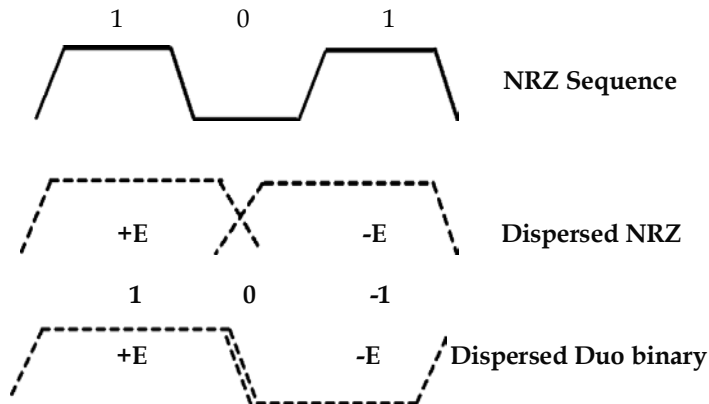
Figure[10].Dispersed NRZ and Duo binary Pulse.

When input stream has a 0 then no light is transmitted and for +1 and -1 the electric field +E and -E are transmitted respectively. Thereby the three level electric signal is converted into two level optical signal. The important property of DB signal is that all possible sequence of the three values can not occur. For example, A NRZ data sequence of 1 0 1 is converted into optical domain as +E 0 -E, and after encoding the signal we get +1 0 -1 instead 1 0 1. In figure(10) the effect of dispersion is shown for these two cases.

4   CONCLUSION

In this paper the performance of NRZ-OOK, RZ-OOK, CSRZ, DUO-BINARY for optical communication system is studied. It is observed that NRZ modulation format does not have a best dispersion tolerance among other formats. The NRZ-OOK can be used for small distance communication system to transmit high bit rate and for long distance transmission CSRZ format can be used because of its best tolerance to the dispersion at high bit rate communication system. The RZ pulse shape enables an increased robustness to optic-fiber nonlinear effects and because of its broader spectrum it has a lower dispersion tolerance.

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