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30Gb/s Absolute Polar Duty Cycle Division Multiplexing In Dispersion Uncompensated Optical Systems

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Abstract

In this study the author has modeled and characterizes the performance of 3×10 Gbp/s Absolute Polar Duty Cycle Division (APDCDM) Multiplexing in dispersive environments at 1550 nm. APDCDM technique is examined, with comparison to non-return-to-zero (NRZ) and return-to-zero (RZ) Time Division Multiplexing. In this paper three channel operating at the same speed of 10 Gbps are multiplexed in electrical domain. The experimental simulation results show that the receiver sensitivity of all users in APDCDM system is similar to that of RZ- TDM and 3 dB better than NRZ-TDM. The proposed system offer reduced dispersion sensitivity; this suggests advantages for APDCDM in optical multiplexing systems. It was also showed that APDCDM can support higher bit rate than TDM and also, it is less sensitive to the chromatic dispersion effect.

Keywords*-Optical Communication; Multiplexing technique; Dispersion uncompensat ; Highspeed network*

I. INTRODUCTION

As more capacity is required for telecommunication services, higher data transmission rates become essential to fulfill demand. In general, the maximum transmission rate in high speed optical networks is limited by the bandwidth of electronic components in the terminal equipment [1, 2]. Therefore efficient use of the limited available band width is mandatory. Ultra high speed multiplexing systems requires a transmitter configuration based on short pulses. In this instance, nonlinear optical pulse compression in transmission fiber may be used reduce the liner dispersion of the optical pulses.

Multiplexing is the set of techniques that allows the simultaneous transmission of multiple signals across a single data link. There are several techniques for dividing one channel among many users especially in optical domain. Simplicity is the appeal of Optical Time Division Multiplexing (OTDM)[1], Wave Length Division Multiplexing(WDM) [3, 4] and optical polarization based multiplexing [5] which is used exclusively before the new technique was introduced called Optical Code Division Multiplexing.

A new multiplexing technique, which is based on absolutized Polar return-to-zero (RZ) duty cycles, is introduced in this study

The return-to-zero (RZ) format is however, recognized to generally yield better receiver performance [6, 7]. Recent technical progress in external modulation and short pulse generation enables an RZ signal to be employed, to removing the band with limitation of LD direct modulation.

In this paper, APDCDM technique is implemented in a high speed optical communication link with the setup uses only a single wave length channel; the system can be easily duplicated for other wavelength to represent a WDM system.

Researchers have for some time examined multilevel signaling as a way of increasing the capacity of optical communication systems [8, 9]. Four level signaling (M-ary) has an intrinsic signal to noise ratio penalty due to the fragmentation of the main eye to three smaller eyes [6]. There are other methods employed to provide more transmission capacity such as optical polarization multiplexing [8], so that more than one channel can be transmitted in single wave length. However these methods are not economical and are difficult to realize. Realizing these problems in this paper the authors introduced APDCDM based on return-to-zero duty cycles which is allows signal multiplexing to be performed economically in the electrical domain. By using return-to-zero (RZ) modulation format and simple amplitude modulation (AM) the capacity of 30 Gb/s per optical channel is achieved using 10 Gb/s transmitter and receiver. This achievement shows that APDCDM can become a potential alternative to increase the transmission capacity tremendously.

In section II of the article the basic properties of APDCDM are explained based on theoretical analysis. Results from the simulation study are discussed in subsequent section followed by a conclusion.

II. WORKING PRINCIPLE

The absolute polar duty cycle division multiplexing (APDCDM) is based on having each channel modulated with a unique RZ duty cycle. In this technique each multiplexing user transmits bit ‘0’ with zero volts and for the case of bit one, the odd users transmit with $+A$ volts and the even users transmitted with $-A$ volts. Based on the linear distribution of duty cycle, the multiplexing user transmits bit 1 within Ti second which is calculated as shown in equation (1)

$$Ti = i \times \left(\frac{Ts}{n+1} \right) \text{ (Seconds)} \quad (1)$$

Where Ts is the time slot and n is the number of users. The first user has the shortest pulse width which is calculate using equation (1), when $i = 1$ and the n^{th} user has the longest pulse width, when $i = n$. Therefore, different users share the communication medium to transmit in the same time period T_s and at same carrier frequency but over different duty cycles.

Based on the 2^n possible bits combination, each of these combinations produces a unique symbol for the absolute polar multiplexed signals. Having the knowledge about this uniqueness at the receiver side, the original data for each user can be easily distinguished and recovered by taking one sample per slot for '$n+1$' slots per 'Ts' seconds. This technique allows for automatic bit error detection and correction based on the sequence of sampled amplitudes per symbol duration for the case of multiplexing 'n' users. If only one sample per slot is taken, then, the first sample (taken from the first slot), has [(n+1)/2] +1 levels (when n is odd), and (n/2) +1 possible levels (when n is even) possible levels, the second sample (taken from second slot), has (n+1)/2 and (n/2) possible levels when 'n' is odd and even respectively. While the n^{th} sample has only two possible levels (0 or A volts), and the last sample has one possible level which is 0 volts.

There are $n+1$ number of slots per symbol in the multiplexed signals. All of these slots have an equal duration that can be calculated using equation (2)

$$Tslot = \frac{Ts}{n+1} \quad (2)$$

Note that the maximum amplitudes of the multiplexed signal are

$$\begin{cases} A_{Max} = A(\frac{n}{2}) & When\ n{=}even \\ A_{Max} = A(\frac{n+1}{2}) & When\ n{=}Odd \end{cases} \quad (3)$$

The minimum amplitude that the multiplexed signal may take is '0' volt. The minimum amplitude only happens, when all users transmit bit '0'. For example in Figure 1, case 1 has the minimum amplitude of '0' volts in the first slot.

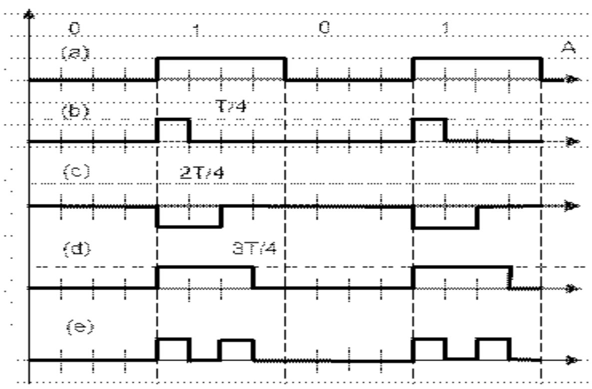

Figure1.(a) example of original signal, carrying bits 0101 with duty cycle of100% Ts; (b), (c), (d) Three multiplexing users with duty cycle of 25%,50% and 75% of Ts for user 1 , 2 and 3 respectively and (e) Absolute polar multiplexed signal

III. SIMULATION SETUP

Figure 1(a), (b) shows the simulation setup used in this simulation study for APDCDM and TDM respectively. In APDCDM the output of the RZ modulator for user 1, user 2 and user 3 is fixed to a duty cycle of 25%, 50% and 75% respectively, and for TDM, NRZ pulse modulation or in the case of RZ the duty cycle fixed to 50% was used in this study. The launched peak power of all users is identical. All users' data are multiplexed via an electrical adder to produce a combined signal. To prevent of having positive and negative levels, the absolute circuit is used after the combiner to have only positive level. Figure 2(a), (b) shows the eye diagram of the system for three users and the absolutized combined signal in optical fiber respectively. Multilevel stair-case patterned signal is produced depending on the bit sequence of each user. This multilevel signal is the key element that enables the signal demultiplexing in the electrical domain at the receiver.

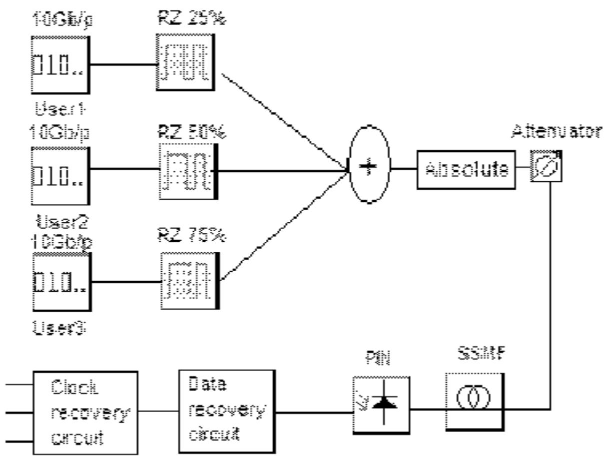

Figure1 (a): Simulation Setup for APDCDM

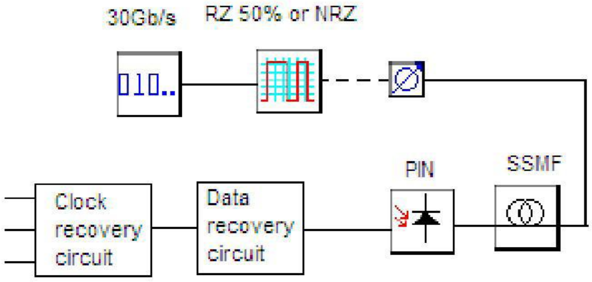

Figure1 (b): Simulation Setup for TDM

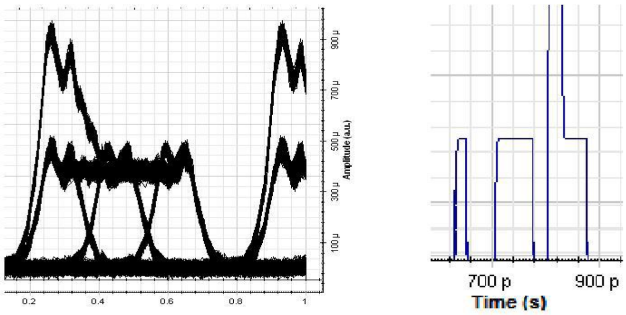

Figure2. (a)Transmitted aye diagram ;(b) Absolutized combined signal

All the sampling circuits are synchronized based on the recovered clock. The first sampling circuit samples at T/8, the second at 3T/8, the third at 5T/8, where T is the bit period (100Ps). The speed of all sampling circuit is equal to the single user's rate. Outputs of the sampling circuits is passed through three comparators in which, output of the first sampling circuit compares with two threshold values thr_1, thr_2 at the Comparator 1. Output of the second and third sampling positions compares with one threshold values thr_1 at the Comparator 2 and 3 respectively. For example for user with 50% duty cycle produces one when

$$\begin{cases} Th1 < S2 < Th2 \;\&\; S3 < Th1 \\ S2 < Th1 \;\&\; S3 > Th1 \end{cases}$$

And it will produce zero when

$$\begin{cases} S2 < Th1 \;\&\; S3 < Th1 \\ S2 > Th1 \;\&\; S3 > Th1 \end{cases}$$

And for user with 75% duty cycle if $S3>Th1$ it means user with 75% duty cycles transmit bit '1' and if $S3<Th1$. It means user three sends zero.

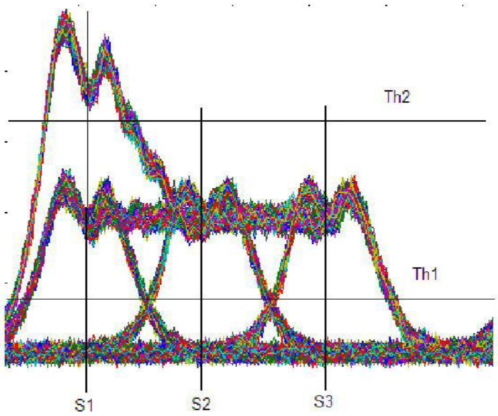

Figure3.Disision making base on transmitted eye diagram for three users

IV. RESULTS AND DISCUSSION

In this simulation the tests were carried out in the speed of 30GB/s for APDCDM, RZ-TDM and NRZ-TDM to test the back-to-back receiver sensitivity and also for the effect of distance and bit rate on BER. Various impairment factors were considered, including chromatic dispersion and nonlinear effects.

Figure 4 shows the receiver sensitivity of the APDCDM system for all the three channels in comparison to that of the TDM using 50 % of return-to-zero and none-return-to zero at 30 Gb/s. In general, the receiver sensitivity of all users in APDCDM system at BER of $1e^{-9}$ is around -13dBm, which is similar to that of RZ-TDM, Although APDCDM and RZ-TDM have the same receiver sensitivity note that APDCDM requires less bandwidth than TDM, which makes it more spectral efficient and less affected by dispersion. Dispersion is more influential detrimental factor for high speed transmissions. When compared with 30 Gb/s NRZ-TDM, this technique shows better sensitivity in the order of 3 dB.

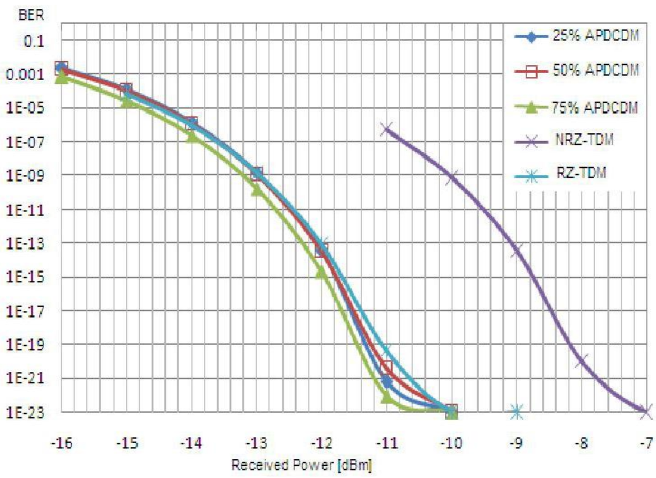

Figure4.Receiver sensitivity for APDCDM, RZ-TDM and NRZ-TDM

Figure 5 shows the effect of chromatic dispersion on the performance of three multiplexing techniques which are tested at the same transmitted power. In APDCDM technique, all users show almost similar behavior at positive and negative chromatic dispersions. Users with 25%, 50% and 75% duty cycles have chromatic dispersion of ±90 ps/nm/km at BER of 1e-9. RZ-TDM technique, the users can sustain the dispersion of around ±78 ps/nm/km at the same BER and for NRZ-TDM ±75 ps/nm/km. This result shows that, the APDCDM technique is more robust to dispersion in comparison with RZ and NRZ-TDM techniques.

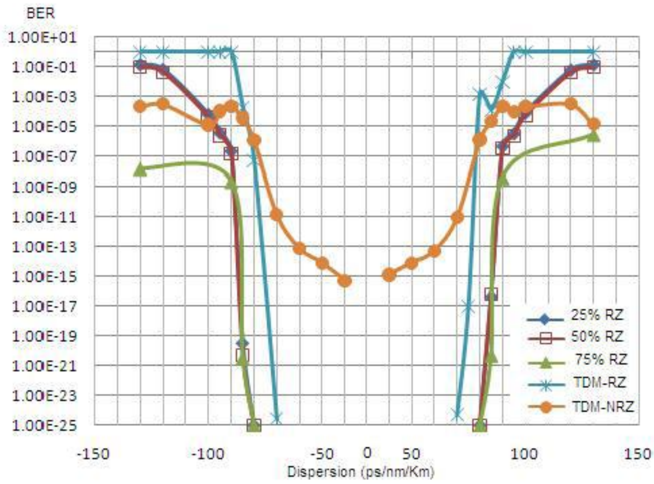

Figure5. Dispersion of DCDM and TDM technique for 3 channels

Figure 6 shows the BER versus bit rate which is tested in the high speed range (10Gbps-16Gbps), for each user over a fixed fiber length at a fixed transmission power for both APDCDM and TDM techniques. In APDCDM technique, user with 75% duty cycle can support higher bit rate than the other two users at BER of 1e-9. In comparison with TDM technique, the worst user (user with 25% duty cycle) in APDCDM technique still can support more than 1 Gbps bit rate than TDM users. According to these results the APDCDM technique can support longer distance and higher bit rate than TDM technique at non-zero dispersion system.

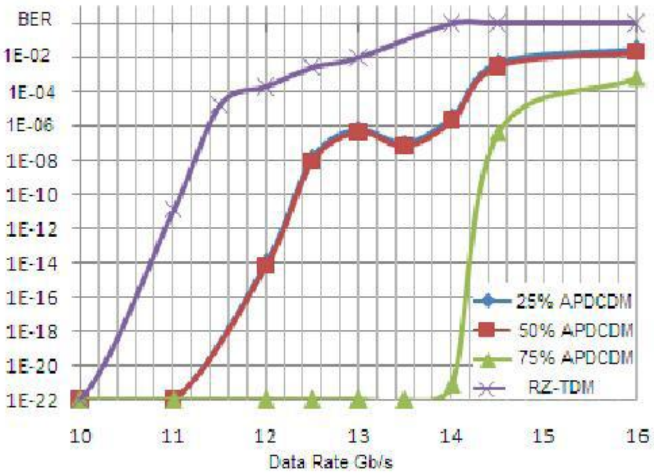

Figure6.BitRate versus BER

V. CONCLUSION

In this paper, Absolute Polar Duty Cycle Division Multiplexing (APDCDM) implemented on the high speed optical network is proposed. APDCDM technique is examined, with comparison to non-return-to-zero (NRZ) and return-to-zero (RZ) Time Division Multiplexing. Basic parameters which are important to determine the system performance were investigated. In back-to-back receiver sensitivity the author showed that APDCDM and RZ-TDM both have same receiver sensitivity but our system has the advantage of less bandwidth compare to TDM which makes it more spectral efficient and less affected by dispersion. Compare to NRZ-TDM our technique shows better sensitivity in order of 3 dB. In the same condition for both TDM and APDCDM, APDCDM shows better performance against bit rate and dispersion compare to TDM. It is important to note that other advantages such as better clock recovery and error detection and correction benefiting from the inherent properties of this technique are not yet being considered in this report.

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