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A NAND Subtraction Detection Technique for Hybrid SCM SAC-OCDMA System

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ABSTRACT: A NAND subtraction detection based on subtraction for hybrid sub-carrier multiplexed (SCM) spectral-amplitude-coding optical code division multiple access (SAC-OCDMA) system is discussed here.SCM technique improves the channel data rate and the multiple access interference(MAI) can be removed by the SAC-OCDMA system.Thus the hybrid system performs well against interference and is spectrally efficient. Double weight(DW) coding is used to code this hybrid system.The hybrid system using NAND subtraction detection technique is compared to the complementary subtraction detection in optisystem software.The performance is compared on the basis of bit error rate and Q-factor for different fiber length.The results showthat the hybrid system with the NAND subtraction detection technique improves the system performance.

KEYWORDS:Hybrid SCM SAC-OCDMA, Multiple Access Interference(MAI), Optisystem, Spectrally Efficient, Subtraction Detection Technique.

I. INTRODUCTION

Recently there has been rapid increasing demand on optical communication network with higher throughput at low cost. The tremendous growth of internet has resulted an increase in the users consuming large amount of bandwidth. Optical Code Division Multiple Access (OCDMA) has proposed as an alternative to frequency and time based multiplexing methods because it allows many users to access the same channel asynchronously through the assignment of unique code word sequences. Also OCDMA offers strong security in the physical layer. But the main limiting factor in OCDMA is Multiple Access Interference (MAI) [1]. In order to eliminate the MAI Spectral Amplitude-Coding Optical Code Division Multiple Access (SAC-OCDMA) system has used,which eliminates MAI completely by employing code sequences fixed in-phase cross correlation.

In SAC-OCDMA systems user is assigned with a sequence code that serves as its address. An OCDMA user asynchronously initiates transmission after modulating its address with each data bit. Thus, this modifies its spectrum appearance. Several code families are developed for SAC-OCDMA such as modified quadratic congruence codes (MQC), M-sequence codes, double weight codes (DW) [2], etc. The ability to totally suppress the MAI is due to the employment of complementary subtraction technique. Therefore it is desirable to develop a detection technique which simultaneously reduce insertion loss and MAI. In this paper, a new detection technique called NAND subtraction is proposed. It can be seen that the NAND subtraction detection technique provides a significantly better performance than the complementary subtraction detection technique. The channel data rate of OCDMA system can be improved by using sub-carrier-multiplexing technique. Thus this hybrid sub-carrier-multiplexingspectral-amplitude-coding optical code division multiple access(SCM SAC-OCDMA) system is proposed for the benefit of combining the advantages of both schemes.

II. RELATED WORKS

In [3] authors proposed and experimented the performance of high-speed digital fiber-optic transmission using subcarrier multiplexing (SCM). Optical single-sideband (OSSB) modulation was used to reduce the impact of fiber chromatic dispersion and to increase bandwidth efficiency. Nonlinear crosstalk must be considered because frequency spacing between adjacent subcarriers can be much narrower. The data rate at each subcarrier is low since chromatic dispersion is not a limiting factor in SCM systems.

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In [4] authors proposed codes with ideal in-phase cross correlation (CC) for SAC-OCDMA systems since these codes eliminate multi user interference and also suppress the effect of phase-induced intensity noise.The proposed codes are obtained by modifying former codes with ideal CC. The performance of this system is significantly improved by using these codes with ideal in-phase CC.

In [5] authors proposed and experimented the performance of hybrid SCM SAC-OCDMA system using complementary subtraction detection technique. The proposed system has been analyzed by taking into account the effects of phase-induced intensity noise and inter-modulation distortion noise. The analysis shows that the proposed system can eliminate the multiple access interference by using Complementary subtraction detection technique, and hence improve the overall system performance.

III.SYSTEM MODELLING

The hybrid SCM SAC-OCDMA system is designed using double weight code. In this hybrid system, it uses incoherent detection techniques using subtraction techniques are used. Here mainly complementary and NAND subtraction detection techniques are discussed.

A. *Hybrid SCM SAC-OCDMA System*

Fig 1 shows the basic block diagram of the hybrid SCM SAC-OCDMA system. At the transmitter, the data is mixed with a different microwave carrier frequency. The sub-carriers are combined and optically modulated with the code sequence, using an Mach Zehnder Optical External Modulator (OEM). Then the modulated code sequences are combined together with a optical combiner and transmitted through the optical fiber. So in this hybrid system, each user is designated with a particular code sequence and sub-carrier frequency, where the pair of code sequence and sub-carrier frequency are unique with respect to every other user. At the receiver the different modulated code sequences are separated by a splitter. Only the intended receiver is able to correctly demodulate the detected signal by using a matched code sequence.

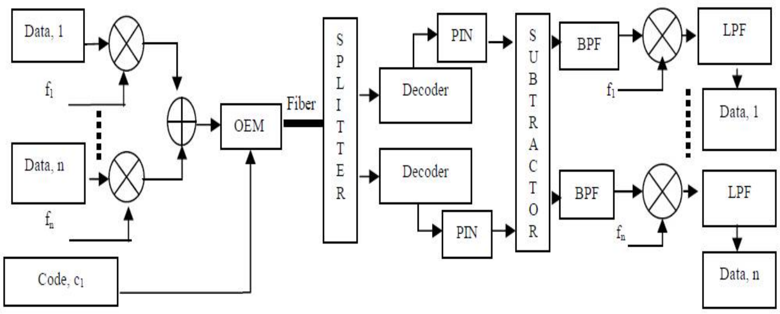

Fig. 1 Block diagram of hybrid SCM SAC-OCDMA system.

Then photodetector is used to detect the decoded signal. An electrical Band Pass Filter (BPF) is used to reject the unwanted signals and split the subcarrier multiplexed signals. The incoming signal is electrically mixed with a local microwave frequency to recover the original transmitted data, and filtered using Low- Pass Filter (LPF). Thus the proposed hybrid system has a high level of security since each receiver must tune to the correct pair of code sequence and sub-carrier frequency to receive the desired data.

B. *Complementary Subtraction Detection Technique*

Complementary subtraction detection technique is also known as balance detection technique. In complementary subtraction detection technique, the cross-correlation is defined as:

$$\Theta_{XY}(k) = = \sum_{i=0}^{N-1} X_i \, Y_{i+k} \qquad ....(1)$$

Where X and Y are two OCDMA code sequences, the complement of sequence X is given by $\overline{X}$ whose elements are obtained from X by $\overline{X}$ = 1-X. Let X = 0011 and Y = 0110 and therefore $\overline{X}$ = 1100. The periodic cross correlation sequence between X and Y is similar to Equation 1 and is expressed as:

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$$\Theta_{\bar{X}Y}(k) = \sum_{i=0}^{N-1} \bar{X_i}\, Y_{i+k} \qquad \text{......(2)}$$

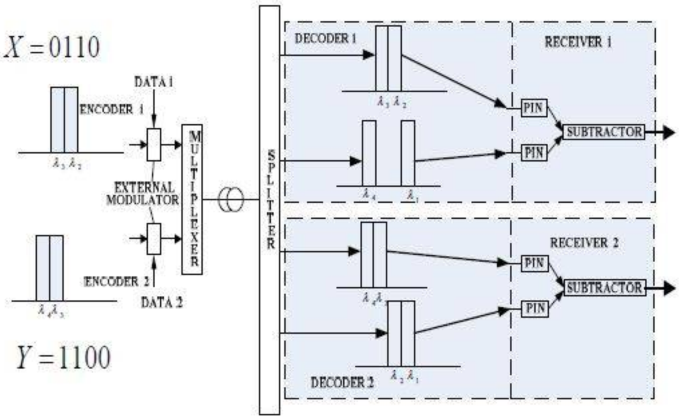

Fig. 2 Implementation of complementary subtraction detection technique.

Here the sequence to be $\theta_{XY}(k) = \theta_{\bar{X}Y}(k)$. Now at the receiver, the photodetectors will detect the two complementary inputs which will be fed to the subtractor whose cross-correlation output, Z can be expressed as:

$$Z_{complementary} = \theta_{XY}(k) - \theta_{\bar{X}Y}(k) = 0 \qquad \text{.......(3)}$$

There is no more signal from other users in the intended channel when $Z_{Complementary} = 0$. Implementation of this complementary subtraction detection technique is shown in fig 2.

C. *NAND Subtraction Detection Technique*

When compared with AND and NOR digital gate, NAND gate is having three times greater mobility of electrons. It refers to the digital logic gates (AND, OR,NAND).

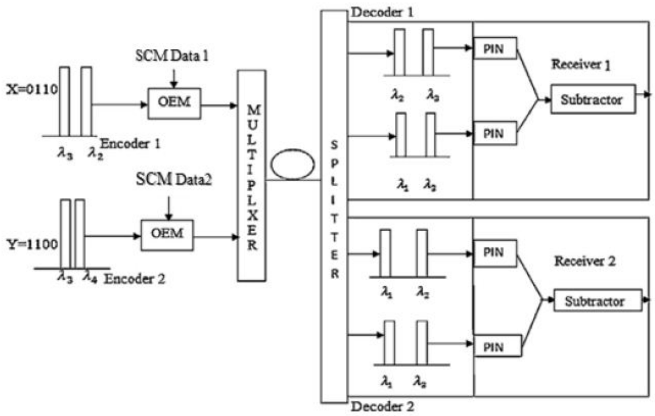

Fig. 3 Implementation of NAND subtraction detection technique.

But in this system the idea of NAND is used as an operation. In the NAND subtraction detection technique, the cross-correlation $\theta_{X\bar{Y}}(k)$ is substituted by $\theta_{(\overline{X\bar{Y}})Y}(k)$ where $\theta_{\overline{XY}}$, represents the NAND operation between X and Y sequences. For example, let X = 1100 and Y = 0110 therefore the NAND is $\overline{XY}$ = 0010.

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IV. SIMULATION SETUP

The proposed hybrid SCM SAC-OCDMA system is simulated on optisystem software version 12. The simulation of the transmitting section is shown in fig 4. The schematic block diagram of the simulation layout consists of a PRBS generator and is directly fed to the NRZ electrical driver is multiplied by a sub carrier at frequency .65Mhz. Then.Then the output of the multiplier is given to the Mach Zehnder modulator. White light source having a center wavelength of 1550nm and power of 5dB passes through an encoder which is implemented using FBGs is also given to the input port of Mach Zehnder modulator. The encoded data which comes out of Mach Zehnder modulators from all the users is then given to an ideal multiplexer (MUX). Output from MUX is then allowed to pass through the optical fiber.

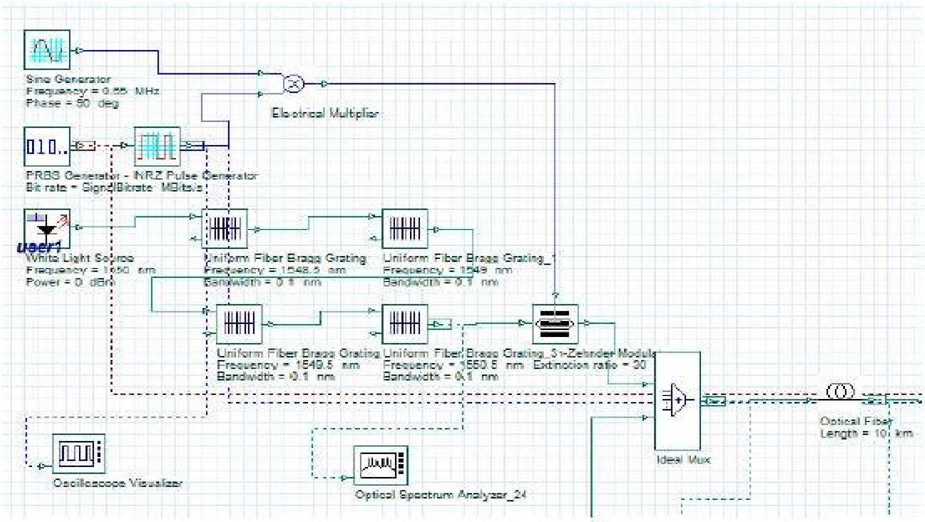

Fig. 4 Simulation of transmitting section

From the transmitter section the signal passes through the optical fiber. Now the output of the optical fiber, which is a single mode fiber, is fed to the input of the optical splitter which splits the input into the 1:2 outputs. Now the 2 outputs of the filter are fed to the corresponding receiver of users. Receiver section includes decoders, photodetectors, and filters along with a sub carrier. The transmitter section is common for both the detection techniques.The simulation of complementary subtraction detection technique is shown in fig 5.

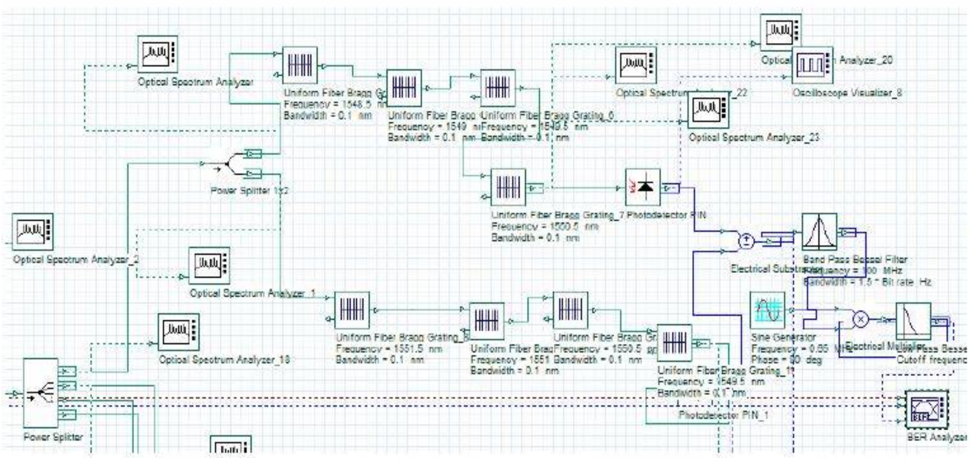

Fig. 5 Simulation of complementary subtraction detection technique.

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In Complementary subtraction detection technique, at the receiver the photo detectors will detect the two complementary inputs which will be fed to the subtractor whose output is calculated which is always zero. So there will be no more cross-correlation terms indicating that there is no more signal from other users in the intended channel and hence there will be no more MAI.

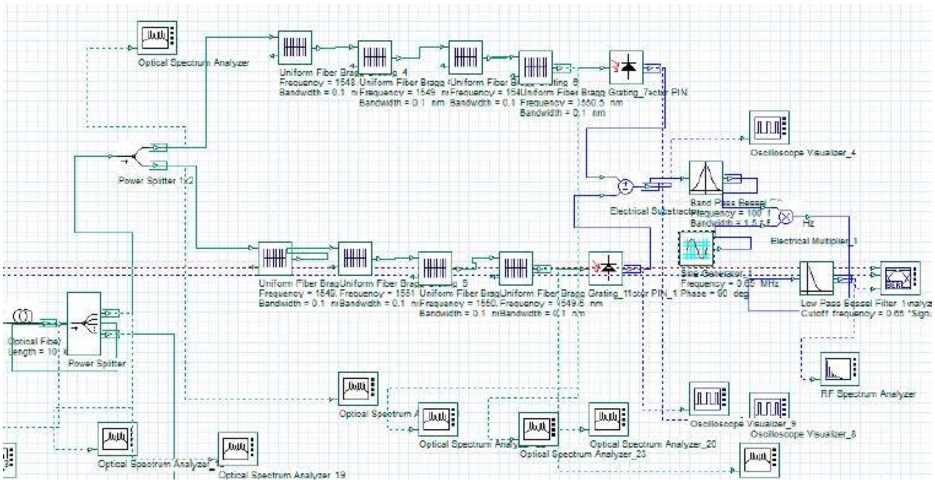

Fig. 6 Simulation of NAND subtraction detection technique

The simulation of the NAND subtraction detection technique is shown in fig 6. In NAND subtraction detection technique, MAI gets eliminated by subtracting the cross-correlation output between the upper and lower branches of the detector.

V. RESULTS AND DISCUSSIONS

As the signals passes through the fiber, distortion may occur which affects the receiver side spectrum. The eye diagram of complementary subtraction detection technique is shown in fig. 7. From the analysis of eye diagram the distortion can be found out.

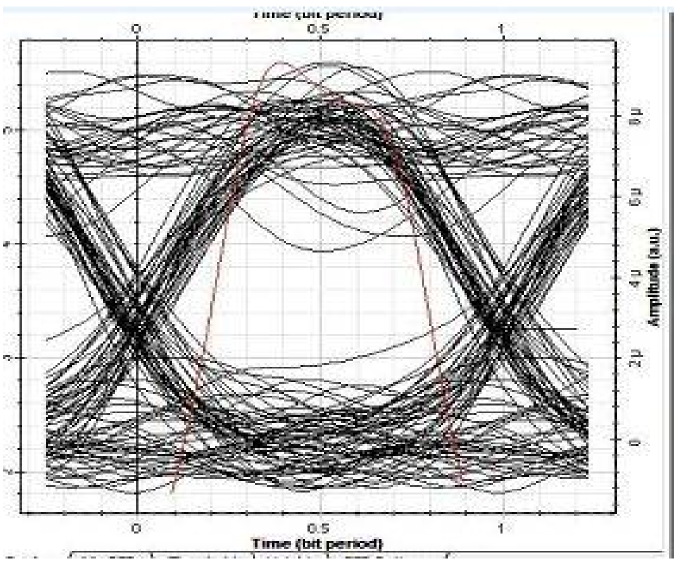

Fig. 7 Eye diagram of complementary subtraction detection technique.

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The eye diagram of NAND subtraction detection technique is shown in fig. 8. By analyzing the eye diagrams of both the detection techniques it is clear that the NAND subtraction detection technique is performing well than the complementary subtraction detection technique.

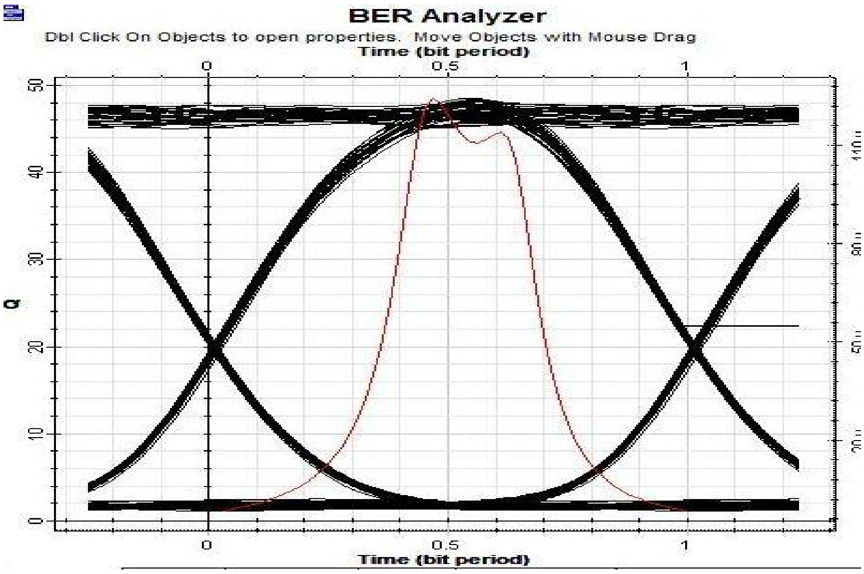

Fig. 8 Eye diagram of NAND subtraction detection technique.

From the eye diagrams the bit error rate (BER) for the two detection techniques at different fiber lengths can be found out. The standard acceptable bit error rate value is $\leq 10^{-9}$. Table 1 gives the BER value of complementary and NAND subtraction detection techniques at different fiber lengths.

Table. 1 BER values for different fiber lengths.

Fiber Length (Km)	BER of Complementary	BER of NAND
10	$1.79 * 10^{-25}$	$3.81 * 10^{-46}$
20	$4.21 * 10^{-37}$	$2.29 * 10^{-45}$
30	$6.04 * 10^{-35}$	$2.92 * 10^{-44}$
40	$2.75 * 10^{-25}$	$8.51 * 10^{-40}$
50	$1.03 * 10^{-9}$	$3.82 * 10^{-32}$
60	$1.34 * 10^{-8}$	$2.08 * 10^{-24}$
70	$1.10 * 10^{-6}$	$2.39 * 10^{-24}$
80	$1.51 * 10^{-5}$	$2.87 * 10^{-23}$
90	$5.51 * 10^{-4}$	$8.01 * 10^{-22}$
100	$8.16 * 10^{-2}$	$1.32 * 10^{-20}$

From the table 1 it is clear that as the fiber length increases the complementary subtraction detection technique is having a BER value greater then 10^{-9}. But the NAND subtraction detection technique satisfies the BER value criteria even at long distances. So NAND subtraction detection technique can perform well at long distances.

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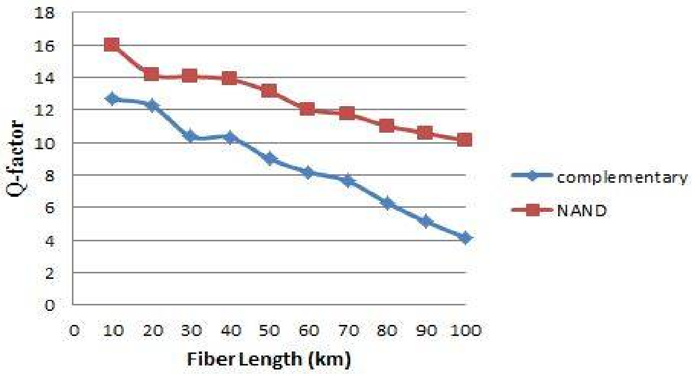

Fig. 9 Graph between Q-factor and fiber length

Fig. 9 shows the graph between the fiber length and Q-factor. From the graph it is clear that the Q-factor of NAND subtraction detection technique is much better than the complementary subtraction detection technique as the length of fiber increases.

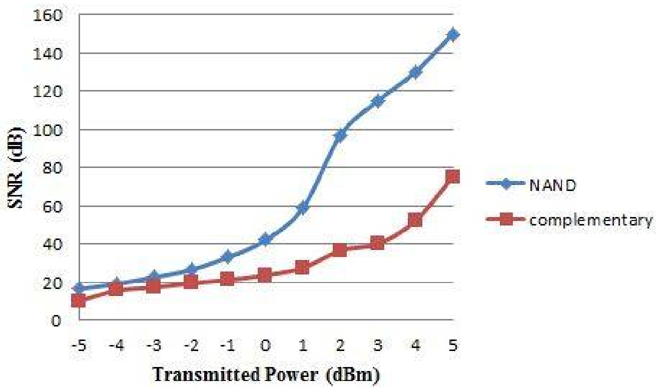

Fig. 10 Graph between transmitted power and SNR.

Fig. 10 shows the effect of transmitted input power on SNR. The distance of the optical fiber was set at 30km. The SNR of the hybrid system increases when the transmitted input power is increased. However the SNR of the hybrid system using NAND subtraction detection technique is significantly higher than the system using complementary subtraction detection technique.

VI. Conclusion

The hybrid SCM SAC-OCDMA system using DW code with NAND subtraction detection technique is compared with the complementary subtraction detection technique. The analysis was based on bit error rate, Q factor and Signal to Noise Ratio(SNR). The bit error rate value which is greater than 10^{-9} indicates poor performance of the system.The hybrid system with NAND subtraction detection technique is having high SNR than hybrid system with complementary subtraction detection technique. Also NAND subtraction detection is having bit error rate within the limit even at long distances.Thus out of these analysis NAND subtraction detection technique exhibits better results for long distance communication.

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BIOGRAPHY

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