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ANALYSIS OF OCDMA SYSTEM WITH SINGLE PHOTO DIODE DETECTION

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***Abstract*— Optical code-division multiple access system has been very helpful in combining the unlimited bandwidth of fiber with the flexibility of CDMA technique to achieve a high quality transmission. However, the main degradation on the performance of OCDMA systems is essentially due to multiple access interference (MAI) originating from other simultaneous users. Spectral amplitude coding garners significant attention because of its ability to reduce Multiple Access interference by employing appropriate decoder architectures. Proposed paper uses a performance study of new decoder architectures for Spectral amplitude coding optical code division multiple access (SAC-OCDMA) system. When using this technique, the multiple access interference (MAI) is eliminated in the optical domain. The theoretical and simulation results show that the proposed new decoder architectures improve the performance compared to conventional decoding techniques.**

Keywords: optical CDMA, Spectral Amplitude Coding (SAC), Multiple Access Interference.

I. INTRODUCTION

Today's telecommunication networks have widely adopted optical fiber as the backbone transmission medium. It has the advantage of low loss, low noise and very high bandwidth. In order to make full use of the available bandwidth in optical fibers and satisfy the bandwidth demand in future information networks, it is a necessary to multiplex low rate data streams onto optical fiber to increase the total throughput.

A multiple access scheme is required for multiplexing and demultiplexing traffic on a shared physical medium. The three major multiple access schemes are described. Digital communication allows the possibility of time division multiple accesses (TDMA). In a TDMA system, each channel occupies a time slot, which interleaves with the time slots of other channels. In a wavelength division multiple access (WDMA) system, each channel occupies a narrow frequency or wavelength. A channel in a CDMA system occupies the same frequency-time space as all the other CDMA channels.

Each CDMA channel is distinguished from other CDMA channels by a unique CDMA spreading code.

In optical CDMA system, the detection process affects the performance of both transmitter and receivers. These detection processes are generally divided into two type’s namely coherent and non coherent detections [10]. In coherent detection the transmitted signals are detected by using the knowledge of phase information of the carriers, incoherent detection doesn’t refer phase information of the carriers. Instead a system with unipolar sequences in the signature code is called incoherent systems, while a system with bipolar sequences are referred as coherent system.

In an incoherent CDMA system, each user is assigned a distinct code word as its corresponding addressed signature based on the spectral amplitude [9]. When user wants to transmit data bit one, its send out a code word to the corresponding addressed signature of the projected receiver. In receiver side all the code words from the different users are linked. If a correct codeword’s are arrives, an auto correlation function will be performed, for incorrect codeword’s, cross correlation operation are generated and they create Multiple Access interference (MAI). MAI can be reduced by using different detection techniques. Most common detection technique is the complementary subtraction technique which also known as balanced detection technique [1, 2].

In this paper, we will compare the complementary subtraction detection with a new detection techniques like spectral direct detection technique, AND subtraction technique and Single Photo Diode detection (SPD). Spectral direct detection and SPD techniques reduce the receiver complexity and it’s providing better performance compared to complementary subtraction techniques.

II. ENCODING METHODS

Optical CDMA provides different types of encoding methods depend on the selected wavelength, frequency spacing and types of optical sources used [2].

- Amplitude encoding
- Spectral encoding
- Coherent phase encoding
- Matrix coding
- Spatial coding

A. Amplitude Encoding

The amplitude encoding is very economical, as only the power of the signal is detected and phase information of the signal is not considered. Optical delay lines are used to encode the optical signals

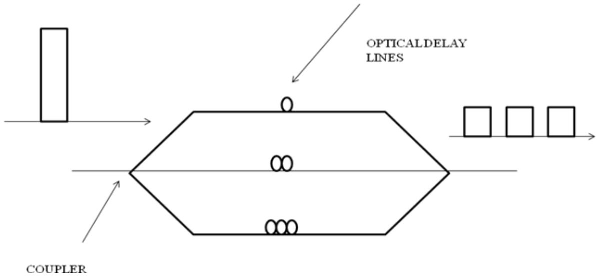

Fig 1 optical dealy line encoder

B. Spectral Encoding

Spectral encoding can use the either amplitude or phase of the spectral components in the signal to encode the information. The spectral encoding scheme uses a low-cost broadband optical source. The two types of spectral encoding are described.

- Spectral amplitude encoding
- Spectral phase encoding

C. Coherent Phase Encoding

Phase encoded optical pulses are generated using electro-optic modulators. Pulses are encoded by using tapped optical delay lines introducing different phase shifts in the different branches.

D. Matrix encoding

Arrayed waveguide gratings are used for encode and decode optical signals.

E. Spatial encoding

In spatial encoding multiple fibers are used as a space channel to encode the optical signal.

III. DECODER ARCHITECTURES

OCDMA encoding /decoding techniques also provide a high level of security for transmitted information. Using OCDMA technique high spectral efficiency is achieved; fiber bandwidth is also very effective. From the several kinds of OCDMA systems, spectra amplitude coding (SAC) scheme attracts increasing interest because multiple access interference (MAI) can be eliminated. The design of encoder and decoder modules for SAC-OCDMA system is based on Fiber Bragg Gratings (FBGs).

A. Types of Detection Techniques

OCDMA systems provides many types of detection mechanism they are,

- Direct detection
- Complementary subtraction detection
- And subtraction detection
- Single Photo Diode detection

B. Direct Detection technique

In this technique only optical spectrum of the desired components are retained and other undesirable components are removed by filtering.

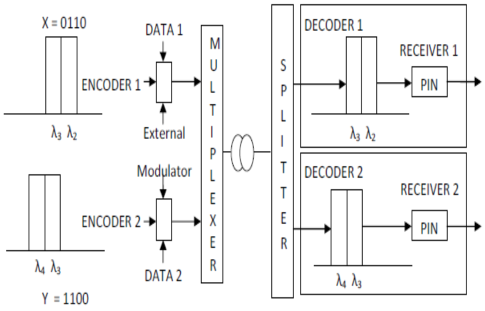

Fig 2 Direct detection technique

This technique is applicable only to those codes, in which the spectral chips are not overlapped with other spectral chips of the other channel. From Fig 2 it is clear that same frequency component being directly detected at the receiver side and hence its circuitry is very simple and less costly.

C. Complementary Subtraction detection

Complementary detection technique is also known as balance detection technique.

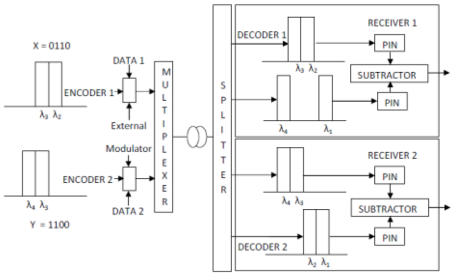

Fig 3- complementary subtraction detection technique

Transmitter of Complementary model is similar to that of direct detection. In receiver, the received signal is divided into two complementary branches of spectral chips as shown in Fig-3. These two branches of spectral signals are sent to a balanced detector that computes the correlation difference [8].

D. AND Subtraction Detection

In AND subtraction technique received optical signal is split by splitter into two parts. Received signal is divided in to two branches, both branches are AND decoder through an attenuator. The attenuator ensures that, the interference signal has an equivalent power incident on each photo detector in the case of an inactive user. The output signal is proportional to the power difference of the two optical inputs. In the presence of an interferer, the difference between the two signals is cancelled out.

E. Single Photodiode Detection

The incoming optical signal is decoded by the decoder, which has an identical spectral response to the intended encoder for the data to be received. The detected output from the decoder is either w power units (P.U.) for active user or *l* P.U. for interferers, where the weight w representing the number of occupied frequency bins in the user's encoder, and the in-phase cross-correlation *l*, which is the maximum number of common frequency bins occupied by any two codes of the family .

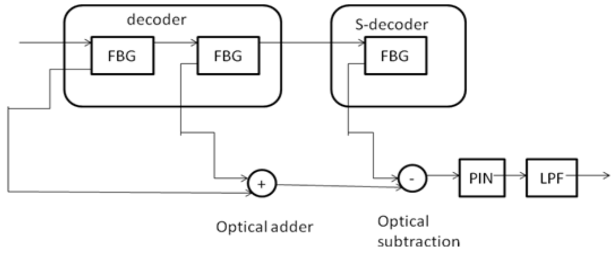

Fig 4- Single photodiode Detection

The remainder of the signal from the decoder is then transmitted to the subtractive decoder (s-Decoder) to cancel out signals with mismatched signatures, i.e., interferers. The cancellation of the interference signals in the optical domain allows the use of only a single photodiode rather than two photodiodes as in typical subtraction detection schemes. This reduces the amount of optical-to-electrical conversion and shot noise generated at the receiver.

IV EXPERIMENTAL SETUP

This project was carried out by using simulation software, OptiSystem13. The major aspect during methodology stage is simulation process. The Encoders and decoder structures can be implemented using any type of optical filtering technology, including thin-film filters, Fiber Bragg Gratings (FBGs), or free-space diffraction gratings [6]. In this system the 200 Mb/s signal is generated and coded with suitable encoding scheme. Coded information signal is transmitted through single mode optical fiber and receiver side detection process is employed [3].

A. Direct Detection Technique

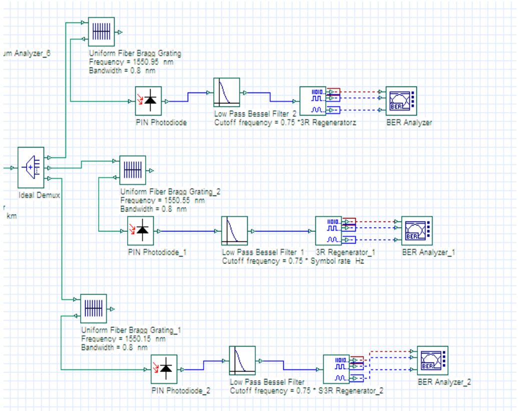

Fig 5 Direct detection technique

The role of the optical transmitter is to convert the electrical signal into optical form, and provide the pseudo random code for each user. The optical transmitter consists of the following components, sequence generator, laser source and modulator. The coded optical signal is transmitted to the receiver via single mode optical fiber. Receiver applies a correct key code to detect the signal directly using FBG's and low pass filter.

B. Complementary Subtraction technique

The role of the optical transmitter is to convert the electrical signal into optical form, and provide the pseudo random code for each user. The optical transmitter consists of the following components, sequence generator, laser source and modulator. The coded optical signal is transmitted to the receiver via single mode optical fiber.

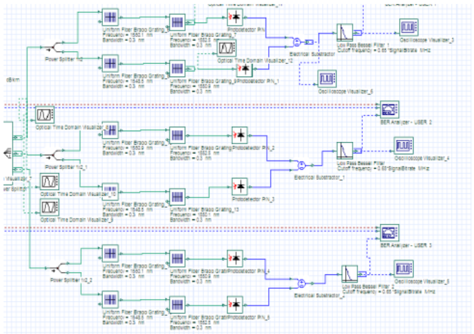

Fig 6 complementary subtraction detection

In complementary subtraction technique the each received channel is split into two branches. Both upper and lower branches are performing the detection operation separately and output of the each branch is subtracted by electrical subtraction. Multiple access interference in the receiver is partially removed in this process.

C. AND Subtraction Technique

In AND subtraction method, the optical transmitter is to convert the electrical signal into optical form, and provide the pseudo random code for each user. The optical transmitter consists of the following components, sequence generator, laser source and modulator. The coded optical signal is transmitted to the receiver via single mode optical fiber. In AND subtraction technique the each received channel is split into two branches similar to the complementary subtraction technique. Both upper and lower branches are performing the AND operation separately and output of the each branch is subtracted by electrical subtraction. Multiple access interference in the receiver is partially removed in this process.

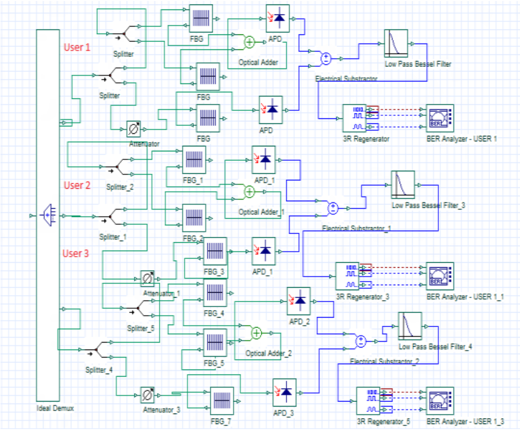

Fig 7 AND Subtraction detection

D. Single Photodiode Detection

The incoming signal is decoded using the same spectral response of the encoder for. The decoder detects *w* power units (P.U.) for active user or ƛ P.U. for mismatched signals, where the weight *w* represents the number of occupied frequencies in the user's encoder, and the in-phase cross-correlation is ƛ the maximum number of common frequency signals occupied by any two codes of the family . The remainder of the signal from the decoder is then transmitted to the subtractive decoder (s-Decoder) to cancel out signals with mismatched signatures. The s-Decoder contains only frequency bins from different interferers. After optical subtraction, the output from the subtractive decoder is either zero P.U. for active user or ƛ P.U. for interferers. This technique can be performed using low cost uniform FBGs to decode the received signal. The interference signals are cancelled in the optical domain before the conversion of the signals to the electrical domain and this rejects both PIIN and MAI in the optical domain.

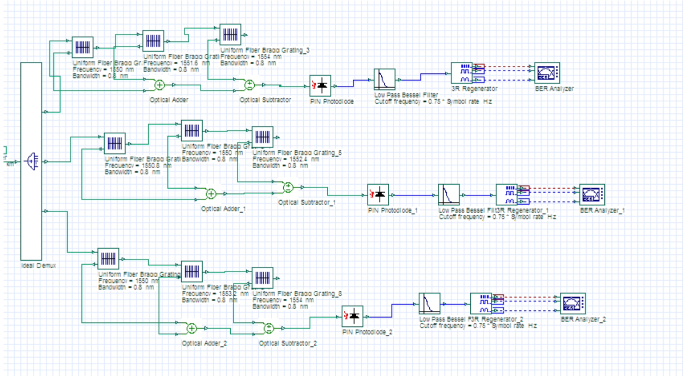

Fig 8 Single photodiode detection

V RESULTS AND DISCUSSION

In our experiment, transmission of three and seven channels at 200 Mb/s is done and it is necessary to consider the effects: Q-factor, BER value, length of the fiber, bit rate.

A. Q Factor for 3 user Direct Detection method

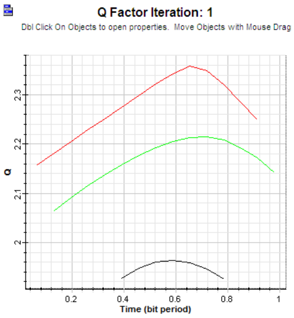

Fig 9 Q-factor for Direct detection technique

USER	Q-FACTOR
User1	**4.53491**
User2	**5.48406**
User3	**5.02224**

Table 1 Q-factor for 3 user Direct Detection method

B. Q factor for 3 user Complementary subtraction method

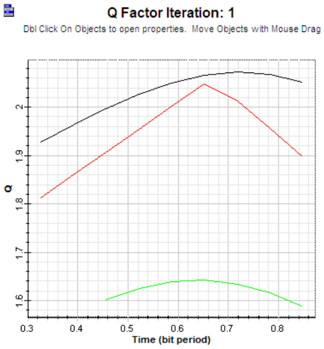

Fig 10 Q-factor for complementary subtraction method

USER	Q-FACTOR
User1	**4.4283**
User2	**4.3212**
User3	**5.0043**

Table 2 Q-factor for 3 user Complementary Subtraction method

C. Q factor for 7 user single photodiode Detection

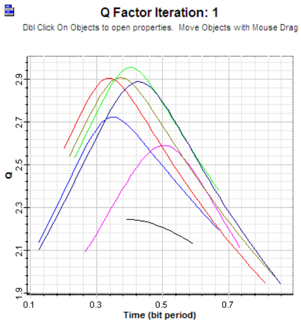

Fig 11 Q-factor for single photodiode detection

USER	Q-FACTOR
User1	**3.98856**
User2	**4.58964**
User3	**4.90868**
User4	**5.72376**
User5	**5.95559**
User6	**5.90545**
User7	**5.74346**

Table 3 Q-factor for Single Photodiode method

The fiber length increases causes dispersion of the fiber is also increases, so BER also increases with the fiber length. Single photodiode detection scheme shows the best performance compared to other methods. On performance basis we can arrange these configurations in the following order:

Single photodiode>direct>complementary>AND subtraction

When bit rate increases pulse width decreases, pulse become more sensitive to the dispersion.

Single photodiode>direct>complementary>AND subtraction

VI CONCLUSION

Thus a comprehensive study of detection of optical Code division multiple access system using different detection methods are designed. Using the Fiber Bragg Gratings (FBG) and filters, it was possible to achieve long transmission distance with more number of channels occupying the desired spectrum bandwidth. To enhance the system, it is necessary to redesign the encoding/decoding methods to increase the number of transmitted channels. Work is under way to improve the Q-factor of the design to eliminate the multiple access interference (MAI) and phase induced intensity noise (PIIN).

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