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Performance analysis and improvement of spectrally amplitude encoded/decoded OCDMA system

Himanshu Monga*, R.S. Kaler

Department of Electronics and Communication Engg., Thapar University, Patiala (Punjab), India

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ABSTRACT

In this paper we have studied and analyzed the spectrally encoding/ decoding OCDMA system for different lengths of fiber in terms of quality factor (Q) and bit error rate (BER) performance. The performance characteristics like bit error rate, eye diagrams and eye closure penalty at the output are studied by simulating for different lengths of fiber. An upper bound on the bit error probability for phase encoded OCDMA system is maintained under the above considerations. The effect of both dark current and thermal noises is neglected. The advantages of this system over the conventional time-encoded system include the availability of larger number of low cross correlation sequences and the implementation of efficient decoders for low error probability detection.

It has been observed that there are two major problems giving rise to performance degradation of the system in terms of no of users and type of code. In optical CDMA, multiple access interference (MAI) is dominant factor compared to photo detector shot noise, dark current and thermal noise that limits number of user as well as data rate of the system.

1. Introduction

Optical code-division multiple-access (O-CDMA) is an attractive technology since it potentially provides flexible, robust, and asynchronous communications in access networks. CDMA schemes are categorized as implementing the code through the optical field and relying on coherent detection, or through time slots and wavelengths with reliance on incoherent detection. Coherent schemes are susceptible to coherent beat noise that occurs when the correctly decoded signal temporally overlaps with the multiple access interference (MAI) from other users [1]. So recent implementations of coherent O-CDMA resort to timing coordination between users, ranging from complete bit-level synchronization [2] to time slot assignment within the bit [3]. Another approach uses very long spreading codes to minimize the amplitude of the MAI while keeping users asynchronous; however, only 10 of 512 possible codes deliver adequate bit-error-rate performance (BER < 10^{-9}) [4]. Incoherent schemes are less susceptible to coherent interference [5], but due to time slot allocation, are difficult to implement and less spectrally efficient with increasing data rates and time slots.

A single mode fiber is used for high-bit-rate transmission in low-loss-transmission windows but dispersion is an important impairment that degrades overall system performance of an optical communication system [6].

The major limitation in transmission medium is group velocity dispersion (GVD) and non-linearities due to optical Kerr effect and their distribution over propagation direction, which degrades the system performance. Hence it is of utmost importance to compensate for the pulse spreading due to GVD and non-linearity [7].

In optical communication system, each source which generates the digital data is encoded with optical/electronic encoder then in the form of optical pulses transmitted through optical channel, and then at the receiver side transmitted data is recovered with the help of decoder. Fig. 1 shows a block diagram of General Optical Communication System with an Encoder and Decoder. The messages are first encoded by optical encoder and then transmitted via channel. At the receiver side received message is first decoded in the decoder and then the original messages are recovered.

In a code division multiplex access (CDMA) system all nodes are allowed to transmit simultaneously, occupying the same wavelength band. Separation of the communication links is done by encoding each bit with the help of a spreading code. By assigning a unique spreading code approximately orthogonal to all other codes, multiple communication links with low interference can be realized at the expense of enlarging the transmit bandwidth. Recently, interest increased on implementations often called “optical (O-) CDMA” or “fiber-optic (FO-) CDMA”. CDMA provides random, asynchronous communication, free of network control. It neither requires synchronized clocks like TDMA, nor narrow optical filters and wavelength stabilized lasers like WDMA. If coding and decoding is done in the electrical domain, the network is flexible

* Corresponding author.
E-mail address: himanshumonga@gmail.com (H. Monga).

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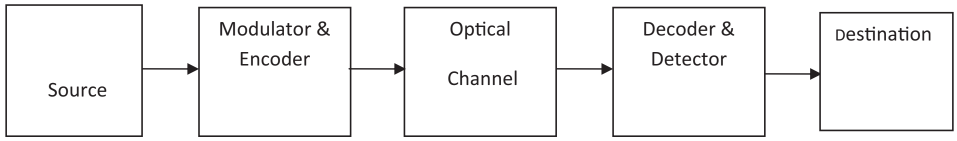

Fig. 1. General optical fiber communication system.

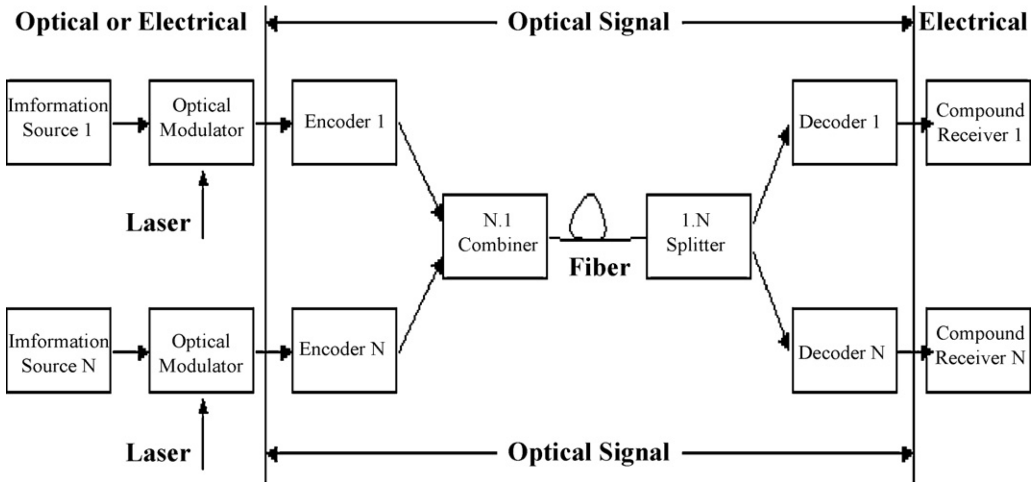

Fig. 2. Block diagram of optical CDMA network.

and easily re-configurable. Fig. 2 shows a block diagram of typical optical CDMA network employing the same.

Direct detection optical CDMA systems have been investigated widely to apply for high speed LAN, because they allow multiple users to access network simultaneously. In an O-CDMA system, each bit is divided up into n time periods, called chips. By sending a short optical pulse during some chip intervals, which represents 1, and no pulse, which represents 0, an optical signature sequence, or codeword, can be created. Each user on the O-CDMA system has been assigned a unique signature sequence. The encoder of each transmitter transmits one signature sequence for each bit 1; however, a binary 0 bit is not encoded and is represented using an all-zero sequence. Since each data bit is represented by high rate signature sequence, the bandwidth of the data stream is increased. Therefore O-CDMA is a spread-spectrum technology. The O-CDMA encoded data is then sent to the N.1 combiner-fiber-1.N splitter (in a local area network) or a 1.N coupler (in an access network) and broadcast to all nodes [7].

Erbium doped fiber amplifier (EDFA) used in the proposed setup can be extensively used in optical fiber communication systems

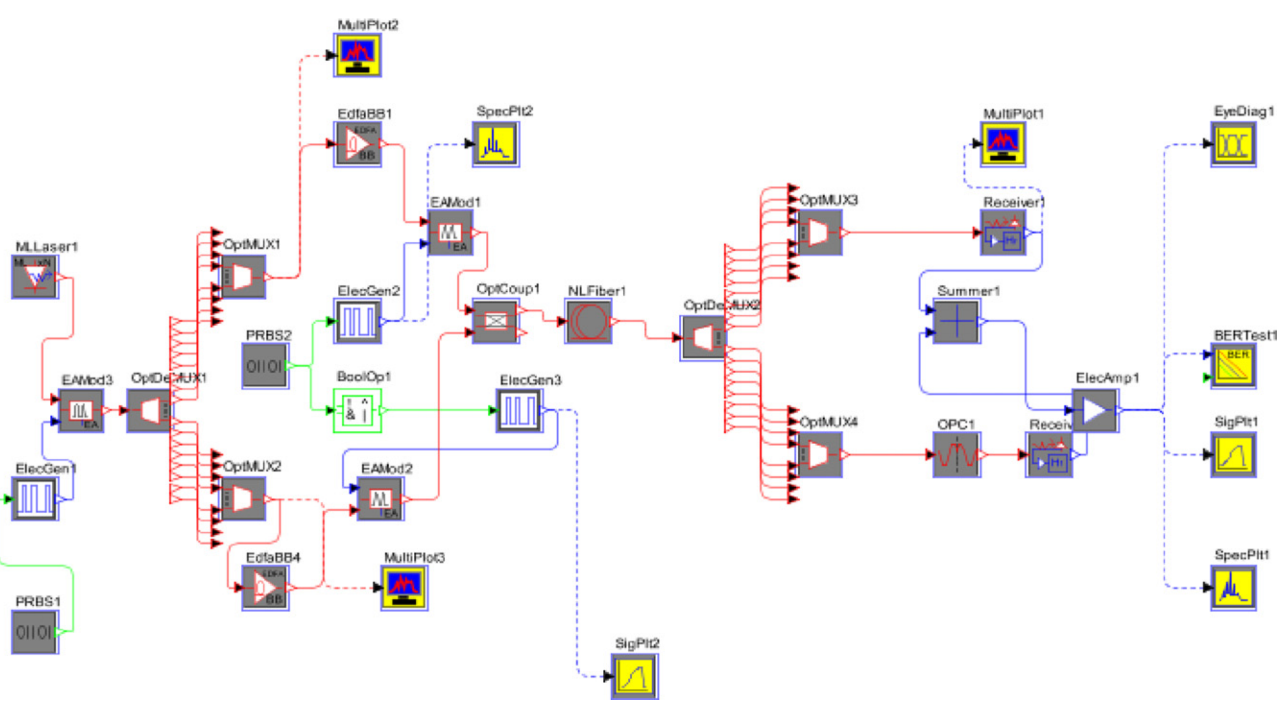

Fig. 3. Simulation setup of OCDMA system based on spectral encoding.