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Performance analysis of a 16-user 2.5 gigabit optical-CDMA using wavelength/time codes

Himanshu Monga*, R.S. Kaler

Department of Electronics and Communication Engineering, Thapar University, Patiala, Punjab, India

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ABSTRACT

This paper describes a performance analysis of an incoherent optical code-division multiple-access scheme based on wavelength/time (W/T) codes. The system supports 16 users operating at 2.5Gb/s/user while maintaining bit-error rate (BER) < 10^{-11} for the correctly decoded signal. It has been observed that there are two major problems giving rise to performance degradation of the system in terms of number of users and type of code.

In this paper we have studied the optical simulator Encoding/Decoding for different lengths & gain in terms of Quality factor (Q) and Bit Error Rate (BER) performance. The system supports 16 users while maintaining bit-error rate (BER) < 10^{-11} for the correctly decoded signal. Our aim is to design and simulate a Tree Network Topology Optical Code Division Multiple Access System for large number of users using wavelength–time code and to analyze the performance of the system based on BER and Eye Diagram under the influence of number of simultaneous users with different received powers.

1. Introduction

Optical communication systems are a main part of the digital communications in long haul networks, high speed LAN and MAN. The main advantages of the optical fiber communications are the high speed, large capacity and high reliability by the use of the broad bandwidth of the optical fiber. The sharing of spectrum is required to achieve high capacity by simultaneously allocating the available bandwidth to multiple users [1].

The major synchronous multiple access protocols are Time Division Multiple Access (TDMA), Wavelength Division Multiple Access (WDMA) and Code Division Multiple Access (CDMA). TDMA is an efficient multiple access protocol in networks with heavy traffic demands, but in situations where the channel is sparsely used, TDMA is inefficient. WDMA can be used as a degree of design freedom with respect to routing and wavelength selection. But the fundamental disadvantage in WDMA is that sophisticated hardware such as wavelength-controlled tunable lasers and high quality narrowband tunable filters for each channel is required. CDMA was originally investigated in the context of radio frequency communications systems, and was first applied to the optical domain in the mid-1980s. Using optical fiber together with semiconductor laser transmitter has made it possible to transmit high bit rate data signals with low attenuation [1,2].

Optical Code Division Multiple Access (OCDMA) combines the large bandwidth of the fiber medium with the flexibility of the CDMA technique to achieve high-speed connectivity. It allows multiple users to access the network asynchronously, ability to support variable bit rate and bursty traffic, privacy and security in transmission, and scalability of the network. In Optical CDMA systems, every channel is identified by a unique pseudo noise key (signature sequence codes), whose bandwidth is much larger than that of the input data [3,4].

The Optical CDMA offers an interesting alternative for ultra high-speed LANs because neither time management nor frequency management of all the nodes is necessary. Optical CDMA can operate asynchronously without centralized control and does not suffer from packet collisions [5].

In OCDMA, every user channel is identified by a unique signature sequence code, so multiplexing gains can be high. In contrast to TDMA and WDMA where the maximum transmission capacity is determined by the total number of time/wavelength slots (i.e. hard-limited), OCDMA allows flexible network design because the bit error rate (BER) depends on the number of active users (i.e. soft-limited) [2]. In order to realize the high data rates over long distances down the SM fiber, techniques must be found to overcome the pulse spreading and reduce power penalty due to dispersion [7]. The invention of erbium-doped fiber amplifier (EDFA) paved the way for development of high bit rate, all optical ultra long distance which illuminated the need for electronic repeaters [9].

Nonlinear effects along with dispersion are the destructive forces for pulse propagation in ultra high-bit-rate optical trans-

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

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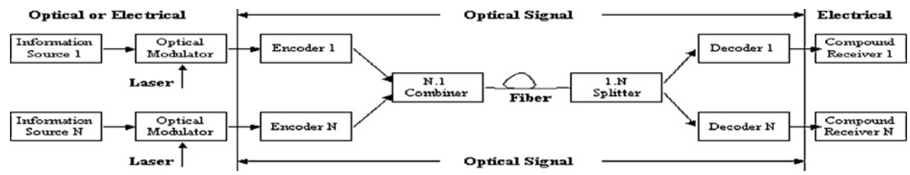

Fig. 1. A schematic diagram of an OCDMA communication system.

mission system, which is needed to be taken in to account [11]. A general Block diagram of optical CDMA multi-user system is shown in Fig. 1.

One of the basic properties of the optical fiber is its enormous low-loss bandwidth of several tens of terahertz [10].

The primary task of the receiver or decoder in an OCDMA network is to recover the signal in the presence of other interfering signals.

Hence the codes suitable for OCDMA systems should have the following properties [6]:

1. A code should be distinguishable from a shifted version of itself.
2. A code should be distinguishable from a possibly shifted version of all other codes in the set.

In OCDMA each user on the OCDMA system has been assigned a unique signature sequence. The OCDMA 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 [8].

Mendez et al. [12] showed rigorously that 2-D W/T codes have better SE than 1-D CDMA/WDM combinations (of the same cardinality). Then, the paper describes a specific set of W/T codes and their implementation. This research shows that OCDMA implementation complexity (e.g., incorporating double hard-limiting and interference estimation) can be avoided by using a guard time in the codes and an optical hard limiter in the receiver.

Shivaleela et al. [13] described the basic principles of a new family of wavelength/time multiple-pulses-per-row (W/T MPR) codes, for incoherent FO-CDMA networks, which have good cardinality, spectral efficiency, and minimal cross correlation values. In addition, an expression for the upper bound on the cardinality of W/T MPR codes is derived. Another feature of the W/T MPR codes is that the aspect ratio can be varied by a tradeoff between wavelength and temporal lengths.

Hernandez et al. [14] developed an optical code division multiple access (OCDMA) technology demonstrator (TD) based on 2-D codes. The 2-D codes are derived from folded optimum Golomb rulers, implemented as W/T ë/T codes. With the TD, They demonstrated six asynchronous users at less than 10^{-11} bit error rate (BER) and up to eight users at 10–8 BER, limited by saturation in the optical preamplifier.

Hernandez et al. [15] discussed a technology demonstrator for an incoherent optical code-division multiple-access scheme based on W/T codes. The system supports 16 users operating at 1.25Gsymbols/s/user while maintaining bit-error rate (BER) < 10^{-11} for the correctly decoded signal. Experiments support previous simulations, which show that coherent beat noise, occurring between the signal and multiple access interference (MAI), ultimately limits system performance.

Mendez et al. [16] described the design and construction of the matrices; analyzed their performance from a communications viewpoint; described their use as codes for the asynchronous, concurrent communication of multiple users; and analyzed the bit error rate performance based on capturing and modeling a typical network topology and performing a numerical modeling of the system. The matrices can be interpreted (implemented)

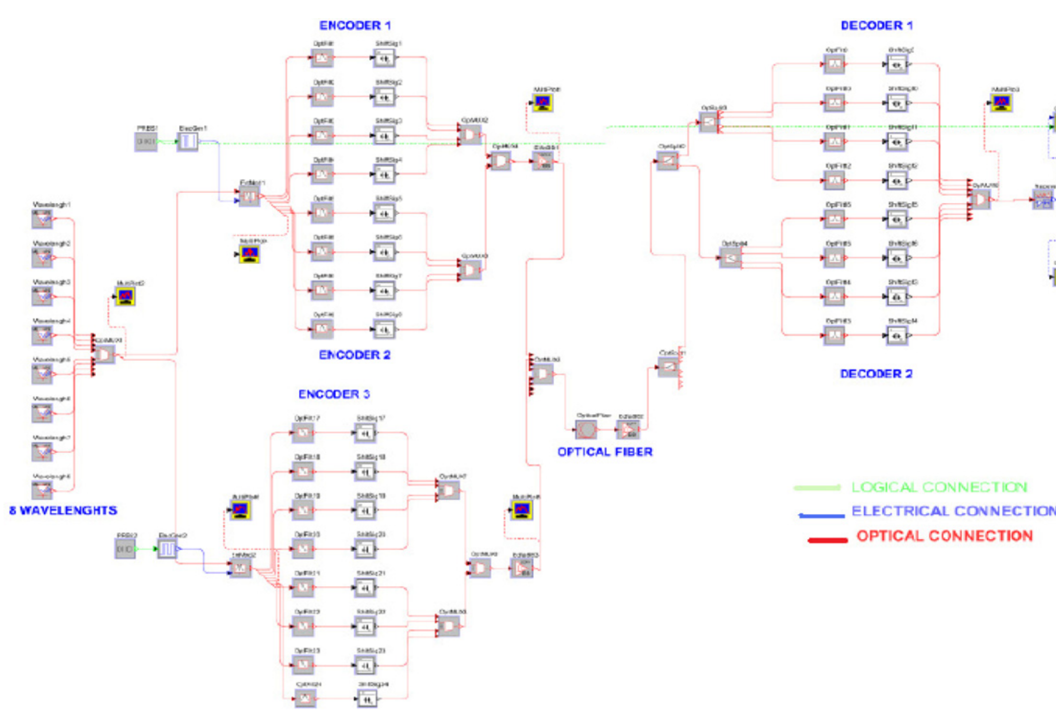

Fig. 2. Simulation setup of OCDMA system.