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Design and Study of Optical CDMA system

Saikat Saha[1], Sugumaran. S[2]

[1,2]SENSE Department, VIT University, Vellore-632014, Tamil Nadu, India

Abstract

In this paper an Optical CDMA system has been designed using Spectral Encoding and Decoding schemes. This technique helps to overcome Multiple Access Interference and moreover it is Bandwidth efficient. Fiber Bragg grating is used for encoding and decoding. The simulation set up has been implemented in OptiSystem 7.0 to investigate different characteristics of OCDMA network.

Key Words: *Optical CDMA, Fiber Bragg grating, Spectral Encoding,*

Introduction

OCDMA

Driven by the rapid increasing demands of communication bandwidth, in both wireless radio and fiber-optic networks multiplexing is essential. Recently, optical code-division multiple-access (O-CDMA), adapted from spread spectrum techniques, has emerged as a promising alternative scheme to time-division multiplexing (TDM) and wavelength division multiplexing (WDM) technologies [1],[2]. With enhanced information security Code-based network access has the potential to simplify the network control and management. The efficient multiple-access protocol also allows many users to access the fiber channel asynchronously and simultaneously without delay and scheduling. However, this scheme is eventually noise-limited due to multiple-access interference (MAI) from correlation between different user codes. MAI results in the encoded signals overlapping and corrupting each other, and thus introduces bit errors that degrade the system performance. Early O-CDMA networks were developed based upon code sequences of incoherent pulses and intensity modulation [3]. The signals were therefore unipolar with no negative components due to the incoherent nature of the system. Each user had a unique spreading sequence: coded transmission was sent to represent data bit “1” and null was used for a “0” bit. Nevertheless, the signature codes used, i.e. optical orthogonal codes (OOCs), generally had much poorer correlation properties than their bipolar counterparts, and their availability was severely restricted [4]. Later coherent systems often relied on phase coding of the optical signal field and coherent detection. Bipolar signaling was used in the form of ‘+1’ or ‘-1’, which could be obtained by manipulating the polarization or phase of the optical coherent carrier signal [5]. The established code sets are utilized in radio frequency (RF) implementations could be used directly in coherent O-CDMA since conventional spread-spectrum systems were developed with coherent reception. However, complex realizations are required due to the need to provide adequate optical phase control and polarization.

SPECTRAL AMPLITUDE ENCODING

Alternative O-CDMA schemes employing the spectral-amplitude coding (SAC) of broadband sources are now receiving more attention since they permit the elimination of MAI and can be simply constructed without using any sampling techniques or aliasing cancellation [4]-[6]. In such systems, data are encoded directly in the spectral domain, modulating the broadband optical signal. Since the coding is performed in the spectral domain and does not rely on direct-sequence encoding, the spreading gain is independent of the bit rate. Thus, spectral-amplitude coding has extreme promise for service differentiation in future access networks, where users with different bit rates and quality of service (QoS) are accommodated simultaneously [2], [7].

Figure 1 shows the ideal spectral-amplitude O-CDMA system [5], [6]. For each data bit, a broadband optical pulse with spectral distribution A(ν), with a shape formed from a sequence of spectral pulses arranged according to the unipolar code used,is launched into the spectral encoder when the data bit is “1” and no pulse is launched when it is “0”. The encoded optical pulses from all users are combined at a star coupler and transmitted over the optical fibre link. At the desired receiver, the superimposed signal is divided by a 1:α splitter and then decoded by two decoders with complementary decoding functions. Note that the notation Ā(ν) indicates the pulse pattern with the complementary spectral distribution of A(ν). The original data can be recovered by using subsequent balanced detection.

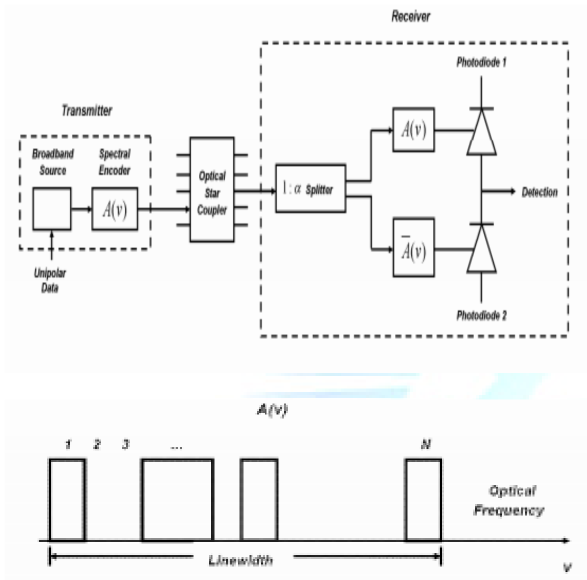

Figure 1. Ideal optical spectral-amplitude CDMA system.

Simulation Set Up:

The design has been simulated using OptiSystem 7.0 which is widely used for optical communication network. Here CW laser has been used as optical source because it has longer wavelength than LED and can travel more distance. PRBS generator and Pulse generator work together as data source. Fiber Bragg Grating(FBG) is used to encode the signal spectrally, that means the signal will be confined in a particular frequency domain. After modulation in MZ modulator multiple signals are mixed through a MUX. ITU-T G.652 standard single-mode optical fiber without any amplifier is employed for a point to point optical transmission link. Each chip has a spectral width of 0.4nm. In the receiver part FBG is again used to decode the signal. Then it is fed to PIN photodiode to convert optical signal to electrical. The nonlinear effects were activated according to the typical industry values to simulate the real environment as close as possible. Table -2 shows the parameter values used for the simulation of the OCDMA system.

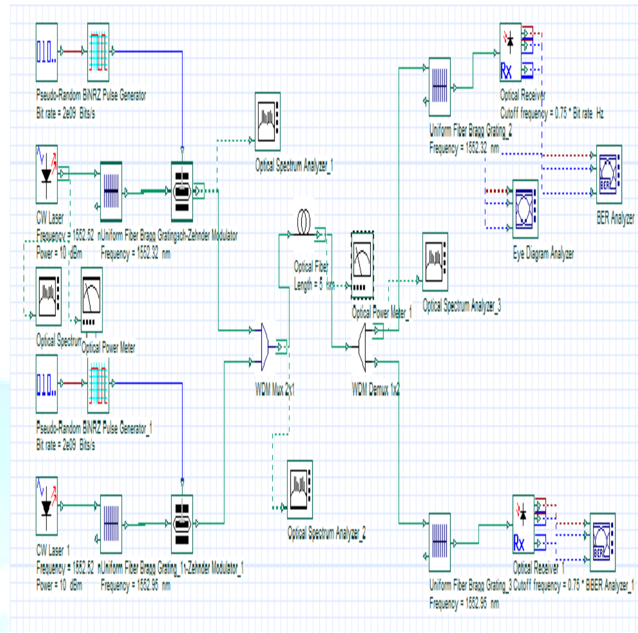

Fig.2 OCDMA Set Up.

Table1. Simulation Parameter

Parameter	Value (Transmitter)	Value (Receiver)
Length of fiber	0 to 100 Km	
Broad Band source power	10dbm	
Bit rate	155 to 25000 Mbps	
Wavelength	1550nm	
Chromatic Dispersion coefficient	18ps/nm-km	3.5ps/nm-km
Dark current	5 nA	
Polarization Mode dispersion coefficient	0.07ps/km	

Result and Discussion

The performance and Characteristics are checked on the basis of output Spectrum, BER, bit rate, transmission length and received power. Fig.3 shows the output spectrum for two user OCDMA network at different bit rates. The Bandwidth is increasing and spectrum gets a little distorted as bit rate increases due to increase in dispersion and attenuation.

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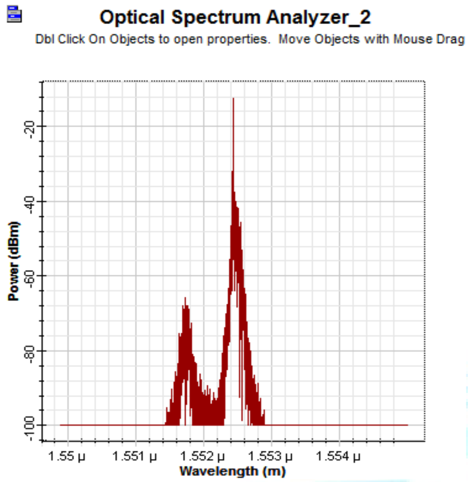
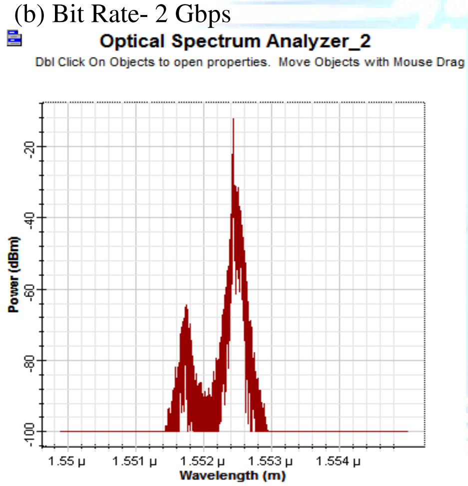
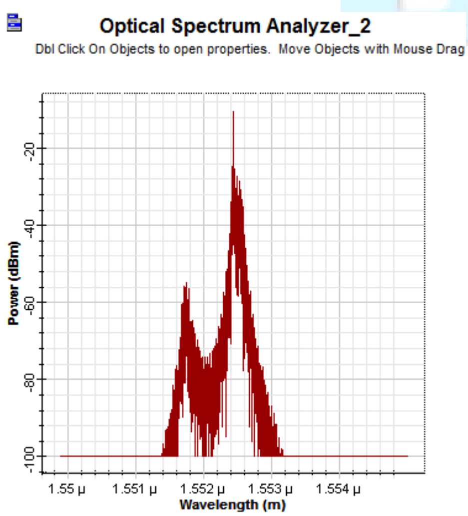
(a) Bit Rate- 1Gbps



(b) Bit Rate- 2 Gbps



(c) Bit Rate- 5 Gbps



(d) Bit Rate- 10 Gbps

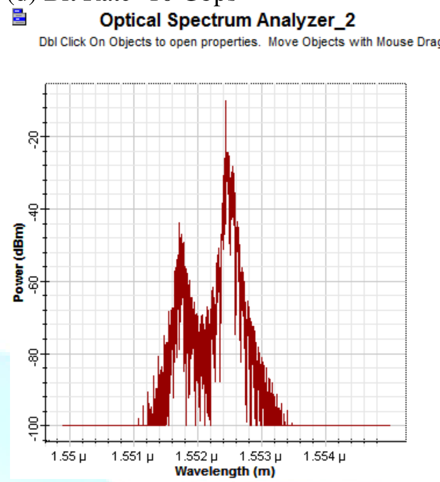


Fig.3 Output Spectrum at Different Data Rate.

In Fig.4 The graph shows that an increase in fiber length causes increment in dispersion of the input signal, so BER also increases with distance.

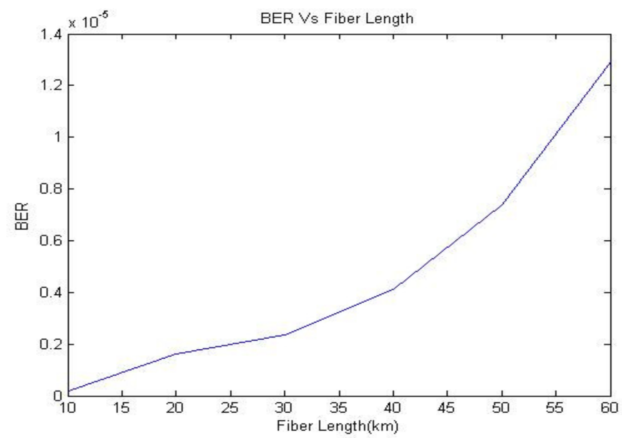


Fig. 4 BER Vs Fiber Length(km)

Fig.5 shows effect of Bit rate on Received power, for this purpose bit rate is varied from 0.2 to 2 Gb/s and other parameter like source power (10dbm) and Fiber length (10km) are kept constant. This graph shows that when bit rate increases pulse width decreases, pulse become more sensitive to the dispersion, dispersion losses increases results in the loss of power so received power decreases.

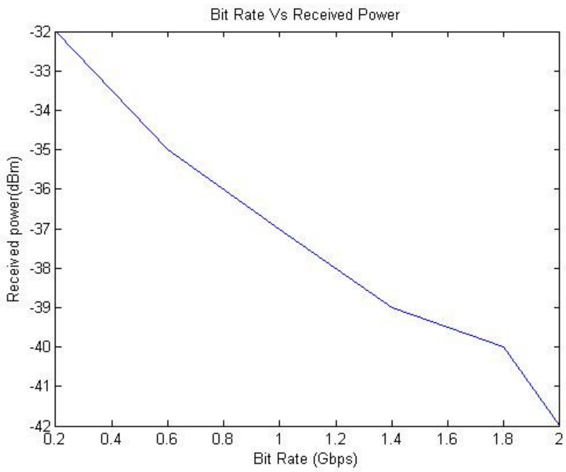


Fig. 5 Received Power Vs Bit Rate

Fig.6 shows the effect of bit rate on BER, for this purpose bit rate varied from 0.2 to 2 Gb/s and other parameter like source power (10dbm) and Fiber length (10km) kept constant. This graph shows that when bit rate increases then BER of the system increase.

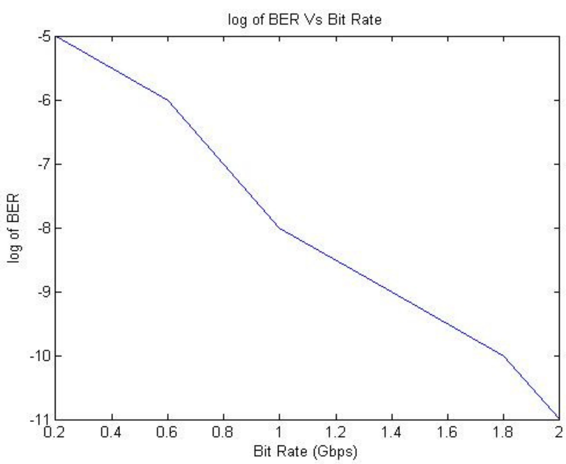


Fig.6 log of BER Vs Bit Rate.

A clear eye diagram can also be observed at receiver as shown in Fig.7. The results imply that unwanted noise has not much effect on this proposed model as it gives good eye diagram.

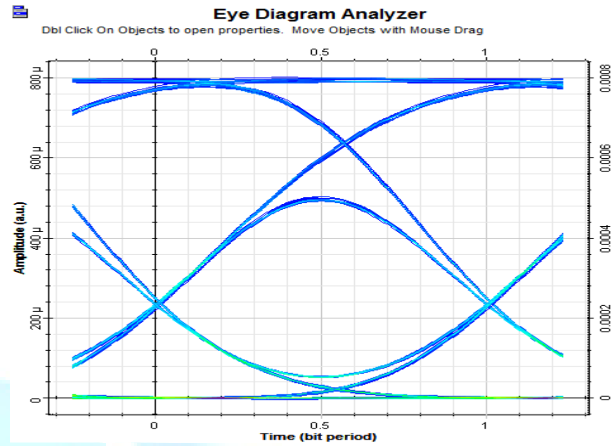


Fig.7 Eye Diagram at the Receiver

Conclusion:

Performance of the OCDMA system decreases as the bit rate increases. This is due to effect of attenuation and dispersion in the fiber. Here FBG is used for spectrally encoding and decoding the system. BER value lies in the order of 10^{-7}-10^{-6} which shows that the design is very much efficient.

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