Implementation of Spectral Amplitude Coding OCDMA System Based on Multi-Carrier Optical Signal

Jehanzeb Khan[1], Yousaf Khan[1], Faizullah Khan[2], Waqas A. Imtiaz[1]

[1]Department of Electrical Engineering, Iqra National University Peshawar, Pakistan, [2]Department of Telecommunication Engineering, Balochistan University of Information Technology Engineering and Management Sciences Quetta, Pakistan

Abstract

Incoherent SAC-OCDMA systems are designed to support low cost passive optical networks. However, incoherent nature of these systems limits their capability to support large amount of data. It is therefore necessary to utilize coherent optical sources like laser diode to provide high capacity in terms of data and the number of subscribers. Use of a single laser source in SAC-OCDMA system significantly increases the cost, which reduce its feasibility for deployment at the access domain. This paper proposes a novel technique for the implementation of SAC-OCDMA system using multi carrier laser. This technique can reduce the cost of SAC-OCDMA system by using a single laser for multiple subscribers in the system. Simulation analysis of the proposed SAC-OCDMA system while using random diagonal codes shows that it can support up to 12 Gbps of data at fiber lengths of 25 km.

Keywords: Spectral Amplitude Coding; Optical Code Division Multiple Access; Multi carrier source; Passive Optical Access Networks

Corresponding author email: *yousafkhalil@gmail.com*

INTRODUCTION

Optical code division multiple access (OCDMA) technology is an efficient technique that allow each subscriber to access the medium simultaneously without any contention (Yin et al., 2008). It is therefore anticipated to resolve the last mile bottleneck between high-speed core networks and Passive Optical Network (PON) at the access domain. Spectral amplitude coding (SAC) family has gained significant attention among OCDMA techniques, owing to its significant advantages like, efficient correlation properties, flexibility of implementation, mitigation of multiple access interference (MAI) and associated phase induced intensity noise (PIIN), support for high capacity in terms of data, reach and the number of subscribers (Lam et al., 2007; Wong et al., 2012).

SAC-OCDMA systems are primarily implemented with incoherent optical source like light emitting diode (LED), which generates a flat spectrum throughout its bandwidth. It facilitates the implementation of encoders and translation of signature codes from binary to spectral representation. However, LEDs are not able to support high data rates for example 5 Gbps and above (Yin et al., 2008). Therefore, it is imperative to utilize coherent optical sources to design an efficient SAC-OCDMA system that can provide the desired performance at minimum possible cost.

Coherent sources usually require coherent encoding and decoding, which usually involve complexity and high cost of implementation. Moreover, use of single laser per chip (number of 1's in code) also elevates the price of SAC-OCDMA system. Literature review shows little work on the implementation of SAC-OCDMA systems with coherent optical sources.

This paper proposes a new technique for the implementation of SAC-OCDMA system by using multi-carrier optical sources at the transmitter. This enables the use of a single laser diode (LD) for multiple subscribes, which can significantly reduce the cost of SAC-OCDMA system. Moreover, multiplexer (MUX) based encoder is utilized at transmitter module, which facilitates the translation of signature codes from binary to spectral representation. Furthermore, direct detection is implemented at decoding arrangement, which receives the non-overlapping spectral chips only. This technique mitigates MAI and associated PIIN by providing maximum difference between the auto- and cross-correlation properties of the received signal. Moreover, utilization of minimal components helps in reducing the cost and complexity of the proposed system. Performance of the system is analyzed through simulation analysis by referring to BER and eye patterns at different data rates and length of the fiber.

MATERIALS AND METHODS

Multi-Carrier Laser

A new domain of research, the realization of a stable DWDM carrier source and its effective implementation has many challenges ahead before becoming a mature adopted industrial solution. Recently many multicarrier schemes have been investigated to generate low noise multicarrier source (Zhang et al., 2011; Chen et al., 2012). Multi-carrier generation techniques like optical frequency comb or super continuum technique, the cascaded phase modulator and intensity modulator single side band modulator with recirculation frequency shifter (RFS) and multi wavelength erbium doped fiber laser (EDFC) has been reported recently (Zhu et al., 2011; Tian et al., 2013). Similarly multicarrier based on single side band modulator with recirculation frequency shifter (RFS) was presented (Ma et al., 2009; Mirza et al., 2009). In (Zhang et al., 2011) FIR based recirculating frequency shifter (RFS) in a feedback loop for minimizing amplified spontaneous emission (ASE) noise was explored.

The schematic configuration of WDM-De-MUX based multicarrier generator is shown as in the Figure 1. For the proposed multicarrier generator, LASER source is directly connected with the phase modulator driven by RF signal, which is amplified by electrical amplifier. Modulated signal is passed through 4-channeled WDM De-MUX giving four optical signals of different wavelengths. For the 4 × 2.5 GB/s WDM De-MUX based DPSK transmitter, four peaks are separated by WDM De-MUX where each individual signal is modulated by DPSK modulator. The four generated signals are amplified by EDFA for stability after passing through WDM De-MUX, which give strong signals of good Tone to Noise Ratio (TNR) to transmit NRZ-DPSK signals through 25Km in standard single mode fiber in passive optical access network having wavelength from 1554.45nm-1554.97nm.The Generated multi-carriers signal is shown as in Figure. 2.

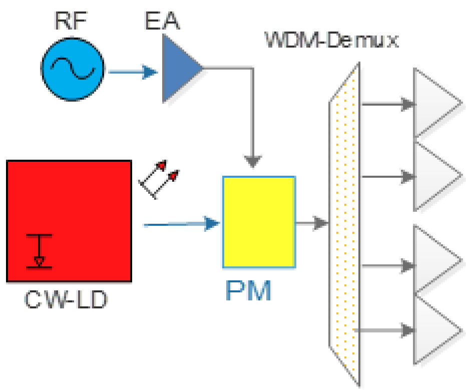

Figure 1. Propose Multi Carriers Generator

SAC-OCDMA System with Multi-Carrier Laser

The proposed SAC-OCDMA system with multi-carrier LD is shown as in Figure 3. It consists of the following components.

Random Diagonal Code (RD)

Performance of SAC-OCDMA system primarily depends on correlation properties of the coding scheme employed at the transmitter module. An efficient code must be able to provide desired capacity in terms of data and the number of subscribers through maximum auto- and minimum cross-correlation properties between same and interfering subscribers respectively. Furthermore, the coding scheme must be able to provide the required properties with large weights, minimum length, and flexibility of implementation (Zhang et al., 2011; Lin et al., 2014). This paper use RD code for implementation of the proposed multi-carrier based SAC-OCDMA system.

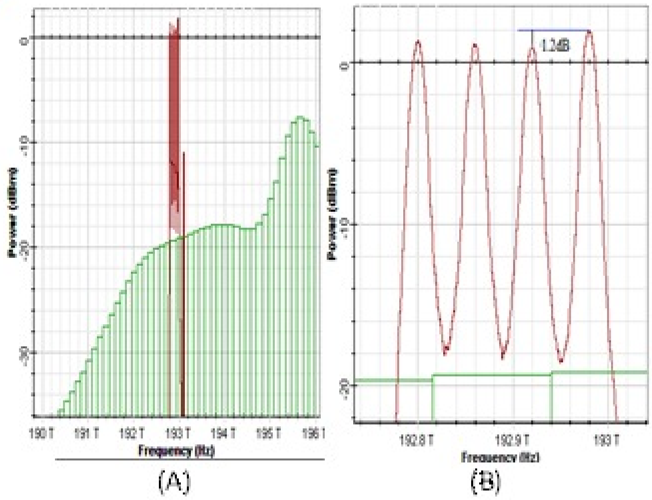

Figure 2. The Generated Multicarriers

RD code is designed with two matrices: data matrix (D_n) and code matrix (C_n). Both matrices are designed such that (D_n) posses zero cross-correlation between adjacent rows, while code matrix contains cross-correlation equal to 1 between adjacent codes. This facilitates the use of (D_n) for carrying data while (C_n) can be used to represent the code portion of the transmitted spectrum.

Moreover, efficient data and code matrix structure of RD code can be used to introduce two optical sources in the system. For example, LD can be used to represent the data chips, which will carry data, and LEDs can carry the code chips. Equation shows RD matrix for 4 subscribers.

$$RD = \begin{bmatrix} 0\ 0\ 1 \mid 0\ 1\ 1\ 0\ 1 \\ 0\ 1\ 0 \mid 1\ 1\ 0\ 1\ 0 \\ 1\ 0\ 0 \mid 1\ 0\ 1\ 0\ 1 \end{bmatrix}$$

Optical Line Terminal

Transmitter module consists of a LD, which is further divided into four spectrums through multi-carrier technique. Each carrier/spectrum can be used to represent the data chip in RD code. Code chips in RD code are represented by LEDs, as shown in Fig. 3. End-face of each optical source is connected with a 3:1 MUX, which utilize three band pass Bessel filters with 10 GHz bandwidth. Each filter is centered at a particular wavelength to transmit the chip in RD code. Figure.4 shows the output of a single encoder for RD code, where the first chip is represented by a LD, and last two chips are implemented with LED (BBS).

Output of the MUX based encoder is fed into Mach-Zehnder Modulator (MZM), which modulates the encoded spectrum with data from each subscriber. End-face of MZM modulator is fed into power combiner, which is further connected to a single mode fiber (SMF).

Optical Network Unite:

ONU consists of a single band pass Bessel filter, with bandwidth 10 GHz, which is centered to receive the non-overlapping spectral chip only. This technique is known as spectral direct detection (SDD) technique, which is shown as in Fig.5 Where a single band pass filter receives the non-overlapping spectral chip only. This help in removing MAI and associated PIIN before the signal is converted to electrical domain, since the received spectrum yields maximum difference between auto- and cross-correlation properties. Moreover, use of a single bandpass filter significantly reduce the cost of the proposed system, which makes it feasible for the common it user at the access domain.

Output of the recovery module is connected with a PIN photo-diode that converts the signal from optical to electrical domain. The signal is then passed through a low pass filter and decision-making circuit, which translates the received signal into required information.

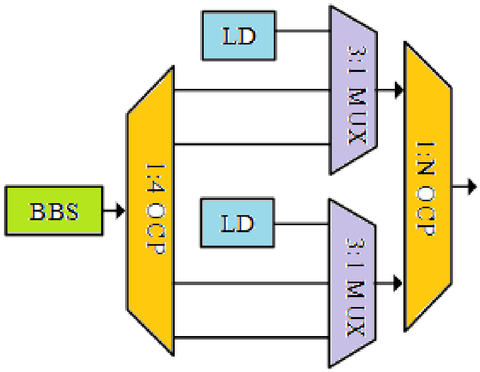

Figure 3. Proposed SAC-OCDMA system for Passive Optical Access Network

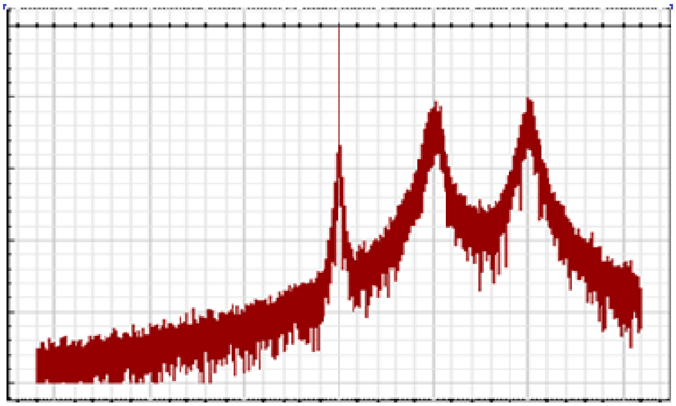

Figure 4. Multi-Carrier Generated Signal

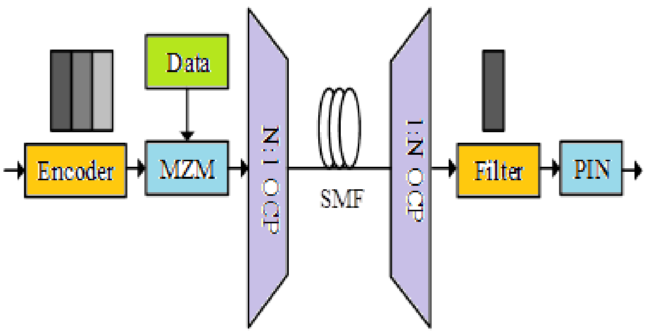

Figure 5. Proposed SAC-OCDMA System

RESULTS AND DISCUSSION

Optisys V.7.0 is used to simulate and analyze the proposed model by referring to BER and eye patterns at different data rates and fiber lengths. Single Mode Fiber (SMF) is used between the transmitter and receiver module with attenuation of 0.25 dB/km, and dispersion of 18 ps/nm/km. Furthermore, all non-linear parameters are activated to simulate and actual scenario. Simulation parameters are summarized in table.1.

Table 1: Simulation parameters and its values

Parameters	**Values**
Fiber Length	25Km
Attenuation	0.25dB/Km
Dispersion	18ps/nm/km
Wavelength	1554.45nm-1554.97nm
Data rate	4*2.5Gbps

Figure. 6 shows the BER of the proposed system by varying the amount of data at the transmitter. It is observed that BER increases as more data is transmitted across the medium. However, the proposed system is able to provide efficient performance through its efficient RD code and SDD combination that cancels the MAI and associated PIIN before the signal is converted to electrical domain.

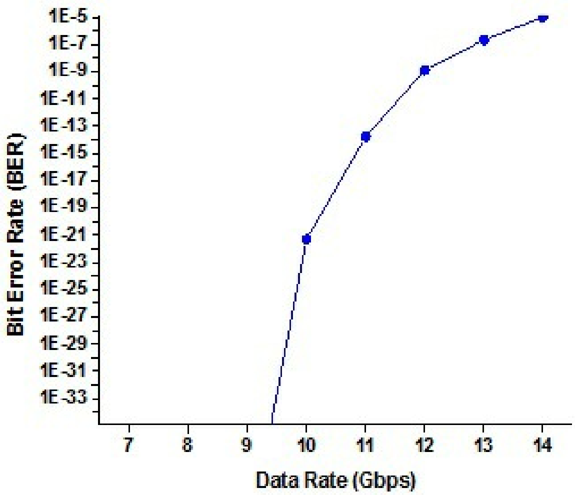

Figure 6: BER vs Data Rates

Figure 7 shows analysis of the proposed system at different fiber lengths with reference to BER. Analysis is performed for 10 Gbps of data at 4 subscribers simultaneously accessing the medium. It is observed that BER increases as the length of fiber between OLT and ONUs increase. It is evident from the fact that increase in fiber length elevates the amount of dispersion across the medium, which affect the quality of the received signal. However, it is observed that the proposed system is still able to maintain efficient performance through nominal BER readings.

Figure 8 shows that eye openings at randomly selected nodes for the proposed system. Analysis is performed at different data rates with multiple subscribers simultaneously accessing the medium. It is observed that eye opening reduces as the amount of data increases. However the proposed system is able to provide the required performance by maintaining nominal eye openings at data rates of up to 12 Gbps.

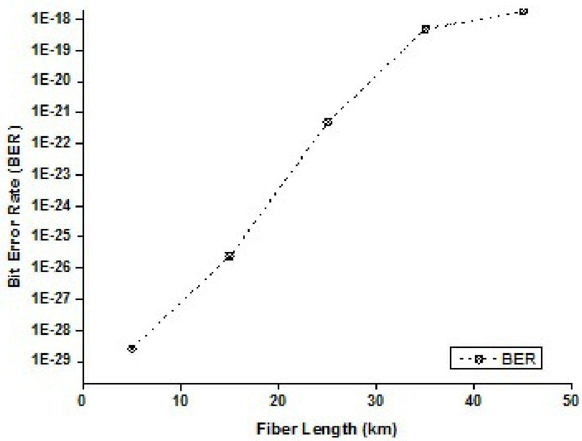

Figure 7: BER vs Fiber Length

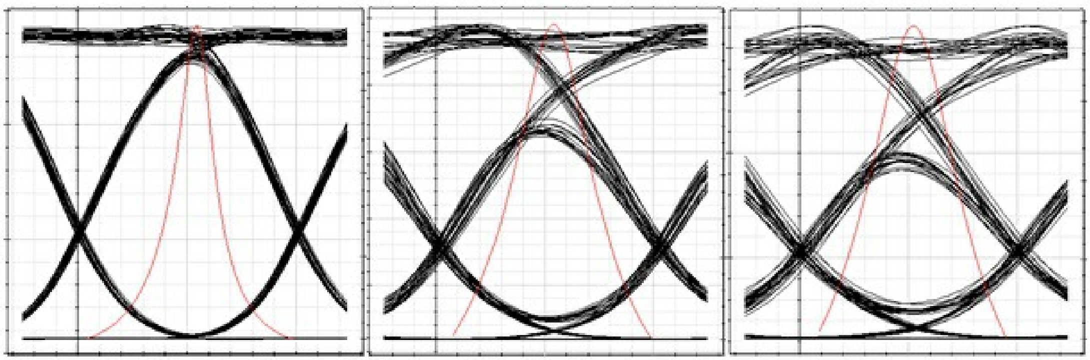

Figure 8: Eye Pattern

CONCLUSION

Use of a single laser source in SAC-OCDMA system significantly increases the cost, which reduce its feasibility for deployment at the access domain. This paper proposes a novel technique for the implementation of SAC-OCDMA system using multi carrier generated signal. This technique can reduce the cost of SAC-OCDMA system by using a single laser for multiple subscribers in the system. The proposed system is able to provide efficient performance through its efficient RD code and SDD combination that cancels the MAI and associated PIIN before the signal is converted to electrical domain. The BER and eye pattern demonstrates good transmission performance of the proposed system.

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