Analysis of OFDM WDM using Direct Detection Technique

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Abstract

This paper presents Long Reach Orthogonal frequency Division multiplexing Wavelength Division Multiplexing (OFDM-WDM) system capable of delivering downstream 40 Gbit/s data. The optical source for downstream data is CW Laser at central office. We use four OFDM transmitter at central office for the 40-Gb/s downstream transmission .We have used direct detection technique for OFDM and did analysis of OFDM WDM using direct detection technique for without compensation and with compensation. We extend the maximum reach of this WDM PON to be 96 km by using Erbium-doped fiber amplifiers at the RN. Bit error rate was measured and constellation diagram observed to demonstrate the proposed scheme. In this paper Long reach and large data service aspects of a OFDM WDM is presented. The results show that the error-free transmission can be achieved for all WDM channels with sufficient power margins.

Keywords: Wavelength division multiplexing (WDM), orthogonal frequency division multiplexing (OFDM), Erbium doped fiber amplifier (EDFA), Single mode fiber (SMF), Photo detector (PD)

1. Introduction

In order to deliver future broadband services economically, service providers have to reduce the cost in order to sustain profit margins. One possible way to achieve this is to simplify the network architecture; hence the number of equipment interfaces and network elements, e.g. electronic switches and routers, can be reduced. Extended reach (ER) access network has been proposed to achieve this [1-3]. The ER access network makes use of a high capacity, high split-ratio passive optical network (PON), with a reach of more than 100 km, to combine optical access and metro into a single system [3]. The local exchange [between the head-end office and the customer optical networking units (ONUs)] would contain a small amount of compact, low power physical layer elements, such as optical amplifiers and temperature controlled arrayed waveguide gratings for wavelength multiplexing and demultiplexing. The higher layer networking equipments would be located in a small number of head-end offices (also called centralized major service nodes). Gigabit PONs (GPONs) are now standardized and commercially available. They typically provide a split-ratio of 32 via passive optical splitters using time division multiplexing (TDM), over a reach of up to 20 km. They offer 1 to 2.5 Gb/s downstream and ~1 Gb/s upstream data rate. The proposed ER-PON usually requires four new features: (1) high data rate in both upstream and downstream directions (> 1 Gb/s); (2) reach extension to ~100 km; (3) a high split ratio (> 100); and (4) using wavelength division multiplexing (WDM). It is viable to directly use 10 Gb/s system in these ER-PONs. This would require the adoption of relatively expensive 10 GHz optical components (if on-off-keying modulation is used), such as optical modulator or semiconductor optical amplifier (SOA), in the cost sensitivity ONU. The cost of the ONU is not shared as it is, for example, the cost of optical line terminal (OLT). In this work, we

propose and demonstrate WDM ER-PONs that makes use of orthogonal frequency division multiplexing (OFDM). Due to the highly spectral efficiency of the M-quadrature amplitude modulation (QAM) in each subcarrier of the OFDM signal, low-bandwidth optical components can still be used. This means we can directly increase the data rate of the system while using the existing optical components developed for GPONs. Besides, the inherent advantage of OFDM frequency diversity transmission allows simple equalization of frequency response by baseband digital signal processing (DSP) [4]. These characteristics can be used to mitigate fiber chromatic dispersion [5, 6] which is one of the major impairments in ER-PONs).

In this work, we propose and demonstrate a long-reach orthogonal frequency division multiplexing (OFDM) wavelength-division-multiplexed (WDM) PON capable of providing 40-Gb/s service to each subscriber using direct detection technique. Thus, the 40-Gb/s downstream signal is obtained by combining the outputs of four OFDM transmitters at central office using the WDM technique.
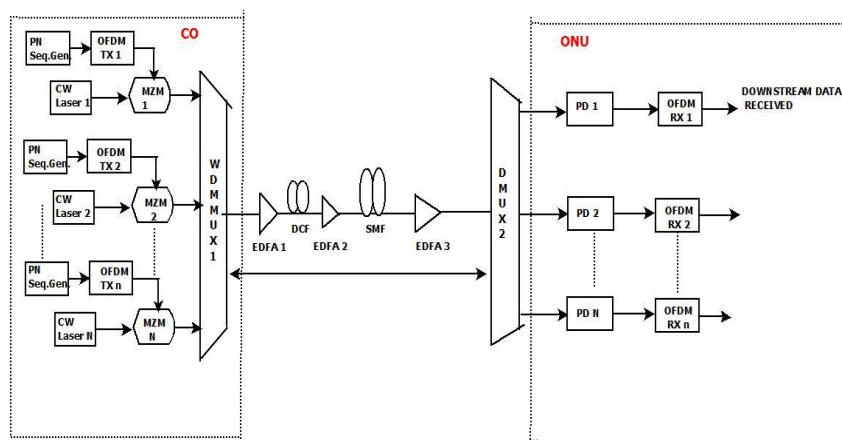

Figure 1. The Schematic Diagram of the Proposed DD-OFDM WDM

2. Operational Principle

Figure 1 shows principle of the proposed OFDM WDM. We are going to use Continuous wave (CW) laser as light source

Which generate light of difference wavelengths. At the central office, continuous wave (CW) optical signals at difference wavelength with specified peak power level are generated. In this paper, external modulation technique is used to improve the performance of communication system. The PN sequence generator generates a downstream data which consist a stream of bit sequence, At the transmitter, this downstream data is given to OFDM transmitter where the OFDM transmitter produces the electrical OFDM signal which is up converted into the optical domain by the electrical to optical (E/O) up

Converter which does intensity modulation. The downstream data is externally modulated over continuous wave optical signal using Mach- Zehnder modulator as external modulator .Downstream data which is generated using OFDM transmitter are transmitted over continuous wave optical signals and given to wavelength division multiplexing 1 (WDM 1) which is used for multiplexing of downstream signal of difference wavelengths. All these downstream signals are transmitted via EDFA 1, dispersion compensating fiber (DCF), EDFA 2, single mode fiber (SMF) and EDFA 3 .As shown in fig.1 EDFA 3 and DMUX 1 are used in Remote node. Downstream signals are transmitted via EDFA 1 to strengthen weaken signals, to make it available for long distance and then after these are transmitted via DMUX 1 which is used for a purpose of demultiplexing of downstream signal and are transmitted to Optical Network Unit (ONU).

At the receiver, the incoming optical signal is converted to the electrical domain by an optical to electrical (O/E) converter, which is in this case a photodiode. The received electrical signal is demodulated using the OFDM demodulator with similar parameters as the OFDM modulator, the guard interval is removed. After that the signal is fed into a m-QAM decoder, and the BER is calculated at the end.

3. Experimental Set – Up

This paper demonstrates a downstream data 40-Gb/s OFDM WDM with the experimental setup shown in Figure 2. For downstream transmission, PN sequence generator generates 10 Gbps. Here, we have designed OFDM WDM system [7-9] for 4 users. This generated bit sequence which is in series applied to serial to parallel converter. The parallel converted bites applied to m-QAM encoder. In this project we are taking 2 bits per symbol and generating a symbol of two bits per symbol such QAM encoder is 4-QAM. The bit stream is generated by a PRBS generator and mapped by a 4-QAM encoder These generated symbols are applied to OFDM Modulator which is inverse Fourier transform IFFT OFDM .The resulting signal is modulated by an OFDM modulator which having parameter number of subcarrier equal to 8, cylix prefix equal to 0.25 .CW Lasers which are operating at wavelength λ1 equal 1549 nm, λ2 equal to 1550 nm , λ3 equal to 1551 nm and λ4 equal to 1552 nm with input optical power equal to 0dBm. CW Lasers have line width equal to 10 MHz.
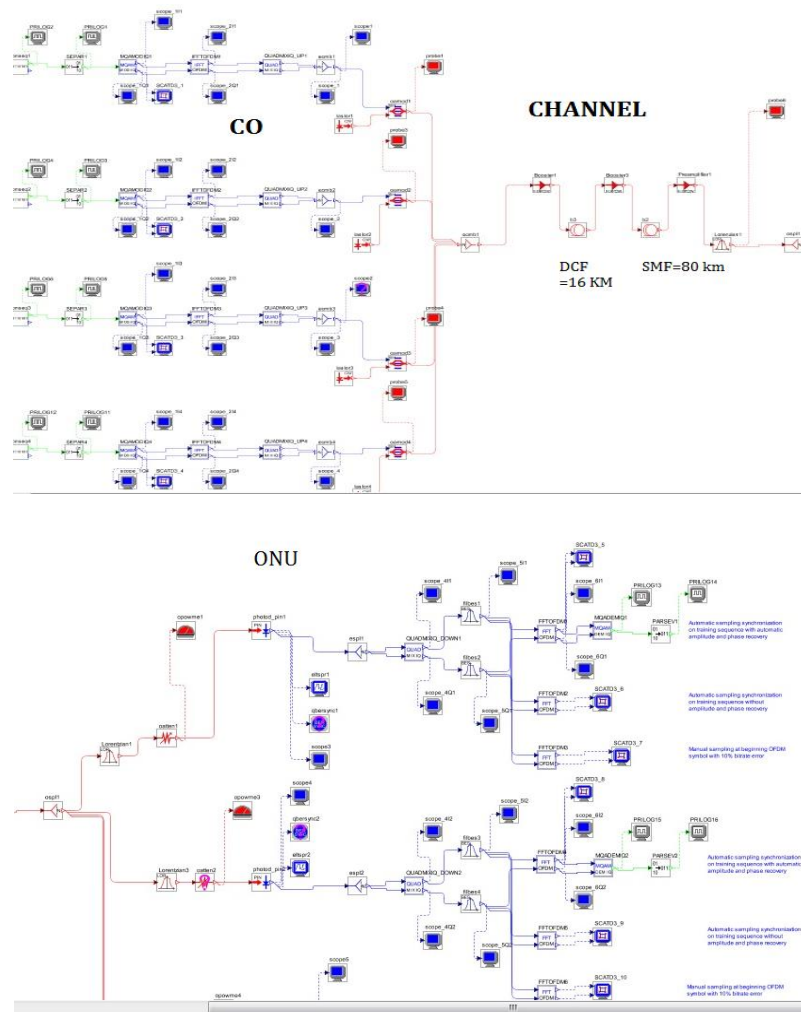

Figure 2. Experimental Set-Up for Proposed Scheme DD-OFDM

After that, the resulting electrical signal is modulated to the optical signal using a Mach-Zehnder modulators (MZM). The resulting optical signals after the four MZMs which will be multiplexed using WDM MUX 1. After multiplexing; those entire four signals (40Gbps=10Gbps*4) are transmitted via EDFA 1, EDFA 2, EDFA 3. The attenuation of SMF is balanced by optical amplifier which is EDFA. These EDFAs are having gain equal to 35 dB and noise figure equal to 10 dB. A single mode optical fiber of length 80 km is used .There are three EDFAs are used to strengthen weak downstream signal. The dispersion parameters for SMF at 1550nm are 16 ps/nm/km and 0.05938ps/nm^2/km. The loss in SMF is 0.2 dB/km.Here DCF is used in order to reduce the dispersion in SMF. The dispersion parameters for DCF at 1550nm are -80 ps/nm/km and 0.16743ps/nm^2/km. The loss in DCF is 0.6 dB/km.The length of DCF is 16 km. Further, all those four difference wavelengths signal are demultiplexed by DEMUX 1 .The demultiplexed signals , at the receiver(ONU) the incoming optical signal is converted to the electrical domain by an optical to electrical (O/E) converter, which is in this case a PIN photodiode. The parameters of PIN photodiode are quantum efficiency equal to 0.7, responsivity equal to 0.8751 A/W and dark current equal to 0.1 nA. After down converting the signal, it passes through a low-pass filter (LPF) and is transmitted to the OFDM receiver to get the original signal. The output of low pass filter is given to FFT OFDM.FFT OFDM work in opposite to IFFT OFDM, remove the guard band. The output of FFT OFDM is given to 4-QAM decoder .The output of decoder is given to parallel to serial converter and finally we can receive the transmitted data.

4. Results and Discussions

We have implemented OFDM WDM using direct detection technique as shown in figure 2.We have considered 4 user WDM system. We implemented the system using optsim version 13 software and considered three cases 1.without dispersion compensation 2.with pre compensation technique 3.with post compensation technique .80 km length SMF used for without compensation technique . It is observed that the performance of OFDM WDM for given case is worst .The implemented system is failure if we consider the first case of without compensation .We have shown the Constellation diagram of 4-QAM for without compensation technique in fig.4 .After that, We have considered the post compensation technique for given OFDM WDM system .We have observed the constellation diagram for 4 wavelength signal which is shown in fig 5.If we compare the constellation diagram for without compensation and with post compensation technique ,it is observed that constellation diagram for with post compensation technique is good one .The constellation diagram is without distortion .We have calculated the bit error rate (BER) for 4 wavelengths signal .We have changed the input optical power from 0 dBm,-5 dBm,-10dBm,-15dBm and measured the received optical power for 4 wavelengths signals and measured the respective BER for that received optical power .We observed the BER in the range of 1E-06 to 1E-08 which is good one. The measured value of input optical power, received optical power for respective wavelength, BER for respective wavelength is shown in Table 2. After post compensation technique we have implemented OFDM WDM system using pre compensation technique and tried to observe constellation diagram for 4 wavelengths signal .The constellation diagram for 4 wavelength signal of 4-QAM for with pre compensation technique is shown in figure 6.If we compare the constellation diagram for three cases without compensation ,with post compensation and with pre compensation technique ,we observed constellation diagram for pre compensation technique is good one compare to others two. We have calculated the bit error rate (BER) for 4 wavelengths signal .We have changed the input optical power from 0 dBm,-5 dBm,-10dBm,-15dBm and measured the received optical power for respective 4 wavelengths signals and measured the respective BER for that received optical power .We observed the BER in the range of 1E-09 to 1E-13 which is good one.The measured value

of input optical power, received optical power for respective wavelength, BER for respective wavelength is shown in Table 1. The measured BER for pre compensation is good compare to post compensation. Finally it can be said OFDM WDM system with pre compensation gave good performance in terms of BER, constellation diagram. We have compared between a OFDM WDM system with 4-QAM and 16-QAM.In Figure 6, we have shown Constellation diagram of 4-QAM for with pre compensation technique for 4 wavelength signals and in Figure 7 ,a constellation diagram for 16-QAM system is shown for 4 wavelength signals. It is observed that constellation diagram for 4-QAM system is good and with less dispersion but constellation diagram for 16-QAM is with more dispersion which give more BER.
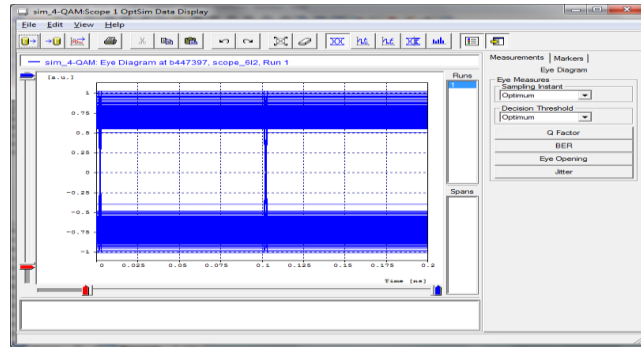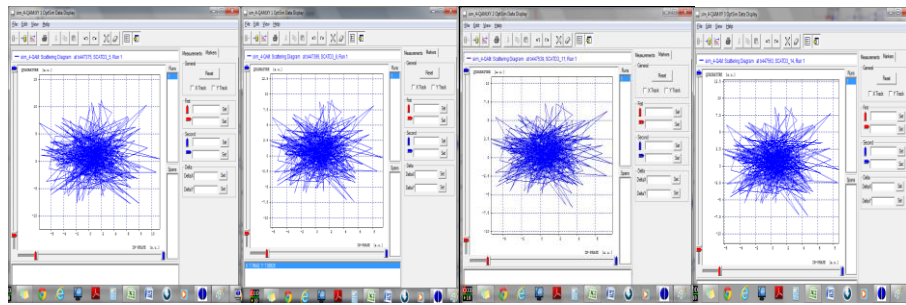

Figure 3. Eye Diagram for 1550 Nm Channel for Pre Compensation Technique

Table 1. Downstream Data Performance Analysis with Pre Dispersion Compensation

INPUT OPTICAL POWER	RECEIVED OPTICAL POWER FOR DIFFERENT WAVELENGH					BER					Log BER			
(dBm)	1549nm	1550 nm	1551 nm	1552 nm		1549 nm	1550 nm	1551 nm	1552 nm		1549 nm	1550 nm	1551 nm	1552 nm
o dBm	-10.267	-3.027	-10.254	-18.858		2.02E-12	8.96E-13	5.53E-12	3.06E-12		-1.17E+01	-1.20E+01	-1.13E+01	-1.15E+01
-0.5 dBm	-10.267	-3.028	-10.254	-18.859		2.26E-12	9.45E-13	5.86E-12	3.20E-12		-1.16E+01	-1.20E+01	-1.12E+01	-1.15E+01
-5dBm	-10.269	-3.030	-10.256	-18.861		4.78E-12	2.19E-12	1.17E-11	6.74E-12		-1.13E+01	-1.17E+01	-1.09E+01	-1.12E+01
-10 dBm	-10.277	-3.039	-10.264	-18.869		2.04E-11	2.45E-11	6.35E-11	5.25E-11		-1.07E+01	-1.06E+01	-1.02E+01	-1.03E+01
-15dBm	-10.301	-3.066	-10.288	-18.893		3.49E-09	4.50E-09	9.74E-09	8.68E-09		-8.46E+00	-8.35E+00	-8.01E+00	-8.06E+00

Table 2. Downstream Data Performance Analysis with Post Dispersion Compensation

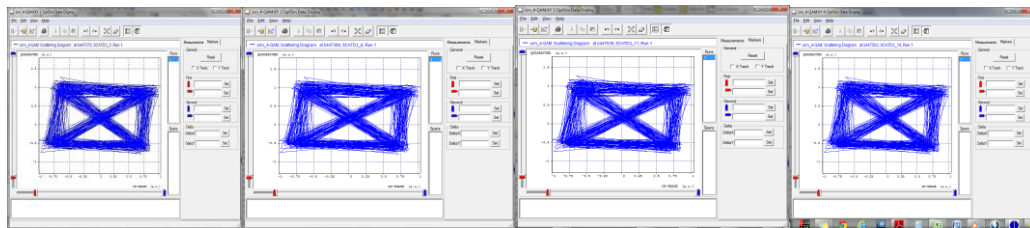| INPUT OPTICAL POWER	RECEIVED OPTICAL POWER FOR DIFFERENT WAVELENGH					BER					Log BER			
(dBm)	1549nm	1550 nm	1551 nm	1552 nm		1549 nm	1550 nm	1551 nm	1552 nm		1549 nm	1550 nm	1551 nm	1552 nm
o dBm	-10.270	-3.031	-10.257	-18.862		9.94E-08	1.59E-07	1.14E-07	1.61E-07		-7.00E+00	-6.80E+00	-6.94E+00	-6.79E+00
-5 dBm	-10.271	-3.032	-10.258	-18.862		3.95E-07	4.18E-07	1.63E-07	6.33E-08		-6.40E+00	-6.38E+00	-6.79E+00	-7.20E+00
-10dBm	-10.276	-3.037	-10.263	-18.867		3.95E-07	4.18E-07	2.33E-07	1.83E-07		-6.40E+00	-6.38E+00	-6.63E+00	-6.74E+00
-15 dBm	-10.29	-3.059	-10.281	-18.886		4.60E-06	1.58E-06	2.52E-06	1.37E-06		-5.34E+00	-5.80E+00	-5.60E+00	-5.86E+00

a)1549nm   b) 1550 nm   c)1551 nm   d) 1552 nm

Figure 4. Constellation Diagram of 4-QAM for without Compensation Technique
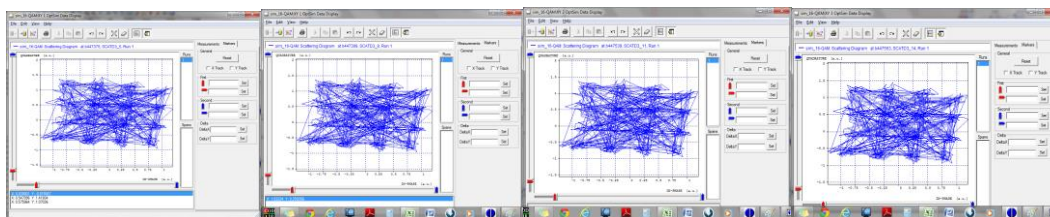

a)1549 nm   b)1550 nm   c)1551 nm   d)1552 nm

Figure 5. Constellation Diagram of 4-QAM for with Post Compensation Technique

a)1549 nm   b)1550 nm   c)1551 nm   d)1552 nm

Figure 6. Constellation Diagram of 4-QAM for with Pre Compensation Technique

a)1549 nm   b)1550 nm   c)1551 nm   d)1552 nm

Figure 7. Constellation Diagram Of 16-QAM For With Pre Compensation Technique

It is successfully demonstrated that Long Reach Orthogonal frequency wavelength division multiplexing (OFDM WDM) system can be successfully implemented for 96 Km. It delivers downstream 40-Gbps data. We have implemented OFDM WDM using without compensation and with compensation technique. We have experimentally demonstrated that a OFDM WDM system with direct detection technique can give good performance for pre compensation technique. The results show that the error-free transmission can be achieved for all WDM channels with sufficient power margins.

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