Indian Journal of Science and Technology, *Vol 8(S7), 6-10, April 2015*

ISSN (Print) : 0974-6846
ISSN (Online) : 0974-5645

OFDM –WDM Architecture with Extended Reach and 1100 Split Ratio for Next Generation Passive Optical Networks

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Abstract

In this paper, we investigate OFDM-WDM-PON as an effective method for achieving high data rates in which OFDM is used as key element to combat dispersion. Large guard band intervals between adjacent OFDM symbols accommodate the distortion introduced by chromatic dispersion leading to reduced ISI. The system design involves the realization of FTTH by integrating OFDM, WDM and PON. OFDM also aids in improving receiver sensitivity. An aggregate of 40 Gbps, Direct detection OFDM-WDM-PON is designed and analyzed. Dispersion compensation techniques are used to achieve a bit error rate in the order of 10^{-8} and a split ratio of 1100 is achieved.

Keywords: OFDM, PON, WDM

1. Introduction

The next generation broadband service requires relatively higher date compared to the present broadband services. The high data rate requirement relies largely on the OFDM systems[1] as it proves to be efficient technique for dispersion compensation. The effect of polarization mode dispersion as well as chromatic dispersion has been greatly reduced[2], by employing OFDM. Before the advent of OFDM, WDM proves to be an efficient method for providing services with high data rate but it is affected by fiber non-linearity and dispersion effects. By employing OFDM-QAM in WDM network extended reach can be achieved[3]. PON's proves to be cost efficient as it supports many users. Also the spectral efficiency can be improved by employing OFDM[4]. The system architecture involves the use of OFDM in WDM-PON with few modifications in order to achieve high data rates as well as an efficient and cost effective optical broadband access network. The use of OFDM in WDM-PON has been earlier demonstrated[5], but the maximum reach is limited to 20 km.

Here in our proposed architecture we tried to maximize the number of splits possible by improving the receiver sensitivity. Also in-order to achieve extended reach we employed various dispersion compensation techniques like pre and post dispersion compensation[6,7] with Dispersion compensated fiber and using Fiber-Bragg's Grating. The use of pre compensation8 technique in-addition to OFDM proves to be little more efficient.This paper is organized as follows: Section I Introduction, Section II QoS in GPON, Section III Implementation, Section IV Results, and Section V Summary.

2. Simulation Set-Up

The 10Gbps data is generated with a PRBS Generator and fed to a serial to parallel converter producing 4 bits. The output is fed to a QAM modulator. The bits are then encoded using 16-QAM by which each transition represents 4 bits. Thus the symbol rate because of QAM is 2.5symbols/sec. Then the QAM output is fed into the IFFT processor where the QAM output is split into lower

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data rate signals called subcarriers and each subcarrier is multiplied by a complex number which makes the subcarriers orthogonal to each other. These signals will be added and thus a sinusoid is produced which is up-converted using a Quadrature mixer circuit. The in-phase and quadrature phase signals of the mixer circuit is combined electrically by using electrical combiner. The combined output is then modulated by using an optical carrier and linear amplitude modulated. Thus an OFDM transmitter block is formed. In the similar manner three more OFDM transmitter blocks were created for different wavelengths, where the wavelengths are 1548.5nm, 1549.5nm, 1550.5nm, 1551.5nm. The power of 10dbm is used in each optical carrier. The next section is the multiplexer where all these wavelengths are multiplexed9 by using a Lorentzian multiplexer which comprises of filter and an optical combiner. These are then amplified using a fixed output power booster and are then launched into the fiber. At the other end of the fiber, a fixed gain amplifier (EDFA) is used to amplify the signal. The multiplexed output from the amplifier is demultiplexed by using a Lorentzian de-multiplexer comprises of a splitter and a filter. Each de-multiplexed output is fed to a photo-diode which is tuned to specific wavelength is used to receive the signal of specific wavelength. The four channels can further be split into a number of splits using an optical splitter which depends on the receiver sensitivity. FTTH is developed by combining one output from the passive optical splitter of each channel and then carried by the fiber to the home where the optical power is split using a passive optical splitter and then using separate filters to receive the desired wavelength. At the receiver end a filter of specific wavelength is used extract the specific wavelength and then the receiver which acts as a photodiode is tuned to the same wavelength as the filter. As we used four channels WDM we used receivers that are tuned to 1548.5nm, 1549.5nm, 1550.5nm, 1551.5nm.

The electrical output from each photodiode is separately processed. The output of photodiode is split using an electrical splitter into two which are processed separately using Bessel optical filter and down converted using a Quadrature mixer circuit, one of the outputs is fed to the in-phase of FFT and other to the quadrature phase of FFT block which converts the sinusoid into a spectrum which are then demodulated using a QAM demodulator which produces 4 bits at a time at the output. By using a parallel to serial converter the data is produced back at the receiver end. Passive Optical Network is introduced after the de-multiplexer. Certain services may not require 10Gbps data rate in such cases PON is used to share the available bandwidth. Based on the available de-multiplexed power and receiver sensitivity the number of splits can be determined. Thus the output power of single channel of the de-multiplexer is split using 1xN splitter. Each de-multiplexed power is split using 1xN splitter. Each de-multiplexed output provides certain services. Certain homes may require more than one service in that case the power available in a single split after 1xN splitter from two channels is combined and sent to the home using 10m fiber where again using receivers of specific wavelength they are extracted. Thus FTTH is created by using OFDM-WDM-PON.

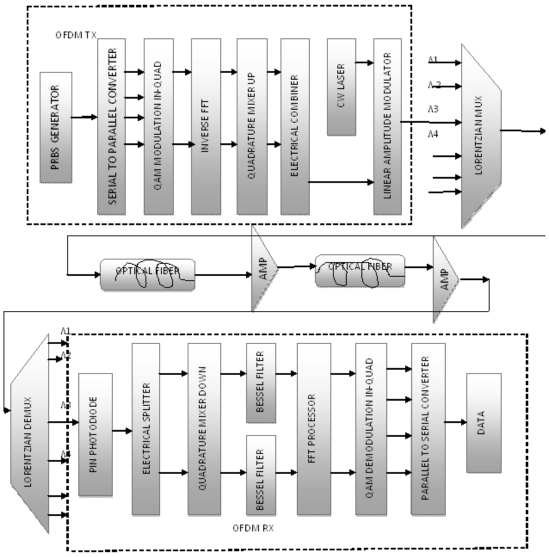

Figure 1. System design.

3. Dispersion Compensation Techniques

Chromatic dispersion is a variation in the velocity of light (group velocity) according to wavelength. This variation in velocity causes the pulses of a modulated laser source to broaden when travelling through the fiber to a point where pulses overlap and bit error rate increases. As this increase in bit error rate interferes with both, the quality and the speed of the signal, Chromatic Dispersion (CD) is a major limiting factor in high-speed transmission.

In the channel the problem of dispersion arises. To compensate this various dispersion compensation techniques[10] like pre-dispersion compensation where DCF is placed before the transmission through the fiber, post-dispersion compensation where DCF is placed after the fiber, Grating compensator uses Bragg's principle to compensate for the dispersion. The scattering plot at the transmitter is shown in Figure 1. The scattering plots with and without dispersion compensation are shown in Figure 2 and Figure 3.

Table 1. Different access network and their reach

OPTICAL ACCESS NETWORK		ESTABLISHED REACH (LINK LENGTH)
1.	DDOFDM WITHOUT DISPERSION COMPENSATING TECHNIQUES	Maximum reach possible is 5 to 10 kms.
2.	DDOFDM with DCF pre-dispersion compensating technique	Reach is extended to 144kms with 120km SSMF and 24km DCF.
3.	DDOFDM with DCF post-dispersion compensating technique	Reach is extended to 144kms with 120km SSMF and 24km DCF.
4.	DDOFDM with DCF pre-post-dispersion compensating technique.	Reach is extended to 144kms with 120km SSMF and 24km DCF.
5.	DDOFDM with FBG grating dispersion compensating technique.	Reach is extended to 100kms.
6.	OFDM-WDM-PON with FBG dispersion compensating technique.	Reach extended to 100kms.

The scattering plot (Figure 2) at the receiver before dispersion compensation if fully distorted. But with the aid of dispersion compensation the scattering plot is free of distortion as shown in Figure 4. Table 1 shows the reach distance that could be achieved without dispersion compensation and with various dispersion compensation techniques in a direct detection of dm wdm passive optical networks.

3.1 Receiver Sensitivity

The receiver sensitivity is measured to determine the number of splits that is possible so as to support the number of users. The receiver sensitivity is measured by varying the transmitted power and measuring the power at the receiver end in order to determine the minimum power that is required by the receiver to produce an output that is acceptable without dispersion. The receiver sensitivity was found to be -25.6dBm.

3.2 Split Ratio Estimation

The number of users that each de-multiplexer can support is determined by the split ratio. Split ratio is the ratio between the powers of a de-multiplexed channel to the minimum power that is required by the receiver to produce an output that is acceptable. The number of splits obtained is 1100. Number of splits for one channel= De-multiplexed power for single channel/Receiver Sensitivity

= 3.03/0.002754 = 1100 splits.

4. Experimental Results

The experimental results are shown in Figures 2-4

5. Conclusion

The distance the data could be successfully transmitted without the effect of chromatic dispersion was found to be as low as 5 to 10 km which makes the system cost-ineffective so to increase the link length different types of dispersion compensating techniques were employed and the data was transmitted successfully without dispersion for 100km. . The reach can further be increased at the cost of increase in power and increase in the number of amplifiers being used. When compared to pre and post dispersion compensation techniques dispersion compensation using FBG was found to be efficient and also

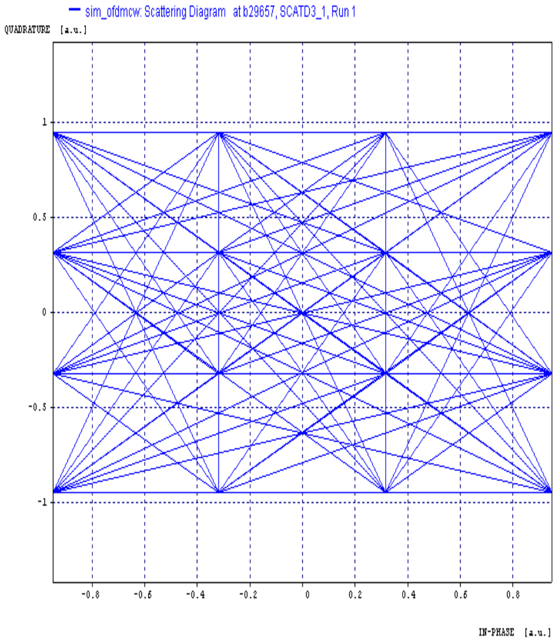

Figure 2. Scattering diagram at the transmitter.

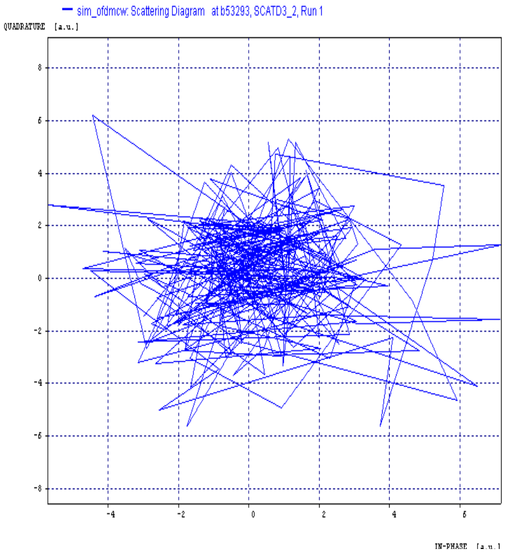

Figure 3. Scattering diagram at the output post Passive Optical Network (PON) without dispersion compensation.

also there is a reduction in the number of amplifiers being used as the pre and post dispersion compensation techniques involves DCF in which the losses were found to be as high as 0.5db/km. Also the BER count was found to be 519 bits for 10Gbps in DD-OFDM and was found to be 436 bits per 10Gbps for each channel in OFDM-WDM and increased to 526 by introducing PON which is acceptable.

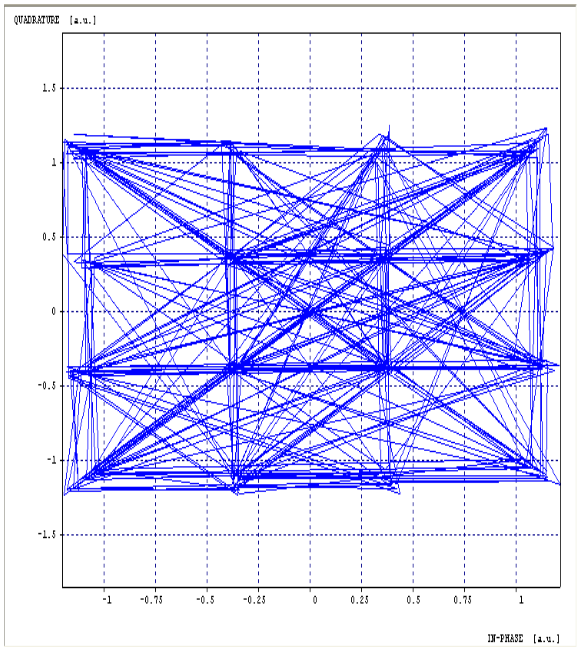

Figure 4. Scattering diagram at the output post Passive Optical Network (PON) with dispersion compensation.

The improvement in the receiver sensitivity is obtained by the system because of OFDM. Because of this improvement in the Receiver Sensitivity, split ratio of 1100 is obtained using OFDM-WDM-PON. Thus in the near future OFDM could be a successful spectral efficient system which will satisfy the need for the bandwidth requirements of the next generation.

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