Performance Analysis of Unidirectional WDM-OFDM-PON Systems with Direct and Coherent Detection Methods

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***Abstract*— The requirement for the fast and efficient data transfer through the existing infrastructure leads the use of new technologies. With the popularity of WDM-PON architecture in the communication networks incorporate with large number of users and higher bandwidth. The OFDM modulation format with WDM-PON increases the bandwidth requirement and better performance.**

Keywords—WDM-PON, OFDM; Coherent detection, Direct detection

I. INTRODUCTION

The increased demand for the bandwidth is stated from the era of copper wire based access network. The solution for this requirement is fulfilled by the introduction of Passive Optical Networks (PON). To increase the performance of PON architecture introduced different multiplexing methods. Among the different multiplexing methods Wavelength Division Multiplexing (WDM) got more popularized by its large capacity and bandwidth. As the distance increases the dispersion in the WDM is also increases. To reduce the distortion we introduced the Orthogonal Frequency Division Multiplexing (OFDM).

OFDM is a multicarrier modulation method. The key distinction of OFDM from general multicarrier transmission is the use of orthogonality between the individual subcarriers. It is a form of signal modulation that divides a high data rate modulating stream placing them onto many slowly modulated narrowband close-spaced subcarriers, and in this way is less sensitive to frequency selective fading. OFDM has been adopted in the Wi-Fi arena where the standards like 802.11a, 802.11n, 802.11ac and more. It has also been chosen for the cellular telecommunications standard LTE / LTE-A, and in addition to this it has been adopted by other standards such as WiMAX and many more.

II. SYSTEM MODEL

A. *Unidirectional WDM - OFDM - PON Systems with Direct detection OFDM*

Figure 1 shows unidirectional direct detection system. This system contains OLTs and ONUs connected through multiplexers and demultiplexers via single mode fiber. In the OLT the data is generated by PRBS. This digital data is analog modulated by QAM coder. This coded signal is modulated in the OFDM modulator with the local oscillator frequency. In direct detection a quadrature modulator is used to modulate the I and Q components separately and the RF to optical up-conversion is done using a laser (local oscillator) and Mach Zehnder Modulator (MZM). All the OFDM modulated signals are multiplexed and send through single mode fiber.

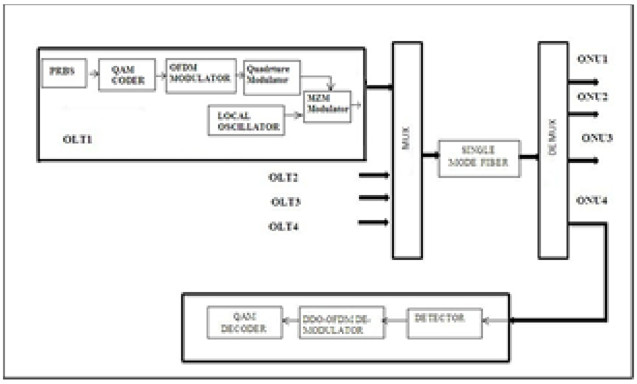

Fig. 1. System model for unidirectional WDM-OFDM-PON with Direct detection

At the ONU the received signal is demultiplexed using a DEMUX. Using a PIN photodiode, which is tuned to the transmitted frequency, the optical signal is converted to electrical signal. Here the direct detected signal demodulated and decode using OFDM demodulator and QAM decoder.

B. *Unidirectional WDM - OFDM - PON Systems with Coherent detection OFDM*

The coherent detection WDM-OFDM-PON system consists of coherent modulation and detection. In the OLT the PRBS is coded and modulated using QAM encoder and OFDM modulator respectively. In coherent detection system a Continuous Wave laser and two Mach-Zehnder modulators are used to up-convert the RF data to the optical domain. At the ONU demultiplexed signal is detected using coherent detector circuitry which incorporates a local oscillator. The detected signals are demodulated and decoded using OFDM demodulator and QAM decoder, as shown in the Figure 2.

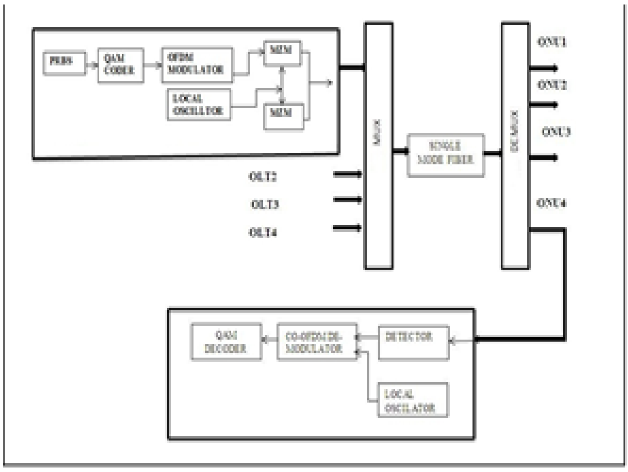

Fig. 2. System model for unidirectional WDM-OFDM-PON with Coherent detection

III. SIMULATION SE UP

Figure 3 contains four identical channels that are multiplexed by a wavelength division multiplexer. For the downlink design, in each channel OFDM is used. As for downlink, four ITU-T standard frequencies working at 193.05 THz, 193.1 THz, 193.15 THz, and 193.2 THz are used as downstream optical source and injected into the MZM. This design is done for 4-QAM and 16-QAM.

The 10-Gb/s PRBS is biased at quadrature point for linear electronic-to-optical conversion and driven by the OFDM signal. With 4-QAM symbol mapping, there are 512 point operations and 128 data-bearing subcarriers. Quadrature Amplitude Modulation (QAM) is a modulation scheme in which two sinusoidal carriers, one exactly 90^0 out of phase with respect to the other, are used to transmit data over a given physical channel. Because the orthogonal carrier s occupy the same frequency band and differ by a 90 degree phase shift, each can be modulated independently, transmitted over the same frequency band, and separated by demodulation at the receiver. For a given available bandwidth, QAM enables data transmission at twice the rate of standard Pulse Amplitude Modulation (PAM) without any degradation in the Bit Error Rate (BER). In addition, the cyclic prefix of 16 samples is added for the modulation of OFDM.

The Quadrature modulator then modulates the I and Q components separately. The MZM together with the CW laser operating at 193.1 THz provides the RF to optical up-conversion. The output laser signals of MZM modulator will be multiplexed using WDM and sent via a Single Mode optical Fiber (SMF). The optical fiber length in this design has been varied from 50 to 100 Km.

At the receiver side, Demultiplexer is used to separate the received signal into four signals for each channel. Each signal has been detected by a single photo diode (PIN detector), which converts the optical signal to an electrical signal. This electrical signal will be demodulated by using an OFDM demodulator and given to a quadrature demodulator for demodulating the I and Q components separately and further given to QAM sequence decoder.

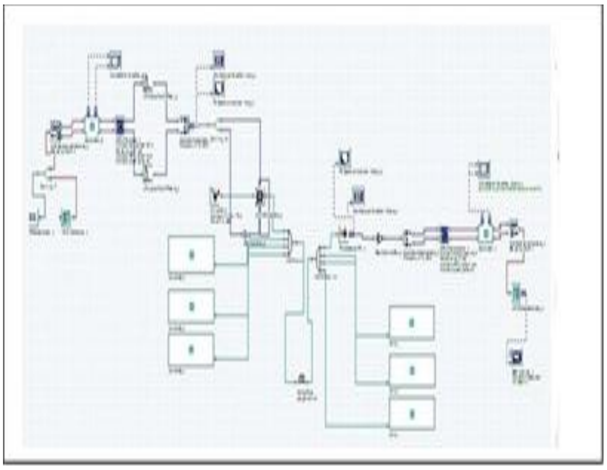

Fig. 3. Simulation diagram for unidirectional WDM-OFDM-PON with Direct detection

In coherent system, the modulation part contains two MZMs instead of single one in the Direct detection scheme.The bit stream is generated by a PRBS generator and mapped by a 4-QAM encoder. The resulting signal is modulated by an OFDM modulator. The OFDM modulated signal is fed to two MZMs through two low pass filters . The local oscillator frequencies 193.05 THz, 193.1 THz, 193.15 THz, and 193.2 THz are used for each of the OLT. The optically modulated signals are combined using an AWG and given to fiber. The simulation diagram is shown in the Figure 4.

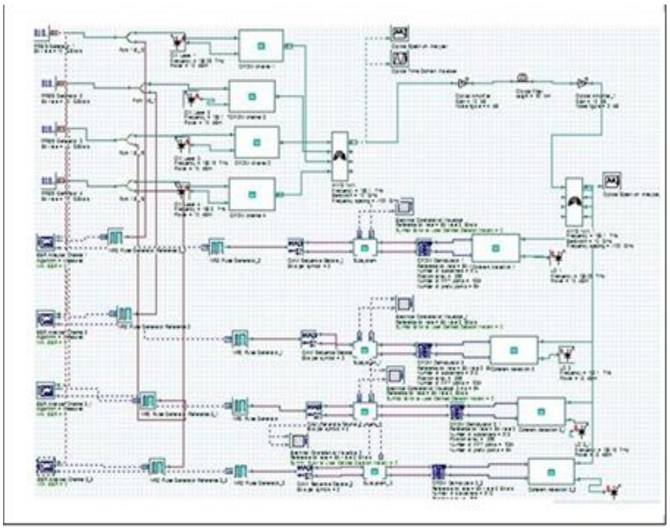

Fig. 4. Simulation diagram for unidirectional WDM-OFDM-PON with Coherent detection

IV. RESULTS AND DISCUSSIONS

Simulations are done with the OptiSystem V.12 software. Different types of visual parameters are used to obtain the performance analysis. The main analysis tools taken into account are Q-factor and BER. With a fixed data rate of 10Gbps and with 0.2dB input power PRBS data is given to the WDM-OFDM-PON system in each channel with direct and coherent detection methods. With 4-QAM signal mapping, the received signals are evaluate through eye diagram representation. Eye diagrams representations of the received signals at different distances are shown in the Figure 5 for direct detection and Figure 6 for Coherent detection system.

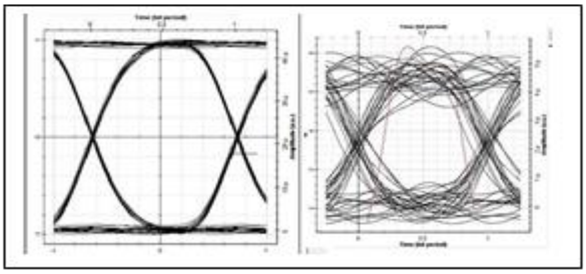

Fig. 5. Eye diagram for unidirectional system with direct Detection at the distances 50km and 100km

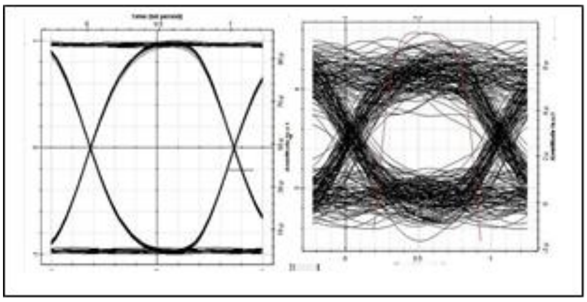

Fig. 6. Eye diagram for unidirectional system with Coherent detection at the distances 50km and 100km

The constellation diagrams for the above system for the same distances are shown in the Figure 7 for direct detection method and Figure 8 for Coherent detection method . From the constellation diagrams it is observed that as the distance increases the noise interference is also increases. Mainly the phase noise and attenuation is increased.

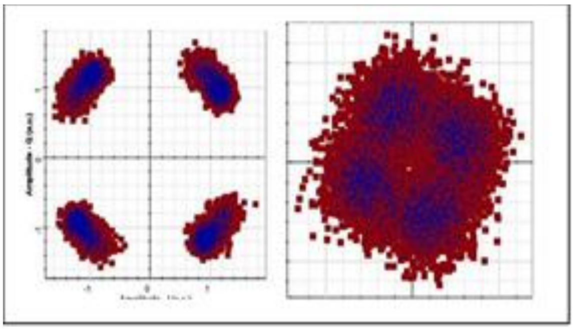

Fig. 7. Constellation diagram for unidirectional system with direct detection at the distances 50km and 100km

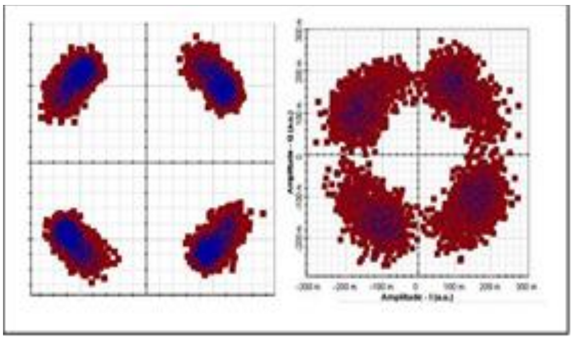

Fig. 8. Eye diagram for unidirectional system with Coherent detection at the distances 50km and 100km with

The analyses of unidirectional systems are done with 4 QAM and 16 QAM signal mapping. The overall observations in terms of Q-Factor are summarized in the following graph shown in Figure 9. From this analysis the coherent detection with 16 QAM signal mapping is better in the unidirectional systems.

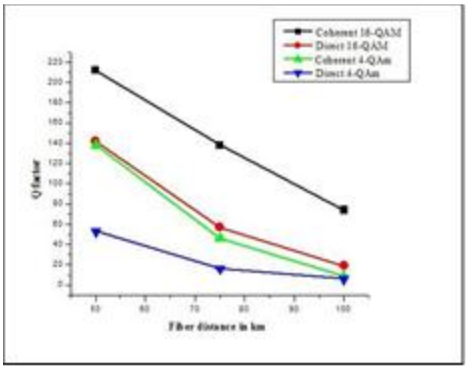

Fig. 9. Relationship between Q-factor with distance in unidirectional systems

CONCLUSION

Provisioning broadband services for downloading high definition data has become a difficult requirement for data providers. An easy way to provide multipath, which are used in most broadband systems between transmitters and receivers, is to use OFDM. From the observations it is concluded that for long distance communication WDMOFDM- PON systems can be used. Coherent detection OFDM method has more prominent performance than direct detection method. In coherent detection method as the modulating signal mapping rate increases, it gives better performance in the constellation diagram.

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