



Performance Comparison of Modulation Formats for Wavelength Re-modulated Bi-directional Passive Optical Network

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Abstract: In this paper, we have investigated and compared the performance of different modulation formats like Non Return to Zero (NRZ), Return to Zero (RZ) and On-Off Keying (OOK) for bi-directional passive optical networks (PON). The PON architecture is implemented by using a wavelength re-modulated scheme which in downstream optical signal is re-modulated as a carrier for upstream transmission. This remodulation scheme is used to make the system cost effective by removing the laser source from Optical Network Unit (ONU). For NRZ, 10 Gbps data is successfully transmitted to 32 ONUs with acceptable Q-factor of 7.11 for downlink and 2.5 Gbps data is received with Q-factor of 6.83 for uplink. Various modulation formats have been shown to verify the results at Optical Line Terminal (OLT) and Optical Network Unit (ONU) side and observed that NRZ is a suitable modulation format.

Keywords: Bi-directional PON, Modulation Formats, Remodulation Techniques, FTTH

I. Introduction

The next generation technology is required to be compatible with today's bandwidth needs and to also offer bandwidth ease to support future growth based on network expansion and new application development. Since optical technology has proven to have large bandwidth capacity, it appears to be the proper choice to solve the complexities of access networks [1]. A passive optical network (PON) technology is now considered to be an effective solution to the last-mile problem and PON access architecture is the accepted choice of triple-play (voice, video, and data) service delivery from service providers to the end users in FTTH access networks [2]. Four major PON technologies are currently accepted as the basis for FTTH deployments: Broadband PON (BPON), Giga-bit PON (GPON), Ethernet PON (EPON or GEAPON) and Wavelength Division Multiplexing PON (WDM-PON). WDM -PON is the next generation in the development of access networks and offers highest band-width [3-4].

Signal modulation format is a key issue, which determines transmission quality and spectral efficiency and one of the most important facts in the system, which affects the choices of all other system parameters, is the signal optical modulation format. The BER and Q-factor may be improved by choosing a proper line coding scheme which includes various modulation formats like Non Return to Zero (NRZ), Return to Zero (RZ), On-Off Keying (OOK) and many more [5-6]. The most commonly parameters used for measuring the performance are Q-factor and Bit Error Rate (BER). The BER defines as the probability of incorrect identification of a bit by the decision circuit in the receiver and Q-Factor measures the quality of the transmission of signal in terms of its signal-to-noise ratio (SNR), higher the value of Q-factor the better the SNR and therefore the lower the probability of bit errors [7]. The BER and Q-factor can be estimated by following expression written in equation (1) and (2). To achieve BER of 1×10^{-9} the Q-factor must be equal to greater than and equal to 6 ($Q \geq 6$).

$$\text{BER} = \frac{1}{2} \text{erfc} \left(\frac{Q}{\sqrt{2}} \right) \approx \frac{\exp(-Q^2/2)}{Q\sqrt{2\pi}} \dots\dots\dots (1)$$

Parameter Q can be estimated as

$$Q = \frac{m_1 - m_0}{\sigma_1 + \sigma_0} \dots\dots\dots (2)$$

Where m_1 and m_0 are the mean of the received signal at the sampling instant when a bit 1 and 0 is transmitted and σ_1, σ_0 are the standard deviations respectively [7]. The NRZ format [5], A pulse of amplitude "+V" of the duration T_b is used to represent a logic "1" and a pulse of amplitude "-V" of same duration represents a logic "0" as shown in fig. 1(a). The RZ format [5], A pulse of amplitude "+V" represent a logic "1" with duration

$T_b/2$ and a pulse of amplitude “-V” of same duration represents a logic “0” as we can see that the pulse return to zero after half the bit duration $T_b/2$ as shown in fig. 1(b).

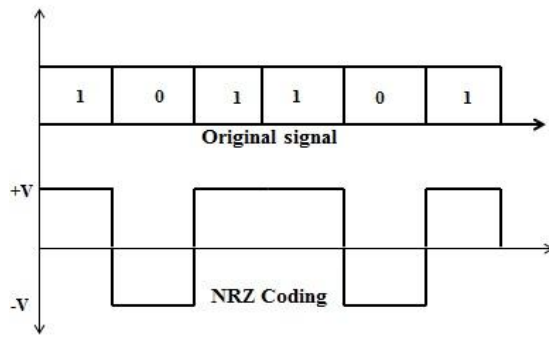


Fig.1 (a): NRZ Pulse Format

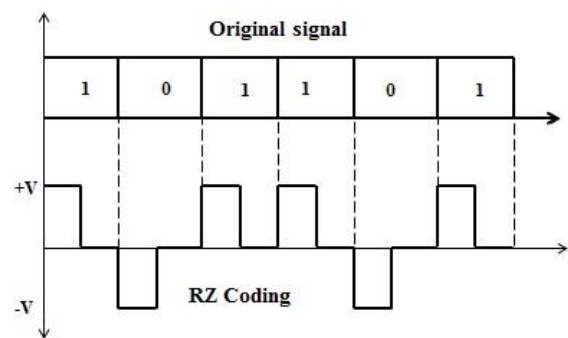


Fig.1 (b): RZ Pulse Format

In literature survey, various works on the performance of PONs with various modulation formats had been reported. Rajneesh Kaler *et al.* [8] presented the comparative investigation and suitability of various data formats like NRZ Rectangular, NRZ Raised cosine, RZ Rectangular, RZ Raised cosine and RZ super Gaussian for optical transmission link at transmission distance of 50 km. Li Li *et al.* [9] investigated different modulation modes of DPSK and OOK are separately employed in the upstream and downstream link, after the comparison with different modulation formats in the downstream including the codes of NRZ, RZ and inverse return-to-zero (IRZ), the symmetric rate of 10 Gbps with 20 km transmission was realized without the dispersion compensation. Till now, we observed that the proposed PON were investigated at lesser transmission distance as [8-9]. Moreover most of the proposed networks were investigated in downlink transmission only [8]. So we investigated the different modulation formats like NRZ, RZ, and OOK for bi-directional passive optical network at different transmission distance and reduce the complexity of the system by using the re-modulation techniques and by getting rid of the RSOA from the existing system. From users point of view provides cost effective system.

This paper is organized into four sections. In Section1, introduction to passive optical networks, various performance measure parameters and different modulation formats pulses are described. In Section2, the simulation setup for investigate the effects of modulation format on re-modulated bi-directional PON. In Section 3, results in terms of BER with distance. Finally in Section4, conclusion is made.

II. System Setup

The system setup of Fibre-To-The-Home (FTTH) using bi-direction PON architecture is shown in figure 2.1. PON consists of an optical line terminal (OLT) and optical network units (ONUs). A bi-directional fiber is used to provide connection between OLT to various ONUs i.e. point to multipoint (P2MP) architecture is used. 1550 nm wavelength for downstream i.e. from OLT to ONUs and 1310 nm is used for upstream i.e. ONUs to OLT. An optical SOA amplifier with 30 dB gain is used for increasing the transmission distance.

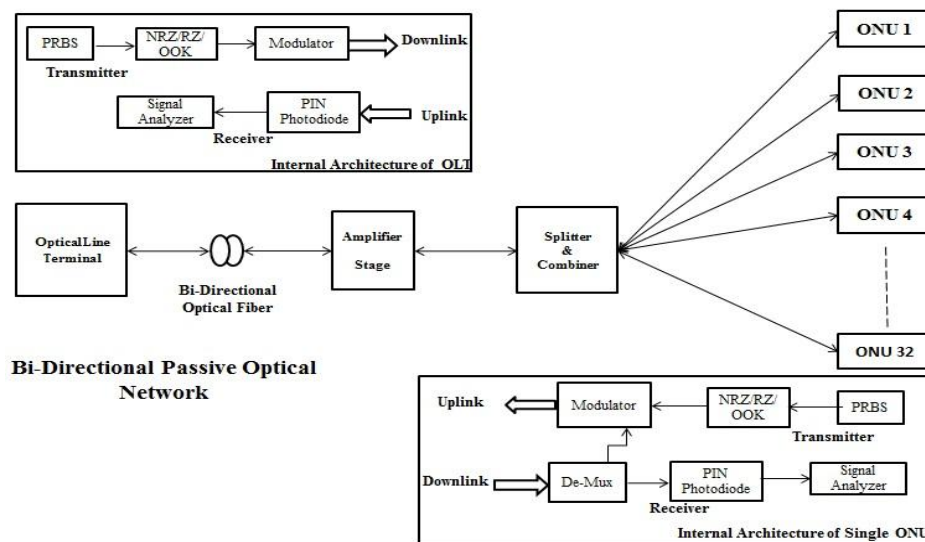


Fig. 2.1: System Setup for Bi-directional Passive Optical Network Architecture

1:32 splitter/combiner is used as passive component for the distribution of data to different 32 ONUs. OLT consists of WDM transmitter and receiver for downlink and uplink transmission respectively as shown in figure 2.1. A Pseudo Random Data source provides data rate of 10 Gbps, then with the help of different modulation formats like NRZ, RZ and OOK, bits are converted into electrical pulses. Mach-Zehnder optical modulator produce modulated output and then 2:1 mux with 0 dB insertion loss is used for multiplexing and this multiplexed signal is fed to the bi-directional fiber. A receiver section consists of 1:2 de-mux with power attenuation of 0 dB for attenuator then passed through the Bessel filter. A Coherent detection technique is used for receiving the information from different ONUs. A PIN photodiode with 1A/W responsivity, 0 ampere dark current, and thermal noise of $10^{-11} A/\sqrt{Hz}$ is used. For synchronization purpose, clock recovery module and time delay is used.

ONU consists of transmitter and receiver for uplink and downlink transmission respectively as shown in figure 2.1. Signal from OLT is demultiplexed using 1:2 de-mux of 0 dB insertion loss one output of de-mux is fed to the receiver section which consist PIN photodiode, Bessel filter and clock recovery module and second output of de-mux is fed to modulator as a carrier for uplink transmission as shown in the figure 2.1 in internal architecture of single ONU this scheme is known as wavelength re-modulated scheme to transmit the data from ONU to OLT a transmitter consists of PRBS, NRZ, RZ and OOK electrical coders and amplitude optical modulator of 0.9 modulation index is used. Wavelength remodulated scheme eliminates the need for an extra light source hence the absence of a specific light source makes the operation of the ONU independent from wavelength and provides cost effective system. This proposed architecture is simulated in VPI photonics version 8.7. The various parameters are set to investigate the performance of different modulation format on bi-directional transmission using wavelength re-modulated technique.

III. Result and Discussion

To analyze the performance of wavelength re-modulated bi-directional PON for different modulation formats the graph between Q-factor versus transmission distance with NRZ, RZ and OOK has been drawn to verify the results at OLT side and ONU side. The variation in Q-Factor for different modulation format at OLT side with different transmission distance is shown in figure 3.1. We have observed the Q-factor of 6.83 with NRZ, 6.11 with RZ and 5.25 with OOK at 150 km at OLT side. As we seen that Q-factor decreases with increase in distance due to fiber non-linearity and ASE noise induced in the amplifiers.

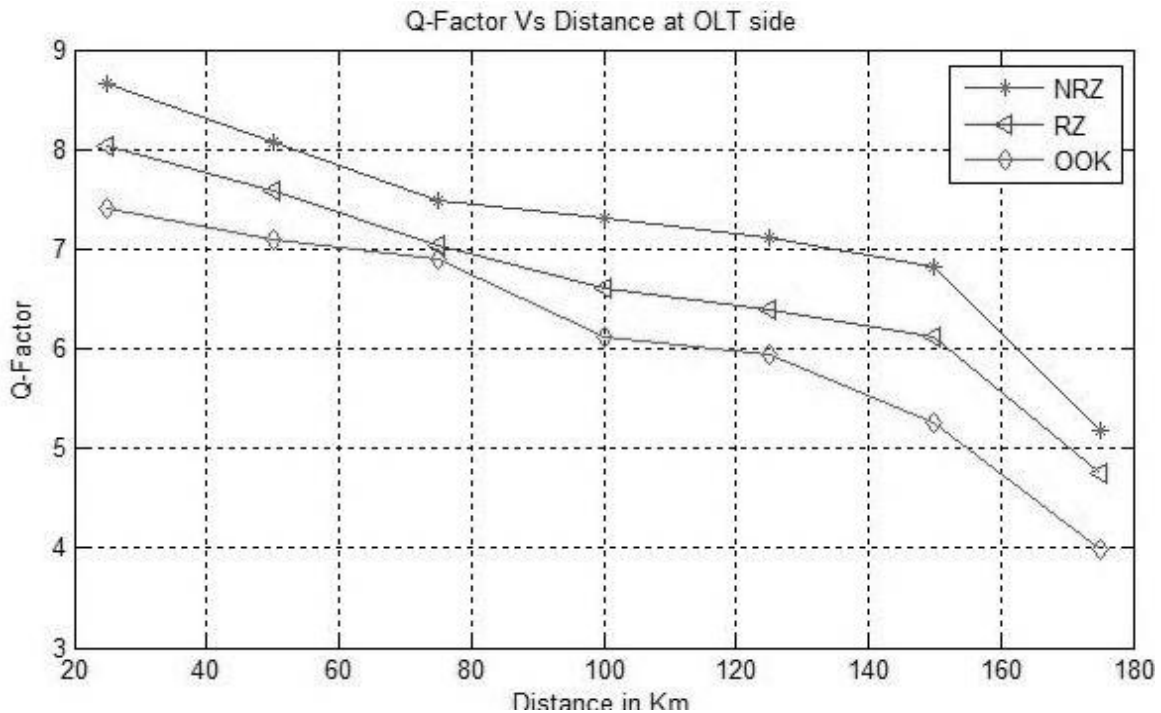


Fig. 3.1: Q-factor versus Transmission distance at OLT side

Similarly, variation in Q-factor for different modulation format at ONU side with different transmission distance is shown in figure 3.2. We have observed the Q-factor of 7.01 with NRZ, 6.71 with RZ and 5.99 with OOK at 150 km at OLU side.

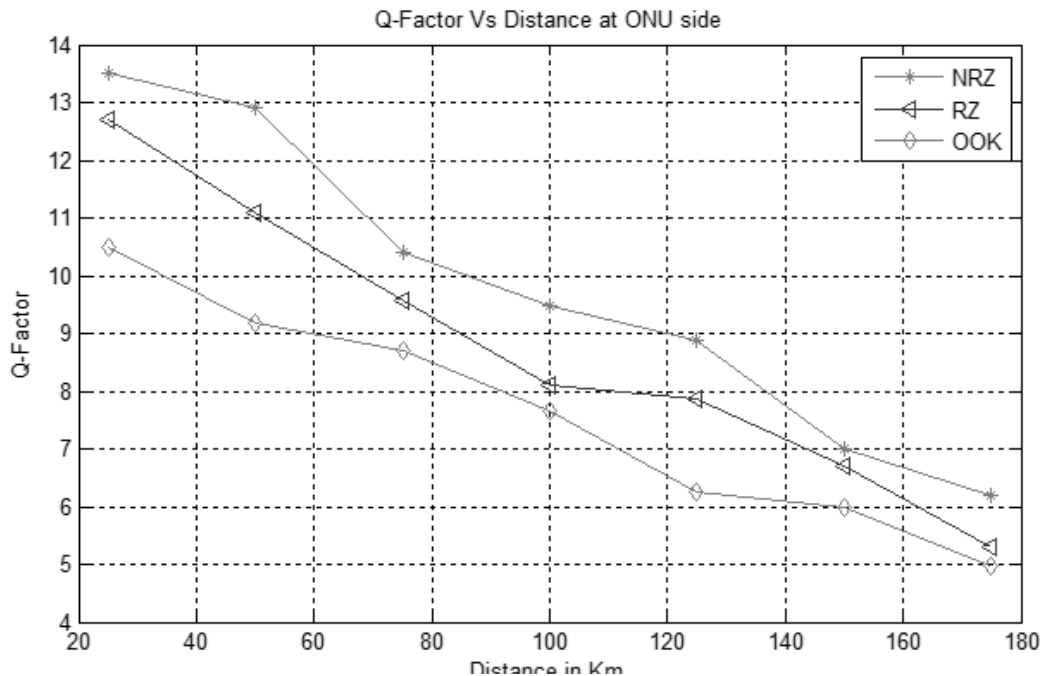


Fig. 3.1: Q-Factor versus Transmission distance at ONU side

IV. Conclusion

Different modulation formats like NRZ, RZ and OOK for bi-directional passive optical network (PON) has been Investigated. A remodulation scheme has been proposed, where downstream optical signal is reused as a carrier signal for upstream transmission for the implementation of PON architecture. 1550 nm wavelength is used to transmit 10 Gbps downlink data and 1310 nm wavelength for 2.5 Gbps uplink data. Data successfully transmitted with Q-factor of 6.83 with NRZ, 6.11 with RZ and 5.25 with OOK at 150 km at OLT side and Q-factor of 7.01 with NRZ, 6.71 with RZ and 5.99 with OOK at ONU side at same distance. It has been observed that the most suitable data format for PON network is NRZ.

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