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Performance Comparison of Different Transmitter Diversity Combinations in WDM-PON Architecture

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***Abstract*: In this work, a wavelength division multiplexed passive optical network by employing transmitter diversity is demonstrated. In order to cope up with downstream and upstream channels interference issues, differential quadrature phase shift keying is incorporated in transmission from centralized light wave unit (central office) to optical network unit (user end) and non-return to zero is used for ONU to central office communication. Demonstrated system cater accumulated symmetrical data rate of 40 Gbps over four WDM channels and system reach is 40 km. Further, investigation and comparison of DQPSK-NRZ system is carried out with DPSK-NRZ system in terms of Q factor and BER. It is perceived that system having more phase shifts such as in DQPSK, surpasses the performance of system with two phase shifts (DPSK) due to less intra-channel crosstalk**

***Keywords*: Differential quadrature phase shift keying, centralized light wave unit, Differential phase shift keying, Non return to zero, Inter-channel crosstalk, Q factor, BER.**

1. Introduction

Due to rapid increase in the online gaming, video calling, high definition videos, and internet services, demands of high speed and wide bandwidth is increasing day by day. Moreover, these bandwidth hungry applications exert great pressure on transmission mediums. Nowadays, in order to cope with extensive data speed demands, a transmission medium is required which will have wide bandwidth and to fulfill these demands, optical fiber is emerged as a right candidate to serve the needs of users. Optical access networks are an important candidate to provide cost effective way out and can also serve numerous users. Passive optical networks are type of optical access networks which do not need energy for user distribution. In order to increase the capacity of passive optical networks, there is need to pack more number of channels to fiber optic and this can be accomplished using multiple access technique such as multiplexing [1]. Widely used multiplexings are time division and wavelength division multiplexing which uses diverse time slots and wavelengths respectively. In TDM, there are limitations of time skews and WDM is free from this issue. Therefore, wavelength division multiplexing is a promising and potential method to provide high capacity passive optical networks [2]. For fiber to the home services, wavelength division multiplexed passive optical network is taken as the ultimate way out to endow with greater bandwidth as well as rapid rate of data transmission. Dual directional or bidirectional passive optical networks are increasing to cater bandwidth hungry services [3]. In full duplex PONs, and WDM based PONs, crosstalk is a prominent limitation which act among diverse channels and also between downstream/upstream communications. For eliminating or suppressing the inter-channel and intra-channel crosstalk, various research works are identified till now by altering the frequency of operation [4], incorporating optical amplifiers [5], diverse modulations [6], optical/electrical filters [7], dispersion compensation [8] etc. But all the components and changes for enhancement of the performance of the PONs, ultimately increases the cost as well as complexity of the system. Multilevel modulations such as differential phase shift keying is widely used in PONs to provide dispersion tolerance and prolonged distances [9]. However, there are other multilevel modulations such as differential quadrature phase shift keying which can further reduce dispersion effects, and nonlinearities.

In this research article, performance investigation and comparison of DQPSK-NRZ based WDM-PON system is done with DPSK-NRZ passive optical network.

2. System setup

A. Optical line terminal to optical network unit transmission (Downstream)

In order to demonstrate a proposed wavelength division multiplexed passive optical network by employing transmitter diversity, a simulation tool Optiwave's Optisystem is considered. Differential quadrature phase shifting based downstream and non-return to zero dependent upstream passive optical network by incorporating WDM is depicted in Figure1. Data rate is fixed to 10 Gbps per channel and total 4 WDM channels at 100 GHz channel spacing are used in the work. First and foremost, each transmitter consists of streams of 1's and 0's and is generated from central office based pseudo random bit sequence generator. Data from binary generator is passed through 4-DPSK encoder in case of DQPSK and further fed to pulse generator such as NRZ. DQPSK signal is properly implemented by incorporating two Mach-zehnder modulators in parallel which act as phase modulators. Output of two parallel mach-zehndar modulators are given to third MZM modulator which gets derive from sine generator of ¼ frequency of bit rate as depicted in Figure 2 (a). Output DQPSK signal has narrow spectrum and has potential to suppress intra-channel crosstalk. Four lasers are used for 4 channels and frequency of first channel is 193.1 THz. Multiplexer is place after four transmitters and it combines the channels into one signal. Multiplexed signals are coupled to optical fiber of 40 km through bidirectional circulator. Optical fiber used in this work has attenuation 0.2 dB/km and effects of dispersion as well as nonlinearities are taken into account. After successfully transmission of the multiplexed signals through optical fiber, singles are given to de-multiplexer which route the specific frequency to particular port according to channel spacings and transmitter sequence. Each channel is decoded by using DQPSK receiver which consists of balanced receivers different bit delays. Delays are 2 times the bit duration. There are 2 PIN photo detectors in balanced configurations and further electrical filter is placed to quell the noises which arise after optical to electrical conversion. Further a 3-R re- generator, bit error rate are used for final evaluation of the downstream signals.

B. Optical network unit to optical line terminal transmission (Upstream)

For the accomplishment of optical network unit to optical line terminal transmission, wavelength reuse has been used by taking the same wavelengths into consider which are assigned for downstream transmission. To perform wavelength reuse, each downstream wavelength/frequency after de-multiplexer is divided into two equal parts. From these two parts, one is assigned to DQPSK decoder for downstream data reception and next is used for the upstream signal. In this way four upstream wavelengths are taken and further modulated with data given by binary data generator and non-return to zero modulation formats. For modulation, a reflective semiconductor optical amplifier is chosen due to its compact size and reliable operations. All the wavelengths accumulated using multiplexer and fed to same bidirectional optical fiber of 40 km followed by receiver which has a PIN photo detector, filter low pass and BER analyzer. Receiver which has a PIN photo detector, filter low pass and BER analyzer.

3. Cases of transmitter diversity

In this work, two different cases of transmitter diversity are considered such that (1) DQPSK in downstream and NRZ in upstream (2) DPSK in downstream and NRZ in upstream. Both the systems are investigated and then compared. Fig. 2(b) represents the DPSK modulation which consists of PRBS, binary not, pulse generator and followed by MZM modulator. Output of first MZM is given to MZM 2 at which sine generator of bit rate/2 frequency is attached for two phase shifts such 0degree and 180 degree. The Table-1, shows the system specifications which are considered in this work. Fig. 3 (a) and Figure 3 (b) represents the simulation system of receivers in case of DQPSK and DPSK respectively.

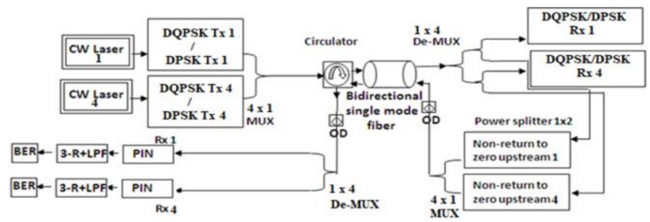
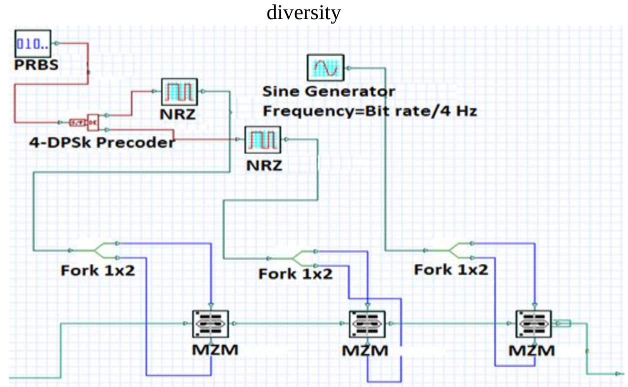
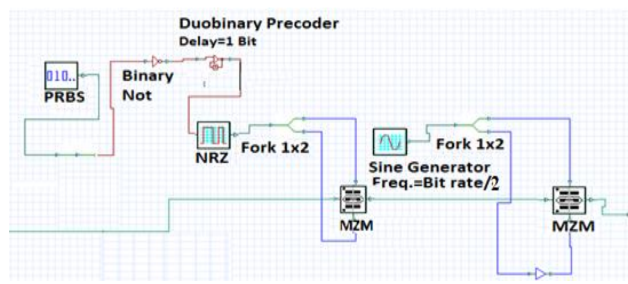


Fig. 1. Wavelength division multiplexed PON system using transmitter diversity



(a) DQPSK



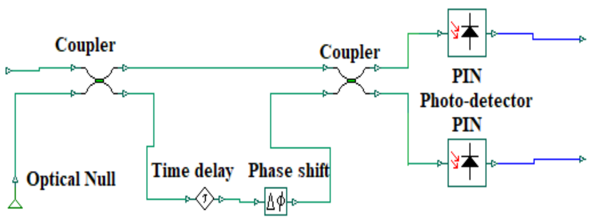
(b) DPSK at optical line terminal

Fig. 2. Simulation architecture

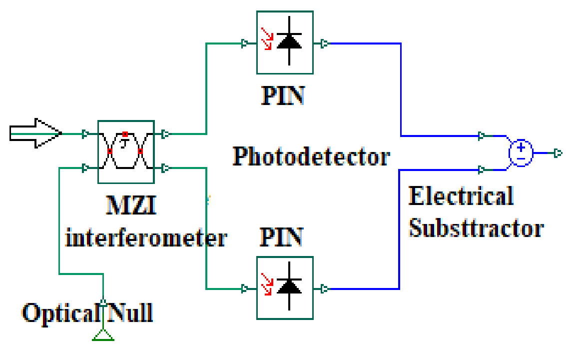
Table 1
Simulation parameters and their values

Parameters	Values
Bit rates(Gbps)	10 Gbps/channel
Type of encoding (Downstream/upstream)	DQPSK/NRZ, DPSK/NRZ
WDM channels	4
Channel spacings	100 GHz
Laser power	0 dBm
Sequence length	256
Samples per bit	64
Reference wavelength	1550 nm
Fiber length	40 km

Investigation of the WDM-PON system has been done and results are analyzed for downstream transmission in case of DQPSK and DPSK by varying the link length of the bidirectional optical fiber. Q factor is checked at different distances such as at 10 km, 20 km, 30 m, 40 km and 50 km. Fig. 5, depicts the performance comparison of DQPSK and DPSK in downstream when link length is varied.



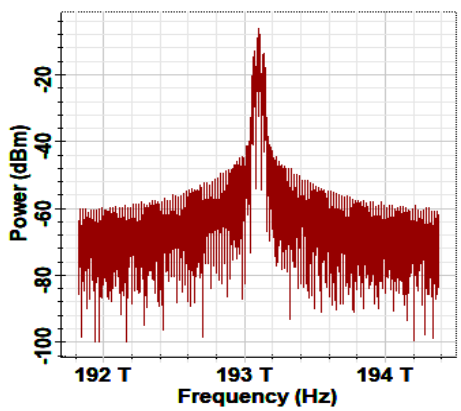
(a) DQPSK



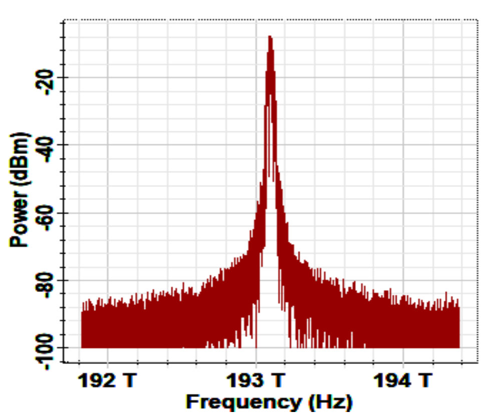
(b) DPSK

Fig. 3. Simulation structures

4. Results and Discussion



(a) DPSK



(b) DQPSK modulations at first WDM channel

Fig. 4. Optical spectrums

In proposed system, two different cases of downstream transmitters are considered such as in one using differential quadrature phase shift keying, and in other case DPSK is used in downstream. Optical spectrum of differential phase shift keying is depicted in Fig. 4 (a), differential quadrature phase shift keying in Fig. 4 (b). It is evident that the spectrum of DQPSK is bandwidth efficient due to narrow carrier spectrum.

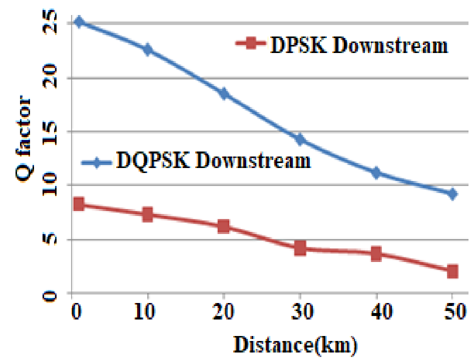


Fig. 5. Variation of Q factor at diverse link lengths in case of DQPSK and DPSK in downstream

It is evident that Q factor goes on decreasing when distance increases from 10 k to 50 km. Here, major factor for the decrease in Q factor is, increase in attenuation. At 10 km, value of attenuation is 2 dBm (10 km x 0.2 dB/km), and at 50 km this attenuation becomes 10 dBm. Therefore it deteriorates the amplitude level of the pulse. Besides attenuation effects, dispersion and scattering losses are also cause signal degradation. In downstream transmission, DQPSK is found out to be optimal because it shows high Q factor as compared to DPSK signal. DQPSK has four phase shift due to which dispersion effects are less. On the other hand DPSK has only two phase shifts and therefore it somehow prone to dispersion effects.

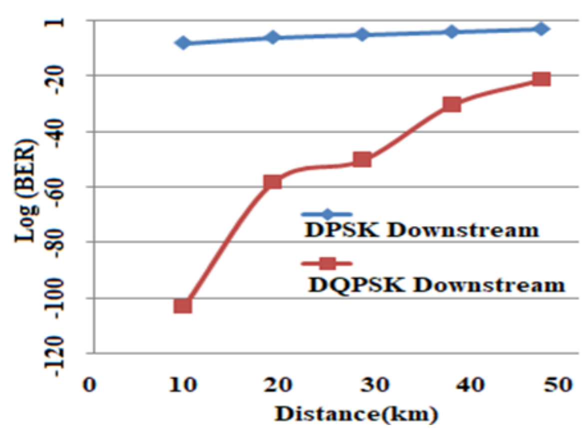


Fig. 6. Variation of log (BER) at diverse link lengths in case of DQPSK and DPSK in downstream

Fig. 6 depicts the log (BER) comparison of DQPSK and DPSK in downstream when link length is varied. It is perceived that more errors are observed in case of DPSK and lesser in case of DQPSK. Results reveal that increase in link length is a root cause of bit errors and BER increase with the increase in distance. Factor such as attenuation, dispersion and scattering are major issues. It is also important to notice that DPSK provide BER -9 upto distance of 15 km and after that it goes below the limits of ITU BER standard (-9). However, DQPSK system can cover distance of 50 km in downstream.

Further, performance of upstream is investigated for DQPSK-NRZ and DPSK-NRZ WDM passive optical networks at different distances. Due to the use of wavelength reuse, performance of upstream is always falls below downstream because each wavelength signal has to cover double distance i.e. 40 km downstream the 40 km upstream. NRZ is used in both cases and here different transmitter for transmitter and upstream are used to decrease the interference of downstream and upstream signals which is more when use of same modulations has been done for downstream as well upstream.

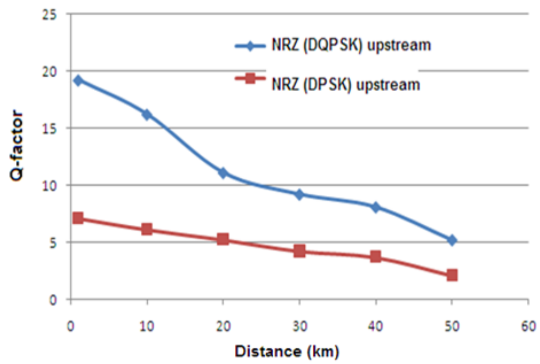


Fig. 7. Variation of Q factor at diverse link lengths in case of NRZ in upstream for DQPSK-NRZ and DPS-NRZ arrangement

It is quite obvious from Fig. 7, that performance of NRZ in upstream is better when DQPSK used. DQPSK signals are better in downstream as a result it provides better carrier signal to NRZ for upstream

Eye diagram is an important decision representation of received signals which provide information about Q factor, BER, eye height, eye opening and eye closer. Eye diagram analyzer is end component which shows high Q and low error when eye is wide open. Also jitter is low when eye height is more in the eye diagram. Fig. 8 shows the eye diagram of downstream signal at 40 km when DQPSK is used in downstream and NRZ in upstream.

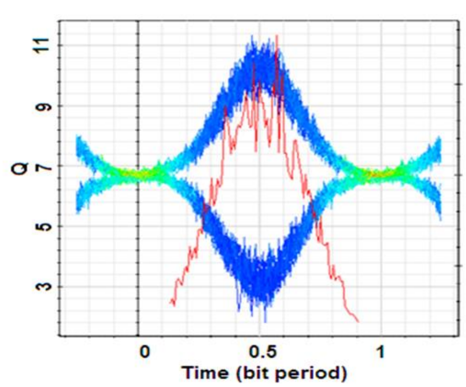


Fig. 8. Eye diagram of DQPSK-NRZ arrangement in downstream at 40 km

Similarly, eye diagram analyzer are also used in upstream performance evaluations of the signals and it is evident from Fig. 9, that eye is open for 40 km link distance when DQPSK is used in downstream NRZ s used in upstream. However, eye opening is less in upstream as compared to downstream because there are more attenuation effects in upstream and also carrier is already covered 40 km distance prior to re-modulation.

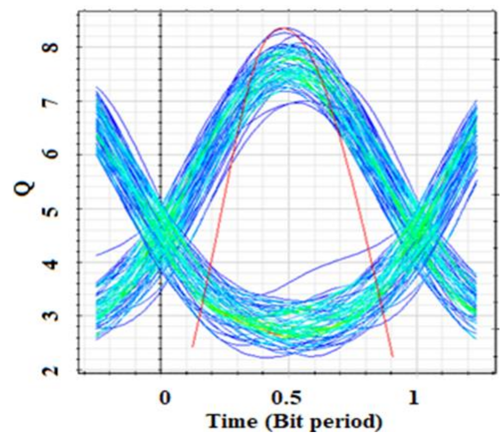


Fig. 9. Eye diagram of NRZ in upstream in DQPSK-NRZ arrangement

5. Conclusion

In this work, attention is given on the design of wavelength division passive optical networks employing transmitter diversity for the suppression of crosstalk among downstream and upstream users. A 4 x 10 Gbps WDM PON system is demonstrated at 100 GHz frequency spacing and two different cases of transmitter diversity are compared such as DQPSK-NRZ and DPSK-NRZ passive optical networks. Moreover, in order to provide cost effectiveness, wavelength reuse is done with the incorporation of RSOA amplifier in upstream. Results revealed that performance of DQPSK is better than DPSK due to four phase shifts which keep the dispersion effects lower and also provide bandwidth efficient carrier spectrum. It is also perceived that downstream transmission surpasses the performance of upstream transmission. Eye opening is more in DQPSK-NRZ system and system successfully covered 50 km link distance on both sides in this case. However in DPSK-NRZ, system has potential to cover only 20 km distance. Therefore, DQPSK in downstream and NRZ in upstream is an optimal combination.

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