Performance Analysis of Downlink Transmission in WDM-PON using Manchester and Dicode Coding

M. Sudha, D. Helena Margaret
Department of Electronics and Communication Engineering, Alagappa Chettiar College of Engineering and Technology, Karaikudi, Tamil Nadu, India

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Abstract
The Reflective Semiconductor Optical Amplifier (RSOA) based Wavelength Division Multiplexed Passive Optical Network (WDM-PON) is a low cost solution that allows colorless operation for optical network units (ONUs). The main approach of this work is to include the level coding technique which involves the spectral shaping and to increase the maximal allowable downstream extinction ratio using remodulation scheme. The main objective of this work is to apply the correlative dicode and Manchester code in the downlink of WDM-PON with remodulated upstream signal. Moreover the system reach is extended by 75 km to 95 km with 10 Gbps downstream is demonstrated. The proposed technique correlates the signal levels via encoding the original data stream to reform the signal spectrum with much less low-frequency components. On the performance of dicode coding in single- fiber WDM-PONs, it produces great robustness against remodulation and reflection noises.

1. Introduction

Wavelength Division Multiplexing (WDM), has proven more cost effective in many systems. It allows using current electronics and current fibers, and their shares fibers by transmitting different channels at different wavelengths (colors) of light. In WDM each communication channel is allocated to a different frequency and multiplexed onto a single fiber.

A passive optical network (PON) is a point-to-multipoint, fiber to the premises (FTTP) network architecture in which unpowered optical splitters are used to enable a single optical fiber to serve multiple instance. A PON consists of an Optical Line Terminal (OLT) at the Central Office (CO) and a number of Optical Network Terminals (ONTs) at the customer premises. A PON configuration reduces the amount of fiber and central office equipment required compared with point to point architectures.

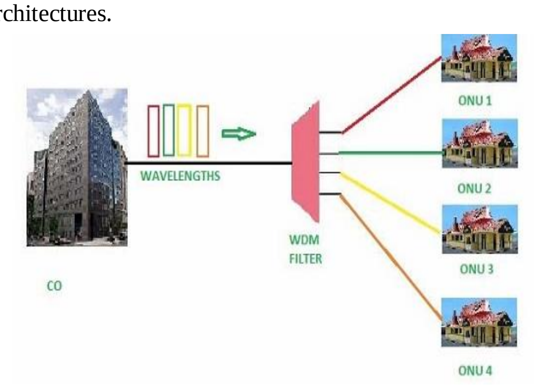


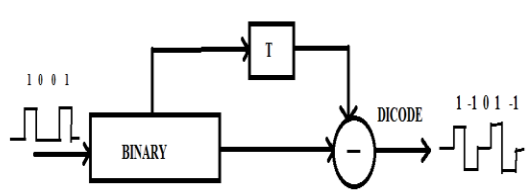
Fig: 1. WDM-PON Architecture

The PON networks use WDM (wavelength-division multiplexing) with different wavelengths upstream and downstream. The PON architecture can be easily supported more wavelengths, and to allow greater bandwidth to the user, by allocating one wavelength to a user or a group of users or greater security by was each user having their own wavelength. Wavelength division multiplexed – Passive Optical Network (WDM-PON) has been considered for a long time as one of the most powerful solutions for the next-generation broadband access network.

2. Dicode Coding

Communications systems transmit signals by means of a number of coding techniques electrical or optical. In electrical transmission voltages may swing between a negative and a positive level, in optical transmitted light may change between a no light conditions to some light intensity level, there is negative voltage but no negative light. Correlative coding, the idea is to introduce a controlled amount of ISI(Inter Symbol Interference) into the signal rather than trying to eliminate it completely. This can be compensated for at the receiver, thereby achieving the ideal symbol-rate packing of 2 symbols per Hertz, but without the requirements of unreliable filters.

Dicode coding is one of the type of correlative level coding and this technique correlates the signal levels via encoding the original data stream to reform the signal spectrum with much fewer low frequency components. This correlative level (CL) coding scheme reduces crosstalk penalties via altering the signal spectrum to separate it from the interferers. Previously spectral-shaping methods have been proven effective in RB (Rayleigh Backscattering) reduction. In contrast, the utilized CL coding has the advantages of simplicity and zero overhead.



Corresponding Author,
E-mail address: sudhamuthugovindaraj@gmail.com

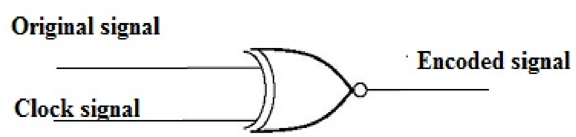
Fig: 2. Dicode Encoder

Dicode code is characterized by its transfer function (1-D) the dicode coding process as a delay-and-subtract register that can be simply realized by a delay line and a power combiner. In order to treat the correlated signal levels independently in the decoding process, the original binary message needs to be differentially coded prior to the CL encoding. Fig. 2 sketches the procedures of the differential precoding realized by a delay line and two logical gates. He dicode-coded symbol in Fig. 2 have a one-to-one relationship with the original binary symbols. Then, the dicode decoding can be conducted bit-by-bit, following the rule that level "1" and "-1 "corresponds to binary "0," and level "0" corresponds to binary "1." Hence, the decoding can be simply accomplished by means of a full-wave rectifier.

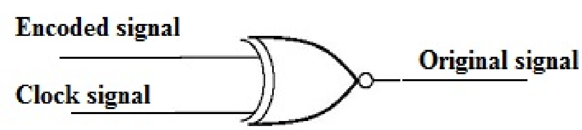
3. Manchester Coding

Manchester coding is one of the most common data coding method. Manchester coding states that there will always be a transition of the message signal at the mid-point of the data bit frame. What occurs at the bit edges depends on the state of the previous bit frame and does not always produce a transition. A logical "1" is defined as a mid-point transition from low to high and a "0" is a mid-point transition from high to low.

A data bit '1' from the level-encoded signal is represented by a full cycle of the inverted signal from the master clock which matches with the '0' to '1' rise of the phase-encoded signal i.e. -V in the first half of the signal and +V in the second half. The data bit '0' from the level-encoded signal is represented by a full normal cycle of the master clock which gives the '1' to '0' fall of the phase-encoded signal. i.e. +V in the first half of the signal and -V in the second half.



(a)



(b)

Fig: 3(a). Manchester encoder **(b).** Manchester decoder

4. System Design

In this system, the DS signals are externally modulated onto different carriers and wavelength multiplexed by an arrayed waveguide grating (AWG) at the OLT, before being launched into the feeder fiber. After demultiplexing, at the O NU, a portion of the received DS signal is detected by the US receiver, and the other portion is delivered to the RSOA for amplification and remodulation. The remodulated US signal is reflected back and transmitted through the same fiber to the OLT.

Since the US and DS signals are operated at the same wavelength band, a circulator is used to separate these two groups of signals at the OLT. Afterward, the US signals can be demultiplexed by an AWG and sent to their respective receivers.

If the same modulation format is used for both US and DS directions, the residual DS signal and the remodulated signal will fall in the same frequency band, causing intensity fluctuations in the mark level of the US signal. Operating the RSOA in gain saturation can minimize the remodulation noise, but demanding high input power to the ONU and shrinking the power margin.

In this network, the dicode level coding and the Manchester coding is applied in the downlink which usually works at a higher bit rate than the uplink, while the ONU sends the uncoded NRZ signal to the OLT.

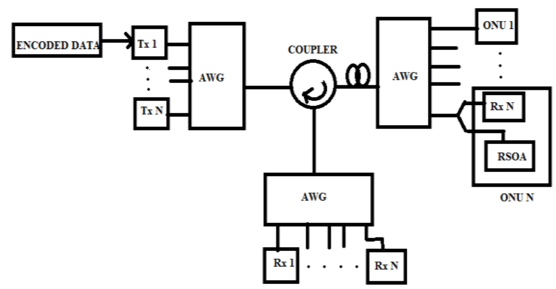


Fig: 4. Block diagram of proposed system

The adopted dicode coding can restrain the intensity noise and allows high (ER_{d}), since the spectral overlap of the DS and US signals is greatly decreased, thus, the system power budget increases since gain saturation at the user terminal is no longer compulsory.

5. Simulation

The proposed wavelength-reused system is experimentally demonstrated on one channel at 1550 nm. At the OLT, 10 Gb/s DS signal is generated by externally modulating a 20 GHz electro absorption modulator (EAM). The signal is then launched into a variable length of SMF. Two optical band pass filters (OBPF) at the ends of the fiber simulate the AWG. Inside the user module, the received DS signal is split by a 50:50 optical coupler into two paths: one is detected by the DS receiver, and the other is fed to an RSOA with a 3dB bandwidth of 1GHz. The DS receiver consists of a 20 GHz PD, an HPF with 150MHz cut off frequency of the dicode DS signal to suppress the crosstalk caused by the reflected US signal, and a 10.5 GHz LPF to minimize other noises.

The electrical subtractor and the ex-nor gate produces the electrical output, here the electro absorption modulator was used to convert the electrical signal into an optical signal and this optical signal was passed to the circulator.

The circulator was used to combine or split the signals. This signal was transmitted using standard single mode fiber and it is amplified using a variable optical amplifier, after the amplification the power splitter was used to split the signals into two. The first one going to the RSOA for upstream transmission and the second passes through the PIN photo detector for downstream receiver.

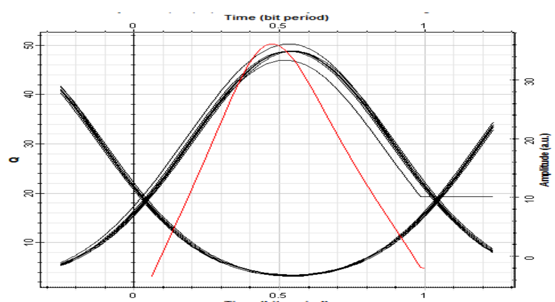
6. Results and Discussion

Downstream transmission (i.e., from OLT to ONU) in a WDM PON requires a multi-wavelength source at the OLT and a wavelength demultiplexer which acts as a branching device. The transmission of downstream at 10Gb/s, the effects like Rayleigh Back scattering, discrete reflection and noises have been analyzed. The Bit Error Rate (BER), Quality factor, signal amplitude, and their comparisons are also analyzed. The transmission of downstream signal at 10Gb/s was analyzed using various encoding techniques like decodes and Manchester coding. In the proposed system the continuous wave pump power is constant at 15 dBm and the fiber length was varied from 75 km to 95 km.

The eye diagram is an oscilloscope display in which a digital signal at the receiver side is repetitively sampled to get a good representation. This diagram is created by taking the time domain signal and overlapping the waveform at a time window of certain multiple bit periods and it is a very useful tool for the qualitative analysis of signal used in digital transmission. It provides at an evaluation of system performance and can offer insight into the nature of channel imperfections.

In general, the following features of the eye diagram are defined

- Eye opening (height, peak to peak): a measure of the additive noise in the signal,



- Eye overshoot/undershoot: a measure of the peak distortion,
- Eye width: measure of timing jitter effects.

The fig 5. (a) is the quality factor diagram for dicode coding at 75 km. From this diagram the signal strength is high. The slope indicates the timing error of the signal, here we can get the smaller slope. The eye opening of this diagram is better, so it produces less additive noise. The Table 1 produces the quality factor, minimum bit error rate (BER) and eye height of various fiber lengths of 75 km to 95 km.

Fig: 5. Eye diagram of downstream transmission at 75 km using (a) dicode coding

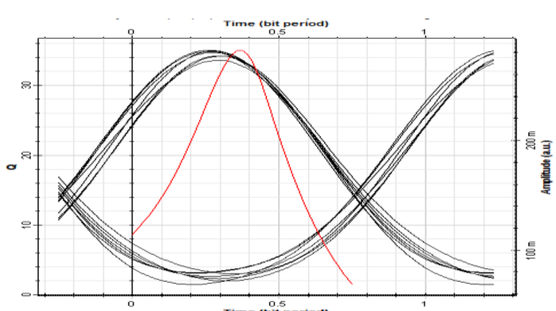


Fig: 5. Eye diagram of downstream transmission at 75 km using (a) Manchester coding

Table: 1. Analysis of Dicode coding with different lengths

Sl. No	Power (dBm)	Length (km)	Q-factor	BER	Eye Height
1	15	75	37.5465	3.00504e-284	0.178365
2	15	80	25.6087	5.65075e-145	0.131238
3	15	85	22.1707	2.86107e-109	0.100198
4	15	90	17.8466	1.37235e-071	0.072380
5	15	95	15.7000	7.30918e-056	0.054518

The fig 5. (b) is the quality factor diagram for Manchester coding at 75 km. From this diagram the signal strength is low compared to fig 5.(a). The slope indicates the timing error of the signal , here we can get the smaller slope. The eye opening of this diagram is deviated, so it produces high additive noise. The Table 2 produces the quality factor, minimum bit error rate (BER) and eye height of various fiber lengths of 75 km to 95 km.

Table: 2. Analysis of Manchester coding with different Lengths

Sl. No	Power (dBm)	Length (km)	Q-factor	BER	Eye Height
1	15	75	35.0046	8.89286e-269	0.182726
2	15	80	21.194	4.8112e-100	0.130164
3	15	85	19.3946	3.97512e-084	0.101143
4	15	90	16.9711	6.08004e-065	0.0725552
5	15	95	14.2317	2.9064e-046	0.0517631

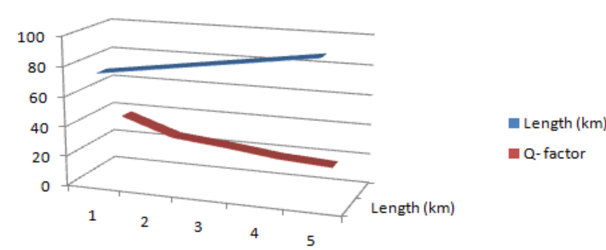


Fig: 6. Graphical Representation of Length vs Quality Factor (a) Dicode Coding

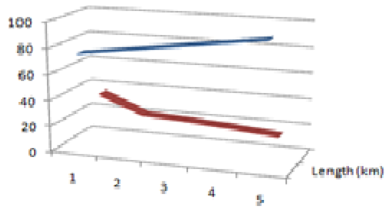


Fig: 6. Graphical Representation of Length vs Quality Factor (a) Manchester Coding

The fig 6 produces the graphical representation of various length with corresponding quality factor. From this figure, if the length is increased then the quality factor is decreased in both dicode and Manchester codings.

7. Conclusion

Thus the cost-effective technique to mitigate the reflection noise in WDM-PON based on various level coding techniques and centralized light generation was presented. The proposed dicode coding with small complexity compared to Manchester coding, which enables spectral shaping and adds no over-head. We apply the modulation techniques in the downlink of the WDM-PON with remodulated US signal.

In this case, the system's reflection tolerance is substantially enhanced via the dicode-coded modulation in the downlink.. In this system, a 75 km to 95 km full-duplex WDM-PON with 10 Gb/s various coded downlink with remodulated uplink is demonstrated with great robustness against remodulation noise and reflection noise.

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