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An Optimized Full duplex Multi Carrier based WDM Passive Optical Access Network

J. KHAN, Y. KHAN++, W. A. IMTIAZ, S. ULLAH

School of Electrical Engineering, Iqra National University (INU) Peshawar, Pakistan

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Abstract: Wavelength division multiplexed passive optical access network (WDM-PON) is anticipated to provide desirable data rates to maximum number of subscribers. However, the use of highly coherent lasers at optical line terminal (OLT) and optical network unit (ONU), limits the deployment of WDM-PON at access domain. This paper proposes an efficient architecture for the implementation of WDM PON by using multi-carrier generation at OLT. A 2.5 Gbps DPSK Signal is implemented at OLT, whereas ON /OFF keying (OOK) scheme is utilized at ONUs for upstream transmission. Simulation analysis using Optisystem shows that the proposed system is able to provide high data symmetric transmission up to 2.5 Gbps. Thus, the proposed multicarrier WDM-PON is cost effective and scalable, and it is successfully verified according to feasibility.

Keyword: Passive Optical Access Network; Multicarrier Signal; Multiplexing/De multiplexing;; bit error Ratio

1. INTRODUCTION

In today's modern world the demand for higher transmission rate with emerging telecom services like Broadband, CATV, HDTV, Video conferencing and internet gaming is swelling day by day. According to the Cisco forecast project between the years 2009-2014 the data traffic is increased 60 percent and will continue to grow exponentially (Chang, *et al.,* 2009; Chen. *et al.,* 2012). To cater for such higher demand, the researchers are being urged to think out of the box solution and apply more innovative techniques for higher capacity network (Chen. *et al.,* 2013). One of the promising solutions to satisfy such a high traffic demand is the deployment of passive optical network as wired access network. A WDM-PON, due to high quality of service is considered as one of the best option to replace the existing access network (Chraply *et al.,* 2009; Tian. *et al.,* 2013).

A number of research groups around the world are addressing diverse aspects of WDM-PON, including modulation formats, coding schemes and minimization of impairments (Hillerkuss. *et al.,* 2012; Li *et al.,* 2014). A new domain of research, the realization of a stable DWDM carrier source and its effective implementation has many challenges ahead before becoming a mature adopted industrial solution. Recently many multicarrier schemes have been investigated to generate low noise multicarrier source (Xie. *et al.,* 2010; Mirza *et al.,* 2009). Numerous schemes have been proposed for the generation of multicarrier signals at OLT (Yeh, 2011 Zhang. *et al.,* 2011). However, these schemes are not considered efficient and cost effective for a duplex multicarrier system. Expensive electrical components used in these systems make it overpriced to implement.

This paper proposes an optimized full duplex wavelength division multiplexing PON by implementing multi carrier signal for downstream and wavelength reuse for upstream transmission in this paper. Performance of the proposed architecture is analyzed by referring to bit error rate (BER) at both up- and down-stream transceivers.

Rest of the paper is organized as; section 2 describes the Principal of Multicarrier Generation while section 3 demonstrates the Network architecture and simulation setup. Transmission performances have been discussed in section 4 and in the last section 5 conclusion of the paper is discussed.

2. PRINCIPLE OF MULTICARRIER GENERATION

The schematic configuration of WDM-De-MUX based multicarrier generator is shown as in the **(Fig.1)**. For the proposed multicarrier generator, LASER source is directly connected with the phase modulator driven by RF signal, which is amplified by electrical amplifier. Modulated signal is passed through 4-channeled WDM De-MUX giving four optical signals of different wavelengths. For the 4×2.5Gb/s WDM De-MUX based DPSK transmitter, four peaks are separated by WDM De-MUX where each individual signal is modulated by DPSK modulator. The four generated signals are amplified by EDFA for stability after passing through WDM De-MUX, which give strong signals of good

++Corresponding author's yousafkhalil@gmail.com, khanjehanzeb5@gmail.com

Tone to Noise Ratio (TNR) to transmit NRZ-DPSK signals through 25Km in standard single mode fiber in passive optical access network having wavelength from 1554.40nm-1551.99nm. The signals from all four DPSK transmitters are multiplexed together before transmission. On receiver side, four DPSK based receivers are used for detection of signals. BER testers are used on the receiver side, which gives good results.

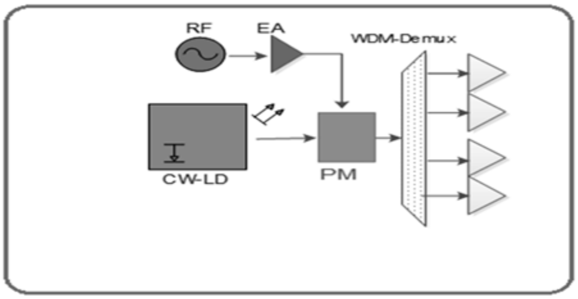

Fig.1: Proposed Multi carriers Generator

The experimental results for four multicarrier signals are shown as in **(Fig.2)**. Output of laser is modulated by boosted RF signal which is boosted by electrical amplifier (EA). Peak to peak voltage of signal after EA is 20V. We used PM in multicarrier generation, because it offers excellent stability of carriers, and for PM there is no DC bias required for its operation. Output of PM is passed through WDM De-MUX, which gives four signals of different amplitudes, which become stable after passing through four parallel EDFAs.

While using 7dBm launch power of laser and the boosted power of RF signal up to 20dB, gave us noise free carriers having TNR up to 20 dBm, and having 1.5 dBm of amplitude difference. In all these experiments the bandwidth of WDM De-MUX was 10 GHz, and insertion loss was kept at 0dB, while the wavelengths at four channels were 1554.40nm, 1553.59nm, 1552.79nm and 1551.99nm. Fig.2A, 2B shows the generated four noise free optical multicarrier.

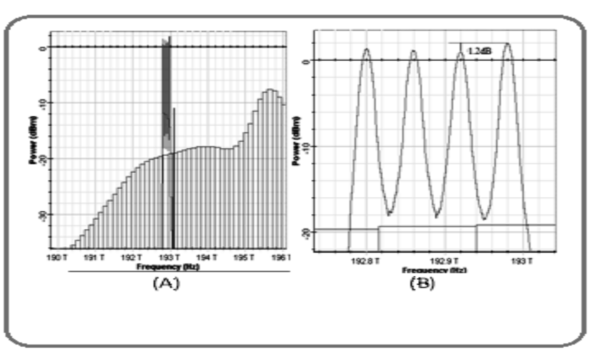

Fig.2: Generated Multi carriers

3. MATARIALS AND METHODS

Network Architecture and Simulation Setup

The proposed multicarrier signals generated from a single source is used to realize bidirectional transmission in WDM-PON. **(Fig.3)** demonstrates the network architecture for downstream transmission. The Optical Line Terminal (OLT) containing one laser diode (DFB-LD) which worked as a multicarrier source and generates four optical carriers having four different wavelengths of λ1 to λ4. The four multicarrier signals are used to generate downstream DPSK signals. The four downstream 2.5-Gbps modulated DPSK signals are multiplexed and over a standard 25 Km single mode fiber (SMF). A WDM Mux and De-MUX used on transmitter and receiver side having bandwidth and frequency spacing of 100 GHz and 193.0THz, respectively. With a half power splitter, a part of the downstream received optical power is tapped off at ONU. DPSK signal of constant intensity is demodulated with the help of balanced photo diodes and 1-bit delayed interferometer (DI) (Zhang. *et al.,* 2011; Zhu, *et al.,* 2011) at the receiving end.

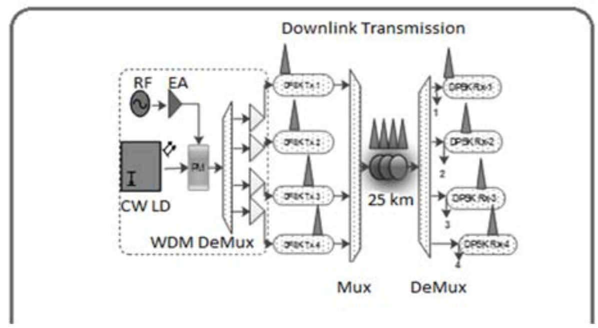

Fig.3: Network Architecture for Downstream Transmission

The downstream optical signal at ONU is further utilized by re-modulating the received spectrum through a 2.5-Gbps RZ-OOK. The resulting OOK modulated upstream signal as shown in Fig.4 is transmitted in the upstream direction through same 25 Km SMF.

Transmission performance of the proposed multi-carrier based WDM-PON is analyzed by implementing system model in Optisystem as per the network architecture shown in **(Fig-3**) and **(Fig.4)**. A combiner is used to superimpose 2.5 Gbps pseudorandom bit stream (PRBS) data of order 27^{-1} over a 5GHz clock. The LN-MZM modulator is used to external modulate the superimposed signal to generate downstream RZ shaped DPSK signal. Four multicarrier signals are generated at OLT from a single distributed feedback lasers (DFBL). The signals are further modulated to generate a DPSK signal at OLT at wavelengths of 1554.40nm, 1553.59nm, 1552.79nm and 1551.99nm. End-face of DPSK modulator is connected to a 25 Km Standard (SSMF).

A half power splitter, at the receiving ONU, divides the downstream signal. One leg of the splitter is connected to a de-modulating arrangement; whereas, another leg is fed into frequency re-use setup. Intensity modulation technique is used to re-use the received DPSK modulated signal for up-stream transmission. The general settings of the fiber used in our simulation are given in **(Table 1)**.

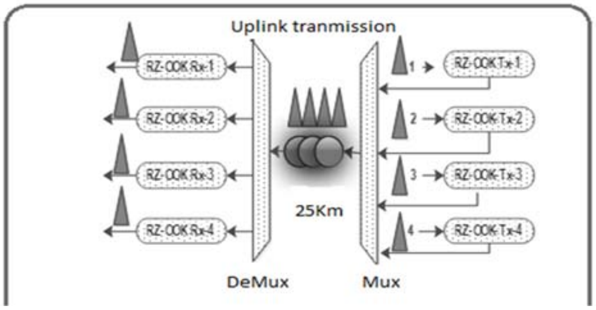

Fig.4: Network Architecture for Upstream Transmission

Table.1: Simulation Parameters

Parameter	Value
Standard Single Mode Fiber Length	25Km
Dispersion of SSMF	16.75ps/nm/km
Dispersion slope of SSMF	0.075ps/nm^2/km
Differential Group Delay of SSMF	0.2ps/km
Reference wavelength of SMF	1550nm
Effective core area of fiber	80um^2
Dark Current of Photo detector	10nA
Responsitivity of Photo detector	1A/W

4. RESULTS AND DISCUSSION

Transmission capacity, in terms of data and reach, of proposed multicarrier LD WDM-PON is analyzed by referring to BER at both up and down-stream transmission. For simplicity purpose, BER at channel 1 and channel 3 are analyzed by observing eye diagram and BER. Moreover, power received at selected channels is also analyzed to determine power penalty in the proposed multi carrier LD based WDM-PON.

(Fig-5) shows relation of BER versus power receiving at PIN photo-diode for back to back (B2B) scenario and after 25Km transmission over SMF. It is observed that the proposed multicarrier generation is able to support high transmission capacity at nominal BER $1x10^{-9}$. Moreover, it is shown that the downstream transmission power penalties of Ch.1 and Ch.3 are 0.8 and 0.5 dB respectively.

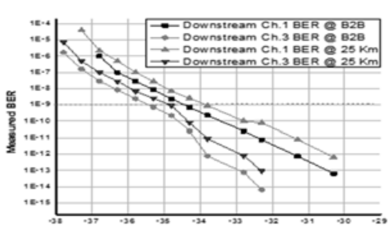

Fig5: BER vs Received Optical Power Downstream Ch.1 and Ch.3

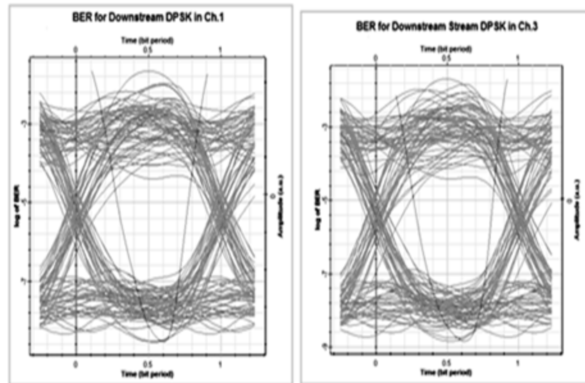

Fig.6: Eye diagram for Downstream DPSK signal for Ch.1 and Ch.3

(Fig.7) shows the performance of the proposed system in upstream direction by referring to BER and received optical power at channel 1 and 3 respectively. It is shown that the proposed setup is able to provide desired performance in up-stream transmission as well by maintaining nominal BER for data rates of up to 2.5 Gbps.

Eye diagram analysis provides various performances such as an opened eye pattern indicates minimal signal distortion and a closed eye pattern reflects distortion of signal due to inter-symbol interference (ISI) and noise. Eye diagrams of downstream DPSK and upstream OOK for Ch.1 and Ch.3 are shown in **(Fig.6,7)** and **(Fig.8)** respectively. Good eye openings ensure high transmission performance in both up and down-stream transmission for the proposed multicarrier LD based WDM-PON architecture.

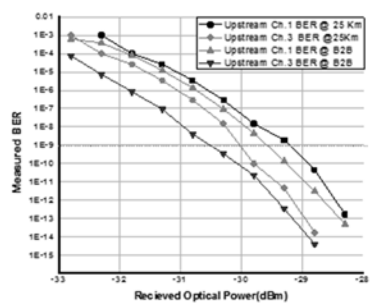

Fig.7: BER vs Received Optical Power for Upstream Ch.1 and Ch.3

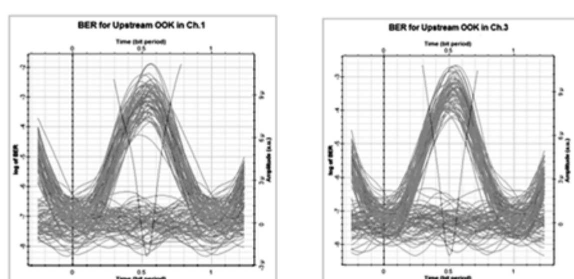

Fig.8: Eye Diagram for Upstream OOK signal for Ch.1 and Ch.3

5. CONCLUSIONS

This paper proposes and demonstrates a colorless multicarrier Laser Diode based WDM-PON architecture for providing the desired transmission capacity at minimum and cost effective manner.. The multicarrier generation is realized by cascading phase modulator and WDM De-MUX at OLT. At the optical line terminal, DPSK modulated data signal at 2.5-Gbps is utilized for downstream transmission. A part of the downstream signal is re-modulated by using an intensity modulated OOK technique for upstream transmission at the optical network unit. Performance analysis using Optisystem shows that the proposed setup can provide error free colorless transmission over 25 km SSMF in both up- and down-stream transmission. Moreover, the proposed setup can significantly reduce the cost of tradition WDM-PON by replacing multi LDs at OLT with a single multicarrier LD, which is able to provide the desired performance.

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