International Journal of Engineering and Advanced Technology (IJEAT)
ISSN: 2249-8958 (Online), Volume-4 Issue-1, October 2014

Integrated All-Optical OFDM –WDM Transmission of 4x2.5Gbps Data Over 50km for a Radio Over Fiber Network

Sreedevi Prasanna, Vijayakumar Narayanan

Abstract— The proposed system integrates all-optical OFDM with Wavelength Division Multiplexing, and the performance is evaluated for 4X2.5Gbps RoF network. The proposed system is designed and simulated using Optisystem11.0 and the performance of the system is studied using Bit Error Rate analyzer. The photo detector noise is optimized to achieve a min BER of 10^{-9} for both upstream and downstream transmission.

Index Terms— All-optical OFDM, Mach Zehnder modulator (MZM), Radio over fiber (RoF), Wavelength Division Multiplexing (WDM).

I. INTRODUCTION

Transmission of data above gigabytes, paved way to all-optical transmission, especially all-optical OFDM which enables wide band data to be transmitted over narrow band parallel channels. All optical technology always has higher data rate than electronic system [1-3]. OFDM is generated by electronic Fast Fourier Transform or Hartley Transform .But achieving OFDM by electronic processors is quite challenging for data rate of 100Gbps or above. Wavelength Division Multiplexing sends a set of um-modulated wavelength along with the downstream data [4][5], which carriers the data of optical network units (ONU) in the upstream direction. The need for increased capacity and frequency channel in future will lead to reduction in size of base stations. Reduction in size will lead to more number of small base stations. Reducing cost of base station will considerably reduce the entire system cost. Replacement of optical source at the ONU by means of source at the central station reduces the overall system cost. In a RoF network, the radio signals are transported between the central and base station. The RF signals that carries data is modulated by optical source to tera hertz frequency and is transmitted on to optical fiber. The received data is converted to electrical domain at the base station and is transmitted to the mobile terminal [6] [7].

Manuscript published on 30 October 2014.
* Correspondence Author (s)
Sreedevi Prasanna, Fiber and Photonics Research Laboratory, Department of Electronics and Communication, College of Engineering Trivandrum., Thiruvananthapuram, Kerala, India.
Vijayakumar Narayanan, Department of Electronics and Communication, Govt. Engineering College Barton Hill, Thiruvananthapuram**,** Kerala**,** India.

II. ALL-OPTICAL OFDM

All-optical OFDM is generated by passively integrated optical components. In the present paper, all-optical OFDM is generated by means of optical modulators [8] [9]. The optical pulses are orthogonalised by means of Mach-Zehnder modulator according to equ.1.

$$E_{o1}(t) = E_{i1}(t)\cos\big(\Delta\alpha(t)\big).\exp\big(j\Delta\beta(t)\big) \qquad (1)$$

Where

$\Delta\alpha(t)$ is the phase difference between two arms of the modulator and $\Delta\beta(t)$is the signal phase change

III. THE PROPOSED ALL-OPTICAL OFDM-WDM SYSTEM

4x2.5Gbps all-optical OFDM system incorporating wavelength division multiplexing is designed for upstream and downstream transmission using Optisystem11.0. The signal parameters for both the transmission is shown in Table1.

Table 1

Parameter	Upstream	Downstream
Data rate	4x25Gbps	4x25Gbps
Coding	NRZ	NRZ
RF carrier	20GHz	20GHz
Signal power	10dBm	0dBm
Sequence length	128	128
Samples/bit	64	64
Number of samples	8192	8192

The parameters are chosen such that a better performance is shown by the proposed system. The upstream wavelength λ_{us} is transmitted at high power compared to downstream wavelength λ_{ds} to obtain satisfactory bit error rate (BER). Separate wavelengths are used for upstream λ_{us} and downstream transmission λ_{ds} .

Published By:
Blue Eyes Intelligence Engineering and Sciences Publication (BEIESP)

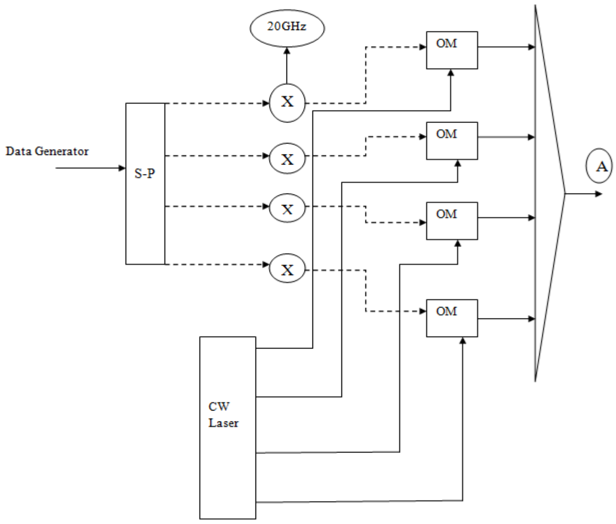

Fig. 1 CW-Laser all-Optical OFDM Downstream Transmission

The signal from the optical source modulates the 20GHz RF data, which is further orthogonalised or multiplexed by means of optical modulator. The optically modulated spectrum of the data is placed at a frequency spacing of 100GHz. The frequency of the cw-laser is controlled along with the spectrum of the optically modulated signal so as to match with the transfer function of the modulator. By controlling the frequency of the optical source we achieved better orthogonality between subcarriers. $LiNbo_3$ MZM is used as the optical modulator in the proposed system so as to achieve single side band modulated signals (SSB). Generation of SSB is done so as to conserve the bandwidth; there by bandwidth efficiency of the system is improved. The orthogonalised signal from the modulator is combined and transmitted. As a part of remote modulation [10], a set of un-modulated wavelength λ_{us} is sent along with the all-optically modulated downstream data by wavelength division multiplexing. The switch placed in the add-drop module allows choosing the number of wavelengths to be dropped to modulate the data placed at different ONU's.

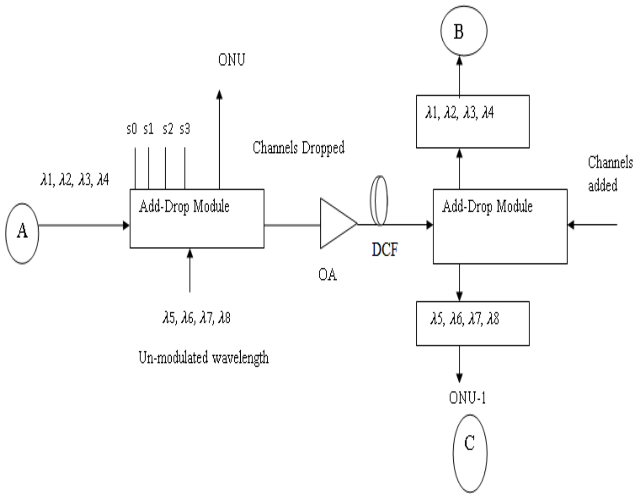

Fig. 2 Downstream Optical Link

All-optical signals are demultiplexed and received at BS-1. The same BS makes use of the un-modulated wavelength to generate all-optical OFDM in the upstream direction at different ONU's. The upstream data requires high signal power compared to the downstream data to achieve a better performance of BER.

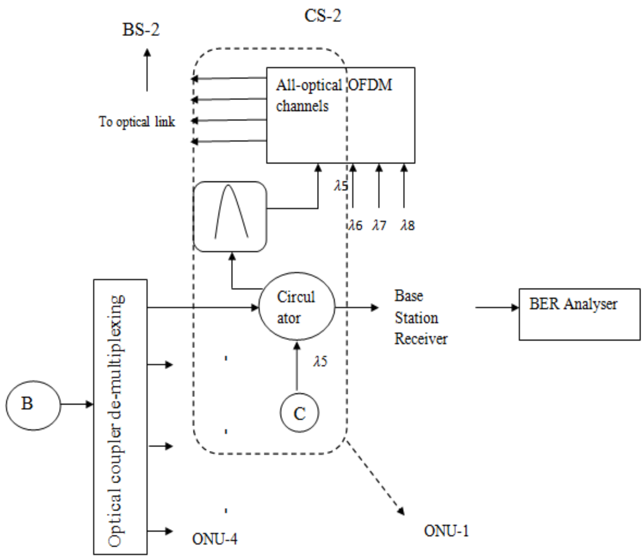

Fig. 3 Upstream Transmission/Reception

IV. SIMULATION RESULTS

The central station is composed of optical sources for both downstream and upstream transmission. The system is simulated for four channels in both upstream and downstream directions. The baseband data narrowed to four channels, each of which are up converted to a frequency band of 20GHZ is optically modulated by $LiNbo_3$ MZM. Optically generated OFDM at the MZM outputs are being modulated by means of downstream wavelengths λ_{ds} , ranging from 193.1THz with a frequency spacing of 0.1THz each . The input to one of the arms of all $LiNbo_3$ MZM is phase shifted to suppress double side band. Add-drop module designed making use of WDM principle at the central station; is controlled by switches which conveniently allow adding and removing of any number of channels. All-optical OFDM data along with the upstream wavelengths λ_{us} ranging from 194.1THZ with a frequency spacing of 0.1THZ for remote modulation ,as shown in Fig.4 is received at BS-1. The un-modulated wavelengths have slightly high power; nearly equal to 10dBm while the power of modulated wavelengths dropped below 0dBm due to fiber non-linearity.

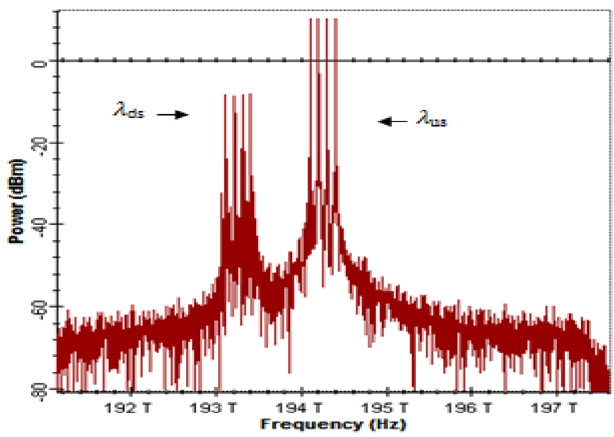

Fig. 4 Transmitted Spectrum

Published By:
Blue Eyes Intelligence Engineering
and Sciences Publication (BEIESP)

ISSN: 2249-8958 (Online), Volume-4 Issue-1, October 2014

To achieve a signal to ratio of 20dB which is an acceptable level in case of optical signal, an optical amplifier is placed in the optical link, where it is designed to operate under gain control mode. Fig.5 shows the time domain signal of the received signal, with no overlap. By means of proper design of optical modulators and signal source, we could achieve better orthoganality of received signal. The un-modulated wavelengths are dropped at the receiver by means of add-drop module, while the modulated signals have been directly detected by means of p-i-n detector. Very clear eye opening are seen in the eye diagram of the downstream received signal as in Fig.6. This shows that data is well detected under the presence of optical noise. The central portion of the eye diagram corresponds to carrier frequency of the transmitted signal carrying data in the downstream direction. The thermal noise of the detector is optimized to 0.9999999999999997e^{-024} W/Hz to achieve performance as shown in Fig.6. The extinction ratio of the receiver is set as 15dBm. Fig.7 shows the variation of min BER and Q-factor with the bit period of the received signal of the first channel received. As all the channels in the downstream channels exhibit almost same eye pattern, rest of the channels also shows almost same performance for the parameters shown in Fig.7.

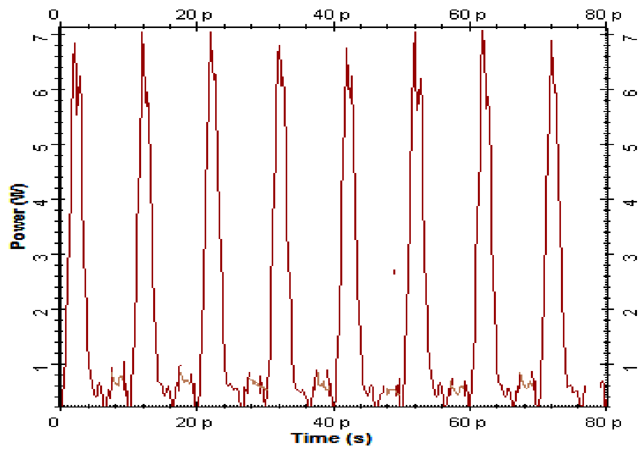

Fig. 5 Received Signals

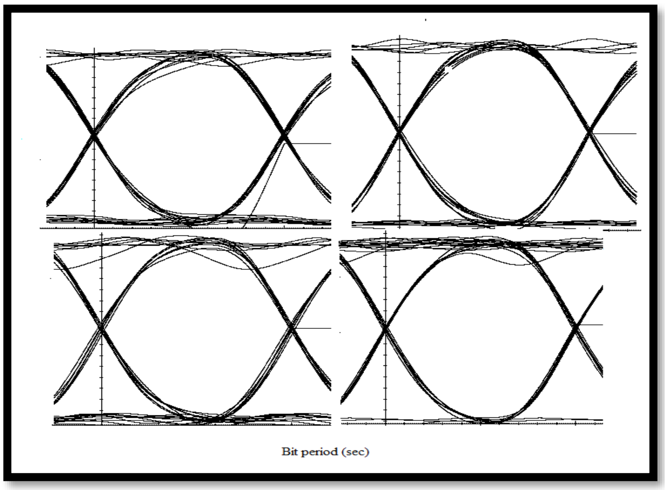

Fig. 6 Eye Diagram of the Four Downstream Channels

The central portion of the received signal where the data is present, exhibits a minimum log BER of nearly -90 which is below the min BER of 10^{-9} for a Q factor of more than 20. The system achieved this performance level with a signal power of 0dBm. The performance of the system can be improved by increasing the signal power and compensating for optical amplifier noise.

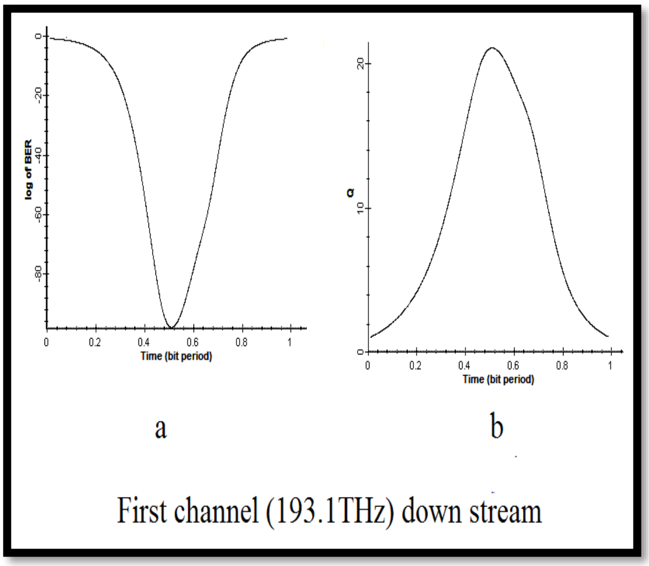

Fig. 7 (a) Min BER and 7(b) Q-factor vs. Bit Period of the Received Signal

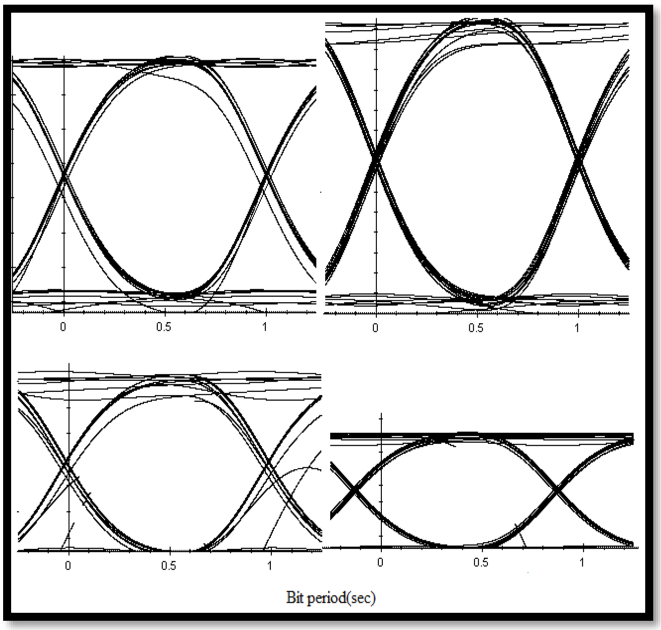

Fig. 8 Eye Diagram of the Four Upstream Channels

The un-modulated channels are fed to four different optical network units (ONU) for upstream modulation. Fig.8 shows clear eye openings at the central portion corresponding to the carrier frequency in the upstream directions. All the four channels are received with minimum bit errors. To achieve a better BER performance the signal power of the upstream transmission is increased to 10dBm. The central portion of the received signal achieves a min log BER of nearly -40, for a Q-factor of nearly 13. Fig.9 shows the change in min BER and Q-factor with respect to the bit period of the first upstream channel (194.1 THz) received. As shown in Fig.8 first two channels have almost same eye openings while the third and fourth channel exhibits a drop in the eye opening compared to others, still they achieved a min BER of 10^{-9}.

Published By:
Blue Eyes Intelligence Engineering and Sciences Publication (BEIESP)

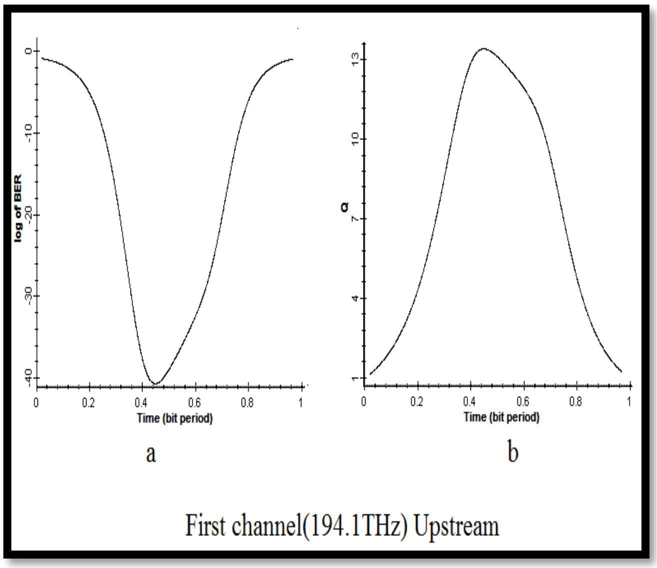

Fig. 9 (a) Min BER 9(b) Q-Factor vs. Bit Period

V. CONCLUSION

A 4x25Gbps system with integrated all optical OFDM-WDM is designed and analyzed for future RoF network. The system performance is evaluated for four channels in the upstream and downstream transmission. In future, the number of channels can be upgraded. Remote modulation is employed in the proposed scheme; instead of using optical sources in each and every base station, which considerably reduce the cost of the base stations for future network. The achievement of min BER of 10^{-9} and below for both upstream and downstream transmission up to 50km leads to the fact that in future the system can be upgraded for a data rate of 100Gbps and above.

REFERENCES

[1] M.Svaluto Moreolo,G.Cincotti, "Fiber Optics Transforms", 10th International Conference on Transparent Optical Networks, pp.136-139, 2008.

[2] M.SvalutoMoreolo, V.Sacchieri, G.Cincotti, G.Junyent, "Trigonometric Transforms for High-Speed Optical Networks: All-Optical Architectures and Optical OFDM", Journal of Networks, vol.5, no.11, Nov.2010.

[3] Seong-Jin Lim,June-Koo Kevin Rhee,Malaz Kserawi, "All Optical OFDM Transmission Systems", Proc. of SPIE-OSA-IEEE, pp.1-6,2011.

[4] Wei Ji and Zhaoyuan kang, "Design of WDM RoF PON based on OFDM and Optical Heterodyne", J.Opt.Commn.network, Vol.5, No.6, June-2013.

[5] Yu-Ting Hsueh , Ming Fang Huang et.al, "A Novel Light wave Centralized Bidirectional Hybrid Access Network: Seamless Integration of RoF with WDM-OFDM-PON", IEEE Photonics Technology Letters.

[6] Linghui Rao, Xiaoqiang Sun, Wei Li, Huang Dexiu, "OFDM-ROF System and Performance Analysis of Signal Transmission", International Symposium on Optoelectronics, China, pp.67-70, 2006.

[7] Wake, Anthony Nkansah, Nathan J.Gomes et.al, " A comparison of Radio-Over-Fiber Link Types for the support of Wideband Radio Channels ", Journal of Light wave Technology,Vol.28,No.16,August 2010.

[8] Jiang, M.kavehrad, " A subcarrier multiplexed coherent FSK system using Mach Zehnder Modulator with automatic bias", IEEE photonics technology letters, Vol.5,N0.8, August 1993.

[9] Daniel J. Fernandes Barros, Joseph M. Kahn, "Optical modulator optimization for OFDM", journal of Light wave Technology, Vol.27, No.13, July 2009.

[10] J.Armstrong, "OFDM for optical communications", J.Light wave Technology, vol.27, pp.189-204, Feb.2009.

Sreedevi Prasanna, completed B.Tech from M.S. University and M.tech from Kerala University in 2000 and 2008 respectively. She worked as Assistant Professor at University of Kerala. Currently she is pursuing her Ph.D at Department of Electronics and Communication, College of Engineering Trivandrum.

Vijayakumar Narayanan, completed his B.Tech and M.Tech from Kerala University in 1988 and 1990 respectively. He took his Ph.D form IIT Kharagpur in 2000. He has more than 20 years of teaching experience. Currently he is working in govt. engineering College Barton Hill, Trivandrum.