Optical Multicarrier Generation Using Mach Zehnder Modulator

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Abstract: ***A low complexity optical frequency comb (OFC) is generated for WDM passive optical network. OFC is generated by a pair of Li-Nb Mach-Zehnder modulator (Li-Nb MZM) connected in cascaded form with external modulated laser (EML). The two Li-Nb MZM are driven by RF signal of 10 GHz. More than 60 flattened carriers are generated from OFC. After generating the Optical Frequency Comb (OFC), it is amplified by 10m long EDFA and the multi-carriers are separated into individual OFC tone using rectangular optical filter with 10 GHz bandwidth. Each OFC tone is modulated with 10Gbps QPSK based transmitter, then it is sent to 50km fiber using a WDM device. At the receiver side OFC channels are demultiplexed and demodulated individually. The proposed setup provides a cost-effective way to generate multiple carriers from a single source using less number of optical devices.***

Keywords: Optical frequency comb, Optical network terminal, WDM-PON, Optical network unit

1. Introduction

In the recent years, due to the ever- increasing demand for high data rate transmissions in optical communications, the generation of optical frequency comb (OFC) remains promising area of research. Optical frequency comb is considered as an optical source whose spectrum consists of a series of discrete, equally spaced frequency lines. For next generation, wavelength division multiplexed passive optical network (WDM-PON) is a broadband optical access solution. The multiple wavelengths of a WDM-PON can be used to separate Optical Network Units (ONUs) into several virtual PONs. A passive optical network is a telecommunication technology used to provide fiber to the end consumer. The conventional light source arrangement at OLT side of WDM PON is replaced with the OFC generator.

There are many techniques for the generation of OFC including the use of mode locked laser. Such lasers produce a series of optical pulses separated in time by the round-trip time of the laser cavity. Another method is to use four-wave mixing where three frequencies mixed to produce a fourth frequency. OFC is created by deploying multi-side-band (MSB) and single-side-band (SSB) recirculating shifting loops (RFS) techniques. While comparing to MSB, SSB modulation produces high number of optical frequency combs but the frequency tones are affected by noise. In the proposed model optical frequency comb is generated using EML as laser source with high data rate.

In this paper first, we have generated the optical frequency comb to deploy it at the OLT side of WDM-PON which supports many users of 10 Gbps data. In the generation of optical frequency comb instead of fiber Bragg grating RF source is used which is more effective. It produces 65 optical frequency combs with minimum amplitude difference. At OLT side, each carrier is separated by an optical filter and is modulated with 10 Gbps data using quadrature phase shift keying (QPSK). The modulated carriers are then transmitted through a 50 km fiber where it is again separated into 65 individual frequencies and filtered separately and then it is demodulated by using QPSK demodulator. The demultiplexer is used to separate individual frequency components and multiplexer is used to combine the modulated carriers for transmission through the fiber.

2. Optical Frequency Comb Generation

For the generation of OFC, two Li-Nb MZM modulators are connected in cascaded form driven by the microwave signal.. A Mach Zehnder modulator is used to control the amplitude of an optical signal. The input waveguide is split in to two arms. If a voltage is applied in one of the arms, phase shift will be induced for the wave passing through the arm. Then, when the two arms are recombined the phase difference between the waves in the two arms will be converted to amplitude modulation.

EML's operating wavelength is 1552.5 nm with linewidth of 10 MHz and output power is at 10 dBm. The block diagram of OFCG is shown in Fig.1and Fig.2 shows the layout of OFCG.

We prefer EML over Direct Modulated Laser (DML) because EML is much faster in processing and can be used with high power laser devices. It can be employed in high speed applications. In external modulated laser, an external modulator is incorporated to modulate the phase or intensity of the laser source. The laser source will be always kept ON and the external modulator will act as a switch, which is controlled by the transmitted information.

For EML, NRZ signal is used which is driven by pseudo-random sequence generator operating at 10 Gbps. The extinction ratio of the MZM in external modulated laser is 5 dB. It is the ratio of two optical power levels of a signal generated by an optical source. We have used LiNb Mach Zehnder modulator for OFC generation because it is a more advantageous than normal Mach Zehnder modulator. Using Li-Nb modulator, we can define the insertion loss, extinction ratio, bias voltage and modulation voltage. The frequency of the source is kept at 10 GHz, power 13 dBm and amplitude 0.2 a.u.

The output of the EML is passed through cascaded Li-Nb MZM. The extinction ratio of the Li-Nb MZM is kept at 30dB. When the EML signal is passed through the first Li-Nb MZM, frequency carriers are generated but much of the carriers are weak and have a greater amplitude difference between the carriers, as shown in Fig.3. When it is passed through the second Li-Nb MZM more carriers become flattened and the amplitude difference between the carriers is very less. The OFC output is shown in Fig.4. The spectrum of OFCG at extinction ratio of 30 dB and 5 dB is shown in Fig.5 and Fig.6 respectively. We get carriers with greater amplitude when the extinction ratio of the EML is at 5dB. The output of the second Li-Nb MZM consists of 65 flattened optical frequency carriers with least amplitude difference.

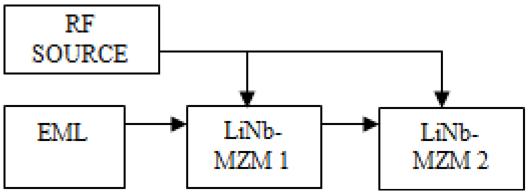

Figure 1: Block diagram of OFC

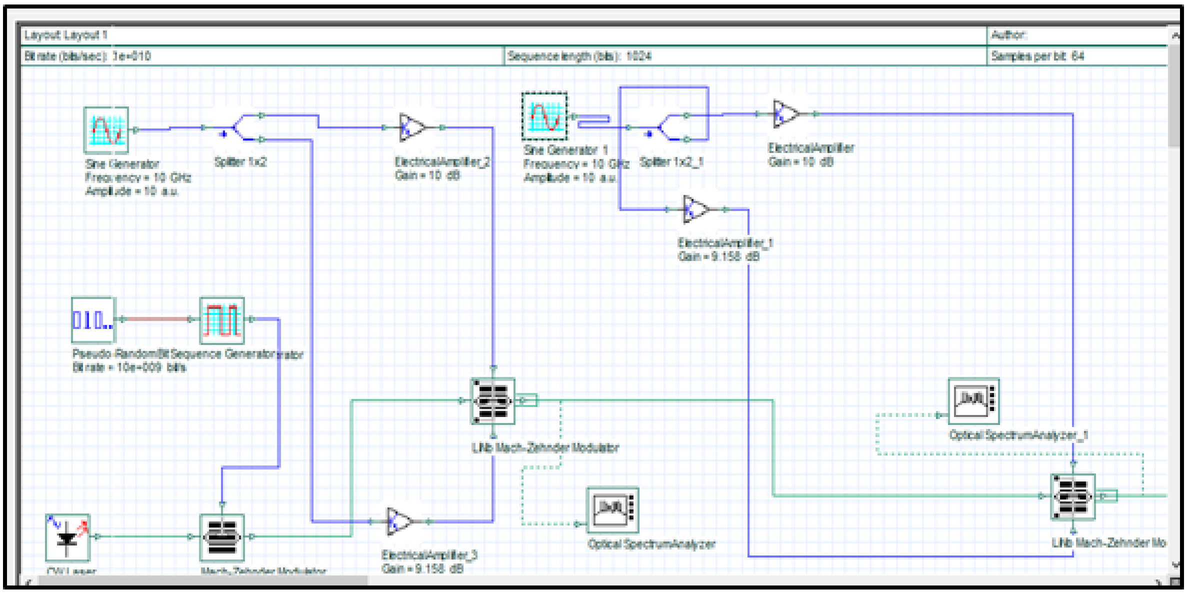

Figure 2: Layout of optical frequency comb

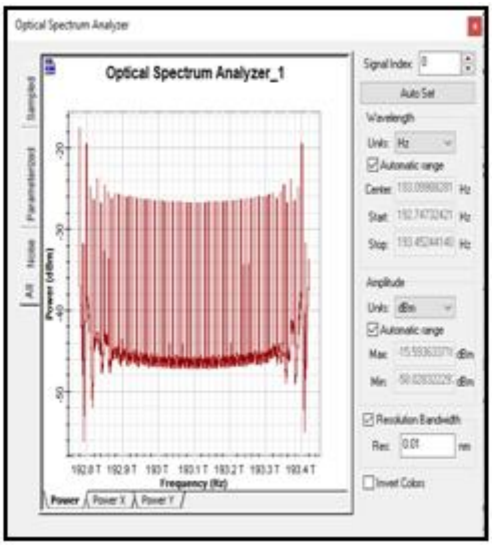

Figure 3: Output of MZM 1

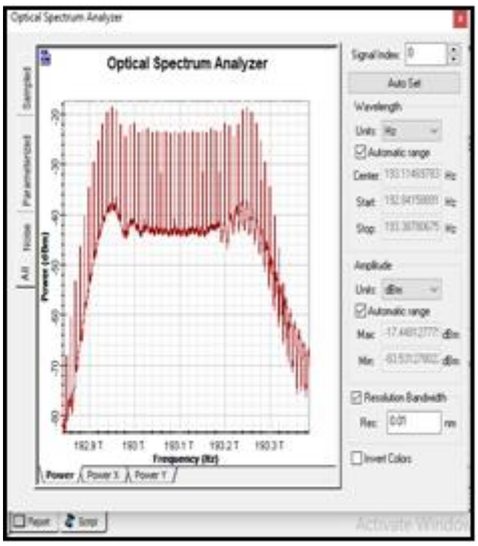

Figure 4: Output of MZM 2

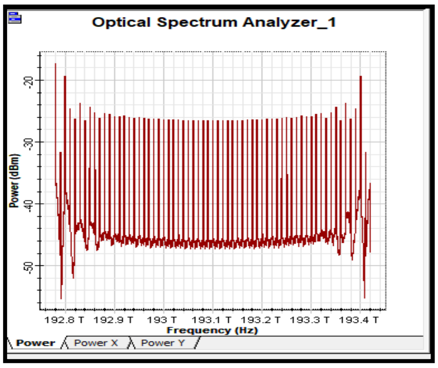

Figure 5: Output of OFCG with extinction ratio of EML at 5dB

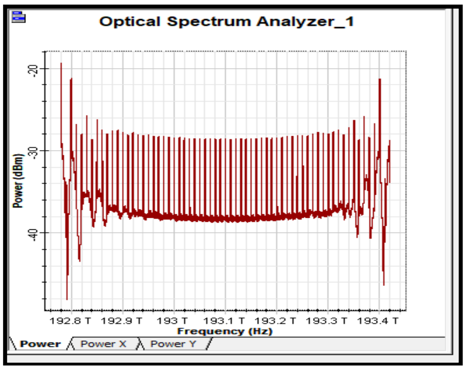

Figure 6: Output of OFCG with extinction ratio of EML at 30 dB

3. Optical Line Terminal

In the OLT side, the Optical Frequency Comb is generated and amplified using Erbium doped fiber amplifier. Erbium-doped fiber amplifier (EDFA) is an optical repeater device that is used to boost the intensity of optical signals being carried through a fiber optic communications system. EDFA of 10m length is used. Then the OFC is separated using Rectangular optical filter of bandwidth 10GHz. The overall block diagram of WDM-PON using OFCG is shown in Fig.7. The overall layout of WDM-PON is shown in Fig. 8.

Filtered single comb is shown in Fig.9. Likewise, the OFC is separated into 65 individual frequency carriers. Each carrier is individually modulated using QPSK. Compared to other modulation techniques, QPSK can transmit at twice the data rate while the bandwidth requirement remains the same.

The QPSK modulator consists of a pseudo random sequence generator which is fed to the PSK sequence generator. The PSK sequence generator separates In-phase and Qudrature phase components, then they are given to two M-array pulse generators. Those pulse generators drive the LiNb Mach Zehnder modulators. The MZM are out of phase with each other and are connected with amplified OFC by using a coupler. After the modulation of all the 65 carriers, they are multiplexed and transmitted through the fiber. The length of the fiber is 50 km and attenuation of the fiber is set as 0.2 dB/km.

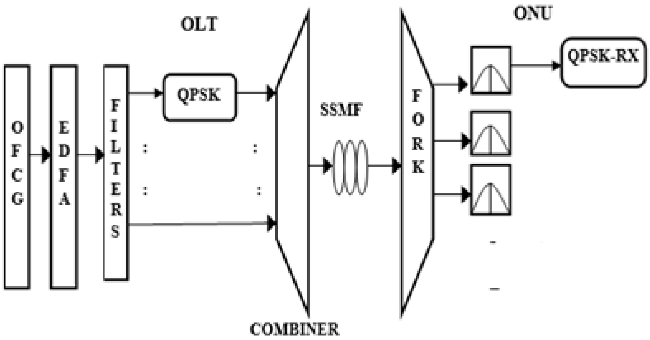

Figure 7: Block diagram of OFC

4. Optical Network Unit

Optical Network Unit is in the user side. After receiving the 65 carriers from the fiber, it is again separated using demultiplexer into 65 individual carriers. The 65 individual carriers are having 65 different data. The carriers are filtered using Gaussian filter of bandwidth 10GHz. After filtering the carriers, they are demodulated using the QPSK receiver. For QPSK demodulation we have used two pairs of photodetectors. The output of first two photo detectors are given to a subtractor and next two photo detectors are given to another subtractor. The output of first subtractor is the in-phase output, and the output of the second subtractor is the quadrature phase output.

The outputs of the subtractors are given to the universal DSP for effective visualization of the demodulated output. The final demodulated output is shown in Fig.10.

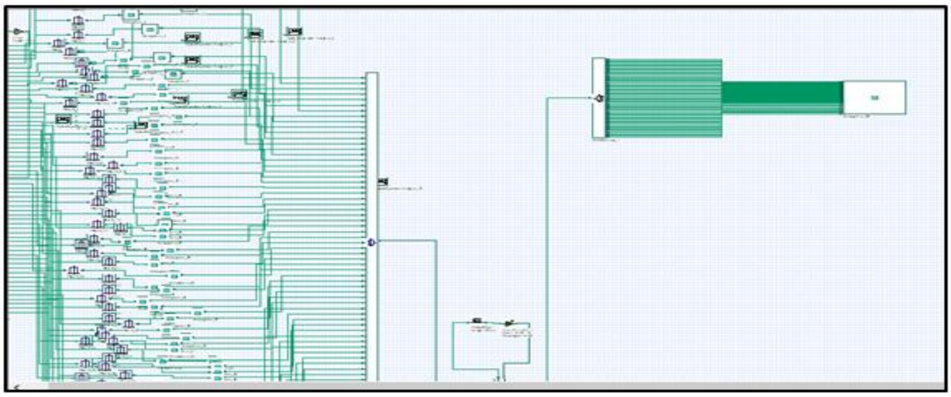

Figure 8: Layout of WDM-PON

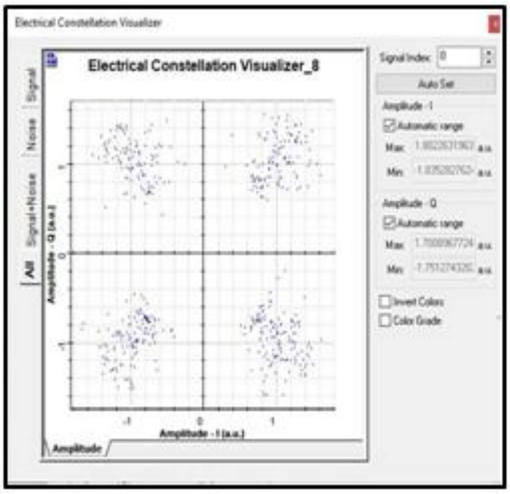

Figure 9: Sampled OFC tone

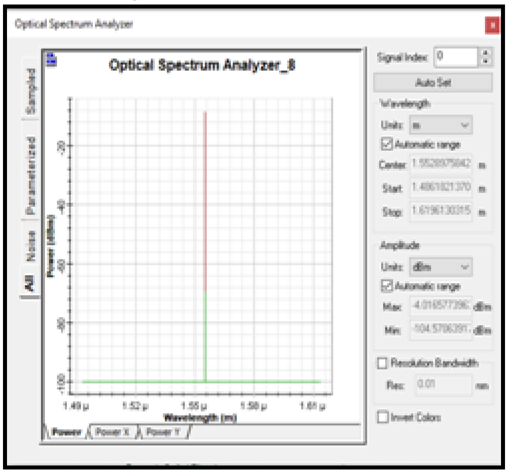

Figure 10: Demodulated output at the receiver side

5. Conclusion

WDM-PON satisfies the needs of the end users demanding high capacity data rate. The new arrangement of OFCG at the WDM-PON is proposed which supports many users to send and receive data in a single physical channel. High data rate transmission is possible by Optical Frequency Comb Generator (OFCG). The OFCG generator produces 65 carriers by using a single laser source and there is less amplitude difference between the carriers. The frequency spacing between the carriers is 10 GHz. Each carrier effectively transmits data at 10 Gbps and hence the over all data rate is around 0.65 Tbps. At the ONU side the carriers are again demodulated using QPSK demodulator.

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