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Enhancing The QoS in Energy Efficient Wdm/OFDM Passive Optical Networks

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ABSTRACT

In this paper, we propose new methodology to enhance the QoS in cost and energy efficient WDM/OFDM PON system. In this, the WDM technique supports more number of ONU and the OFDM technique provides high spectral efficiency and flexible sub-channel bandwidth allocation. Here, we have reduce BER at ONU by using the post dispersion compensation technique inorder to reduce the chromatic dispersion which is a major issue in single mode fiber, when signal travels for a long distance. Also the DCF supports high data rate and long distance transmission. Cost efficiency can be achieved by using the arrayed waveguide grating instead of using WDM MUX/DEMUX and unpowered passive optical device. In WDM/OFDM PON system, 4-QAM is used because it is not that much susceptible to noise when compare to higher order modulation schemes. By using this, here we can increase the quality factor thereby the bit error rate gets decreases. The higher the quality factor indicates the better signal to noise ratio.

Index Terms: WDM; OFDM; Bandwidth allocation; Dispersion compensation fiber; Quadrature Amplitude Modulation;

1. INTRODUCTION

The Passive Optical Network is a telecommunication network in which passive optical splitters are used to enable an optical line terminal(OLT) at the service provider's central office to serve the number of optical Network units(ONU) near end users. There are three types of accessing techniques in PON system as follows Thus the TDMA PON increases the power consumption and also reduces the bandwidth utilization. The WDM PON is not suitable for allocating the flexible sub-channel bandwidth allocation but it supports large number of ONU. The OFDM PON sustains high spectral efficiency and flexible sub-channel bandwidth allocation[1]. It limits the number of ONU connected to it. In WDM/OFDMPON system, we are using the OFDM technique in WDM PON system now we can achieve both the flexible sub-channel bandwidth allocation and also connect the more number of ONU to OLT[1]. Since we are using the OFDM technique, each ONU is assigned to different wavelength and as a result we can reduce the optical beam interference (OBI).

1.1. System Architecture

OLT-Optical Line Terminal; ONU-Optical Network Unit; Cost and energy efficient WDM/OFDM pon system is a two-tiered semi-tree architecture, in which we can connect the total number of wavelength in OLT at centre office to the number of ONUs near end user. OLT is connected to ONU through the AWG (ARRAYED WAVEGUIDE GRATING) MUX, optical fiber, AWG DEMUX and 1 to N splitter. In the first tier, the number of CO-OFDM transmitter in the OLT is connected to the ONU through AWG multiplexer, single mode fiber, post dispersion compensation fiber and AWG de-multiplexer. In the second tier, AWG de-multiplexer is connected to the number of CO-OFDM receiver in ONUs through the RN (remote node)At

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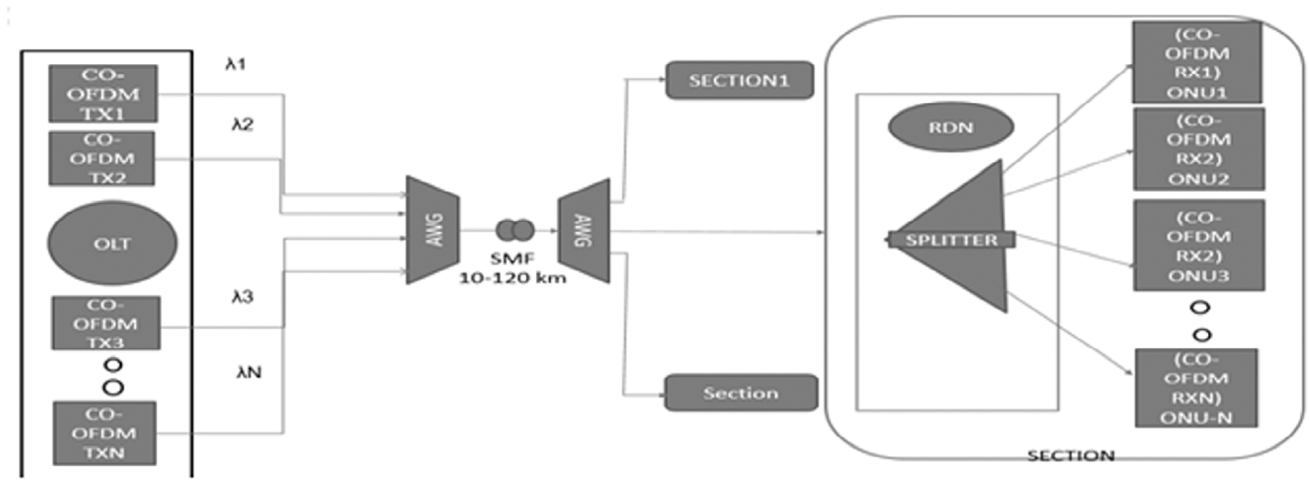


Figure 1: WDM/OFDM PON system

each ONU, the downstream OFDM signal is received by the CO-OFDM receiver and converted into its electrical form. This system is free from the power budget problem, due to the two-tiered semi-tree architecture, RDN-Remote Distribution Node; AWG-Array Waveguide Grating; it take the advantage of OFDM technology to achieve high bandwidth efficiency and flexible for sub-channel bandwidth allocation and highly scalable with an increasing number of ONU[6].

2. WDM/OFDM PON

In this project, we are going to enhance the QoS in cost and energy efficient WDM/OFDM PON system and we have taken the unidirectional WDM/OFDM PON system with coherent detection. Here we have used the OFDM technique in WDM PON system shown in fig1, The OFDM signals are generated using the coherent optical OFDM transmitter shown in fig. 4 at OLT. The reference bit rate is taken as 30Gbps and each PRBS generator is used to generate the bit stream which has the bit rate of 15Gbps.

2.1. Simulation Setup: Wdm Pon

The bit stream is fed to the 4-QAM encoder and it maps two bits to each symbol shown in fig. 6. The resulting signal is modulated by OFDM Modulator block which has the parameter as the number of subcarrier

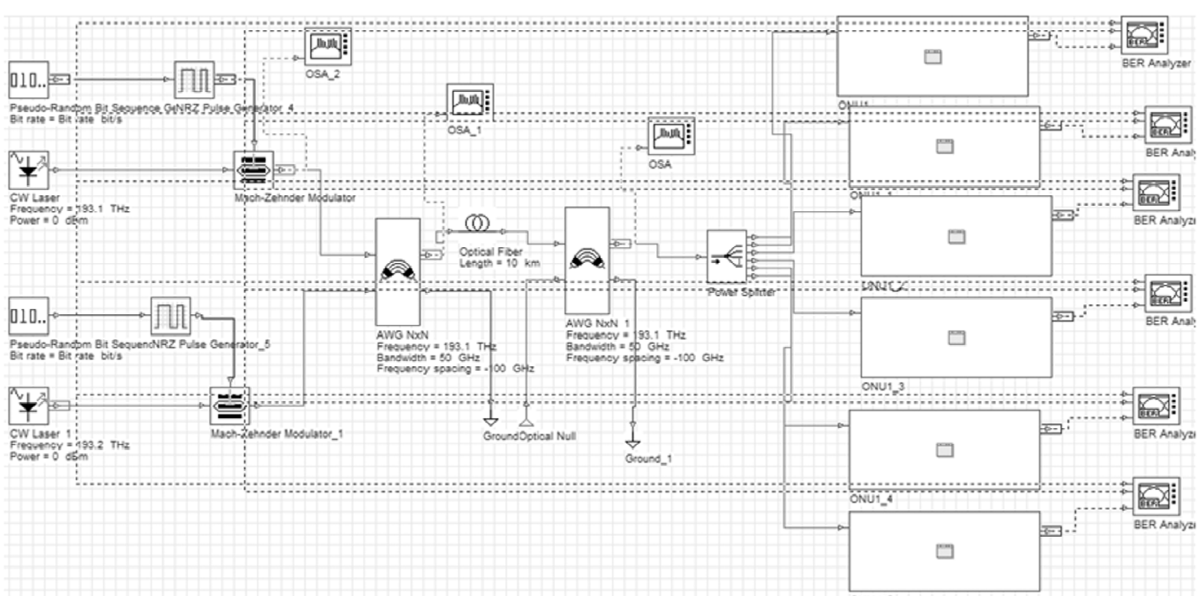


Figure 2: WDM PON system

is 128, number of FFT point is 256 and position array is 64. CW Laser is used which are operating at the wavelength of 1552.524nm and 1551.720nm with input optical power equal to -4dBm and line width equal to 0.05MHz.

After that, the resulting electrical signal is modulated to optical signal using a pair of Mach-Zehnder Modulators (MZM) with the help of CW laser, which up-converts the RF data to optical domain [3]. The signal from the two MZM's are combined using the power combiner and is multiplexed using the arrayed waveguide grating which has the bandwidth 50MHz.Multiplexed signal shown in fig. 8.

After multiplexing, the multiplexed optical signal is transmitted over the single mode fiber for a long haul transmission. SMF which has the parameter of positive dispersion between (15-20 ps/nm/km) here we have used the Dispersion value as 17ps/nm/km, wavelength is 1552.524nm and attenuation is0.2ps/nm/km.

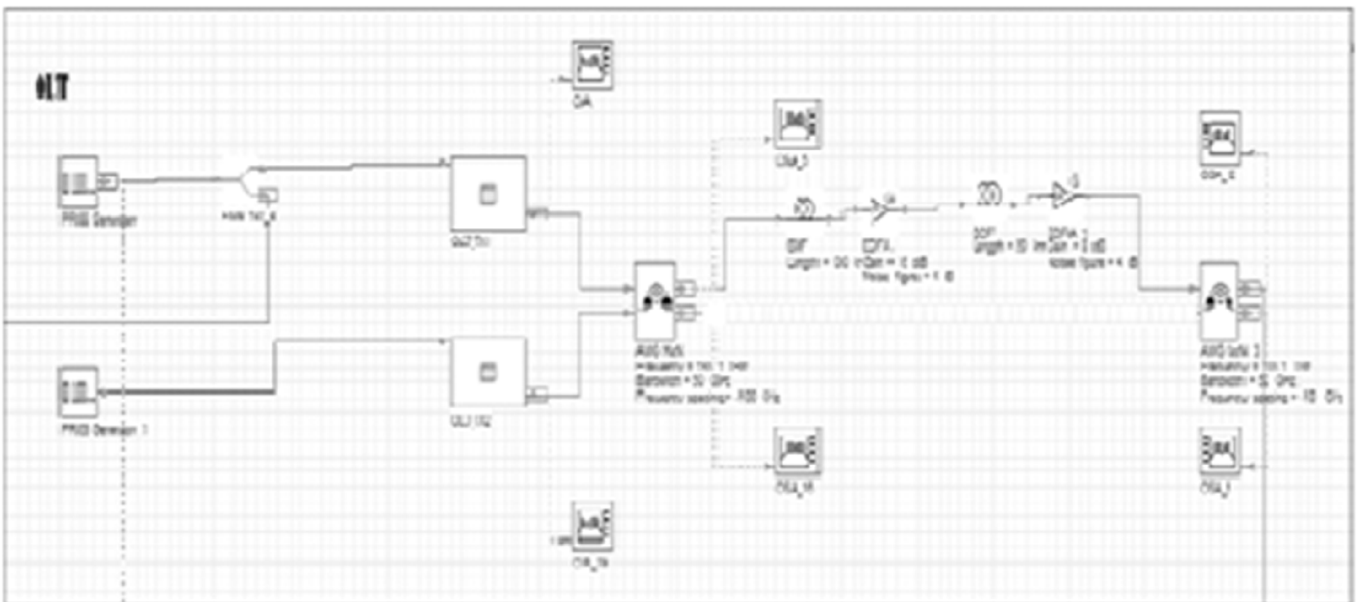


Figure 3: OLT

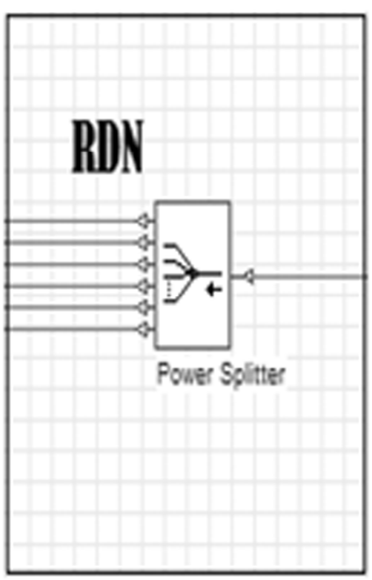


Figure 4: Remote node

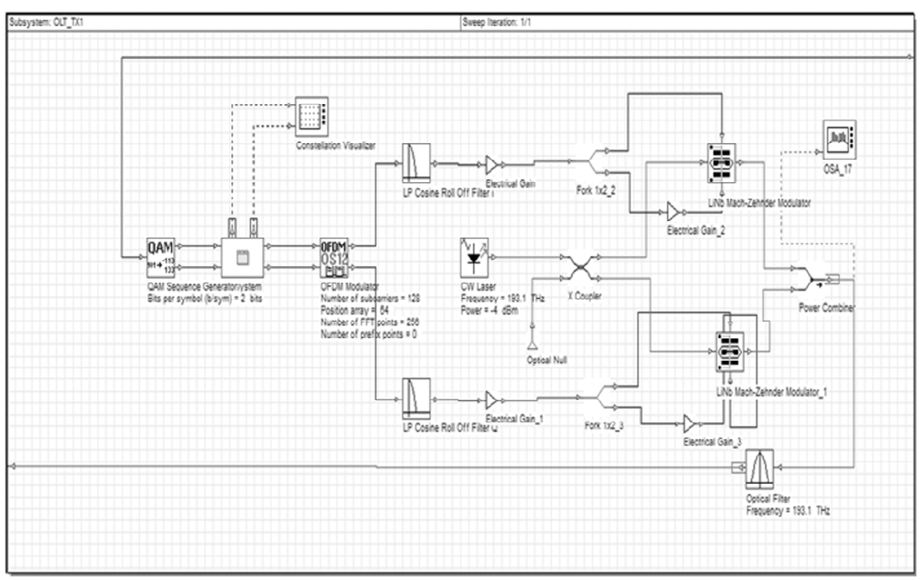
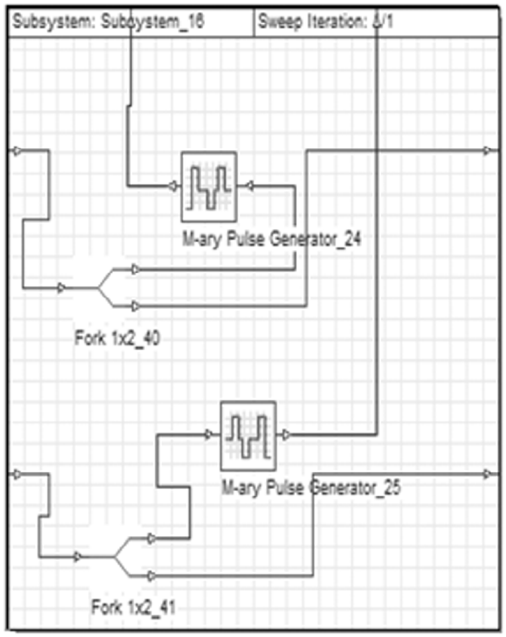


Figure 5: CO-OFDMtransmitter



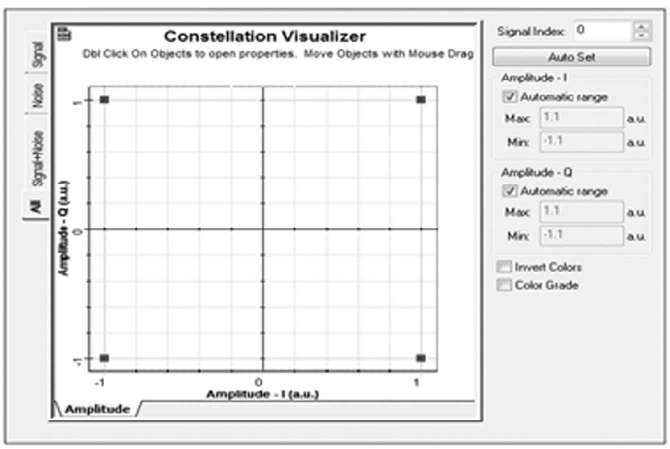


Figure 6: Constellation diagram for CO-OFDM

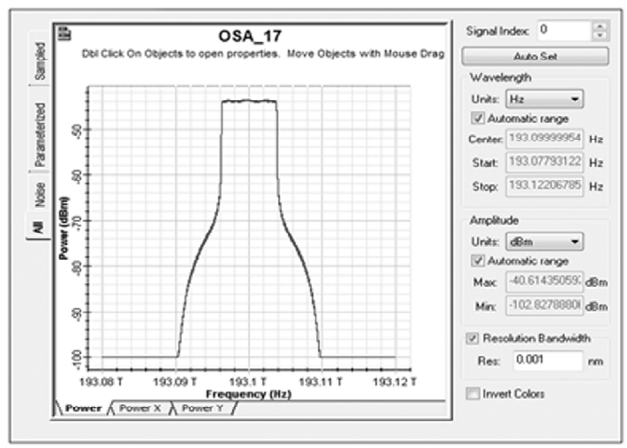


Figure 7: AWG multiplexer

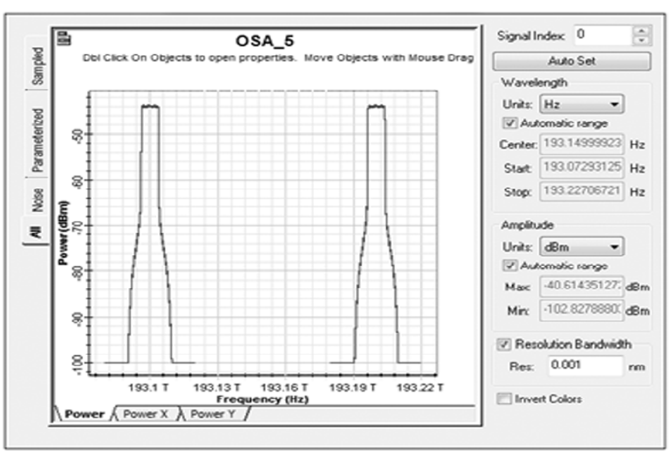


Figure 8: Spectrum analyzer for CO-OFDM

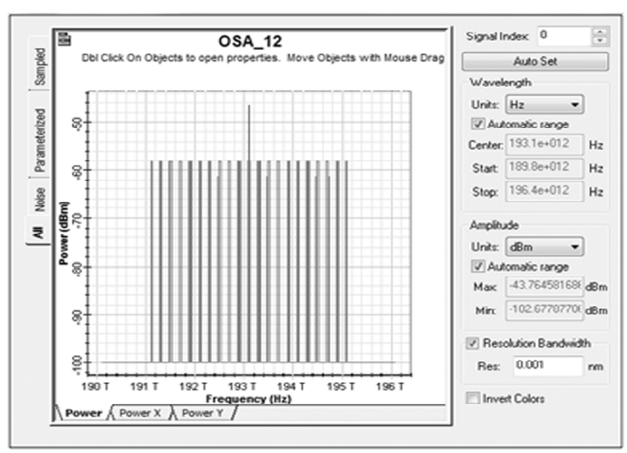


Figure 9: AWG de-multiplexer

There are two EDFA's which are used to strengthen the weak downstream signal. The attenuation of SMF is balanced by using optical amplifier which is the EDFA. The EDFA which is used after the SMF has parameter gain as 16dB and noise figure as 4dB.

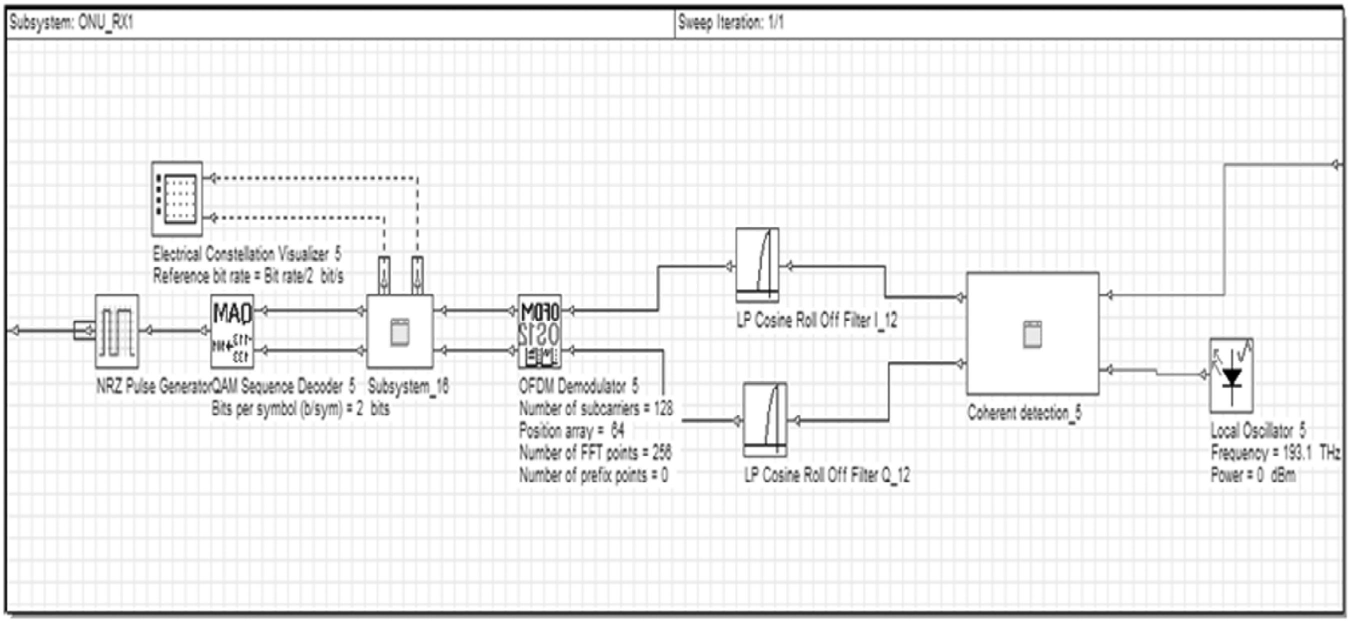


Table1
Fiber parameter

PARAMETER	*SMF*	*DCF*
Fiber length (km)	10-120	2-24
Wave length (nm)	1552.524	1552.524
Dispersion	17	-85
D(ps/nm/km)	70	22
Effective area A (μm^2)	0.075	-0.3
Dispersion slope (ps/nm^2/km)	0.2	0.5
Attenuation α (dB/km)		

The signal starts broadening when the length of the single mode fiber increases. The broadening occurred in the signal due to the positive dispersion of the single mode fiber[2]. The chromatic dispersions the major issue in SMF when signal travel for a long distance. It can affect the quality of the signal and also increase the attenuation power. To recover the original signal, DCF (Dispersion Compensation Fiber) is used after the EDFA which is next to SMF to compensate the positive dispersion of the SMFvalue of single mode fiber and dispersion compensation fiber shown in the table1[3].The condition for perfect Dispersion compensation technique is

This method is called the POST-DCF technique. Dispersion Compensation Fiber which has the parameter negative dispersion between (-70 to -90ps/nm/km) here we have used the negative dispersion value as -85ps/nm/km, wavelength as 1552.524nm and attenuation is 0.5dB/km. Second EDFA is used after the DCF which has the gain 8dB and noise figure 4dB. Parameter

$D1L1 + D2L2 = 0$ … 1

$L2 = -(D1/D2)*L1$…2

L1 = Length of SMF; L2 = Length of

DCF; D1 = Dispersion of SMF;

D2 = Dispersion of DCF

Example: D1 = 17; D2 = –85; L1 = 80;

$L2 = -(17/-85)*80$ $L2 = 16$

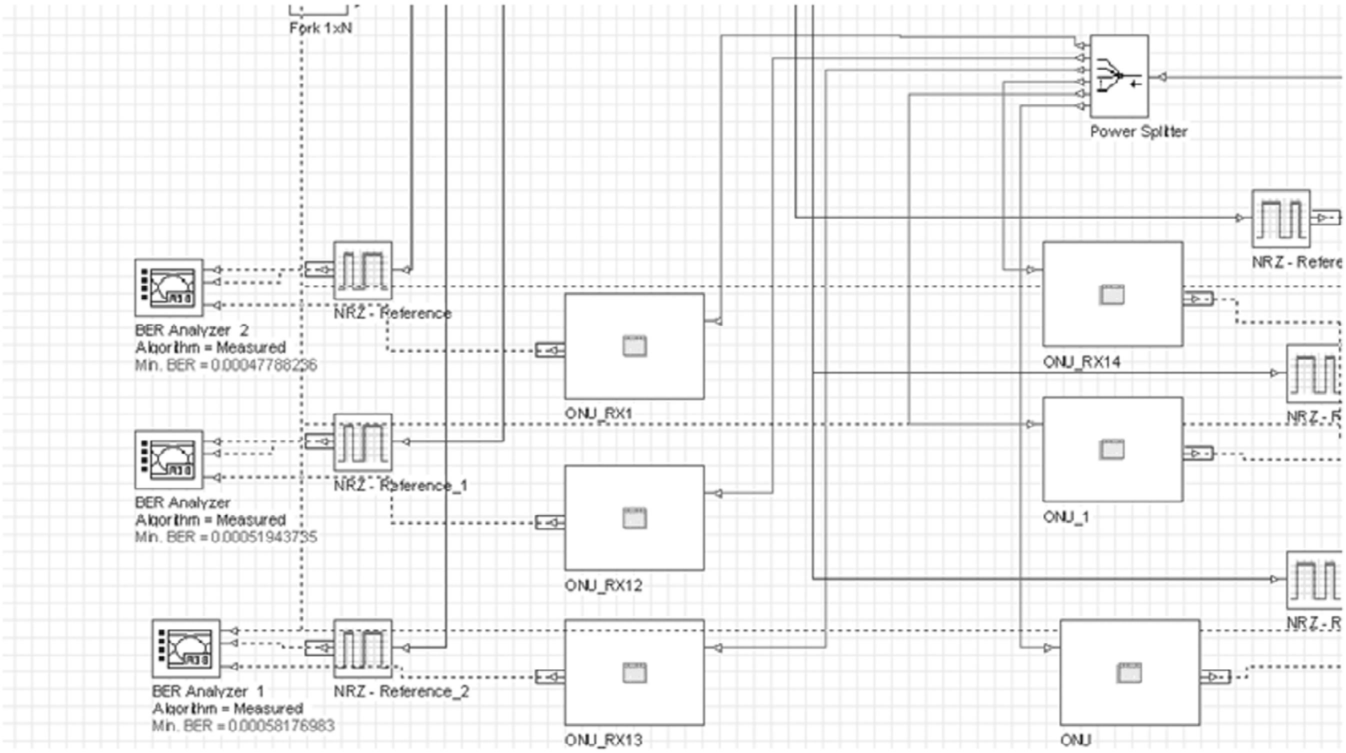
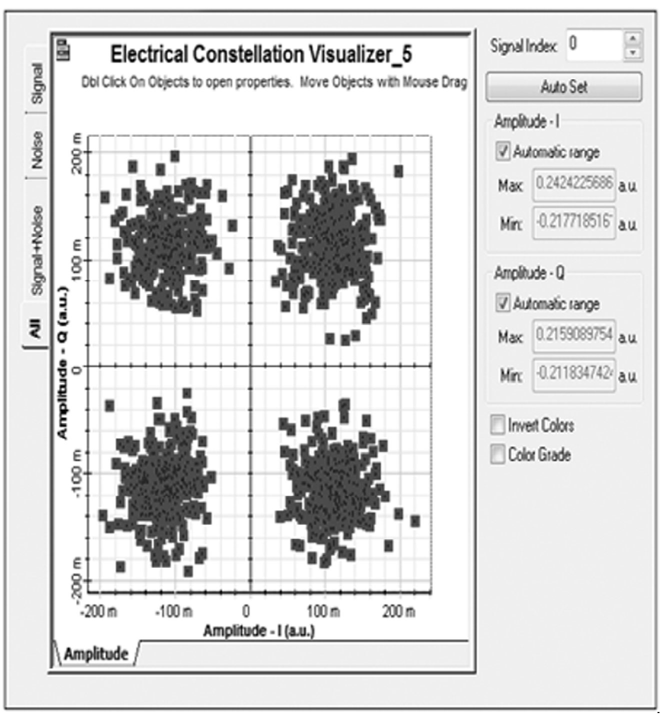


Figure 10: Optical Network Unit



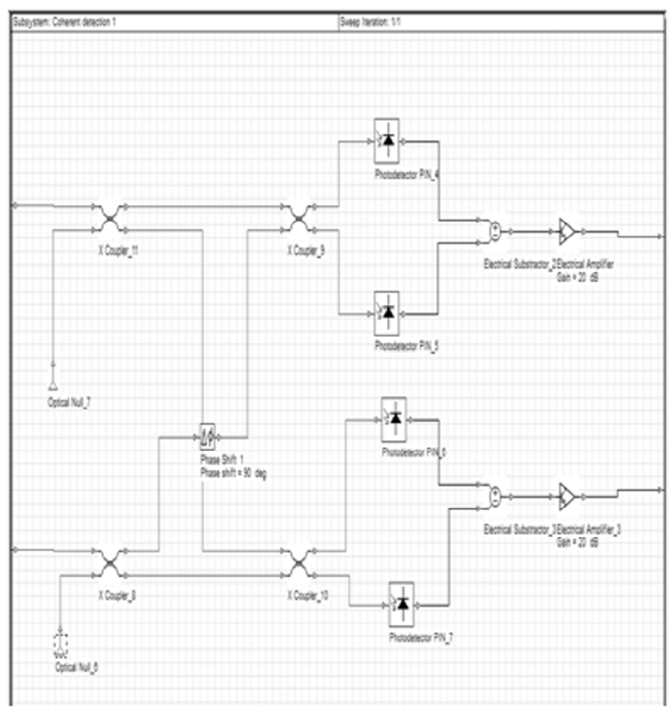


Figure 11: Constellation diagram for CO-OFDM receiver

Figure 12: Coherent detection

Further, those two different wavelength signals are de-multiplexed by using array waveguide grating which is having the bandwidth of 50MHz shown in fig9. The de-multiplexed signal is transmitted to 1xN splitter, which is the remote node (RN) and is then transmitted to ONU shown in fig10.each ONU has CO-OFDM receiver shown in fig11.

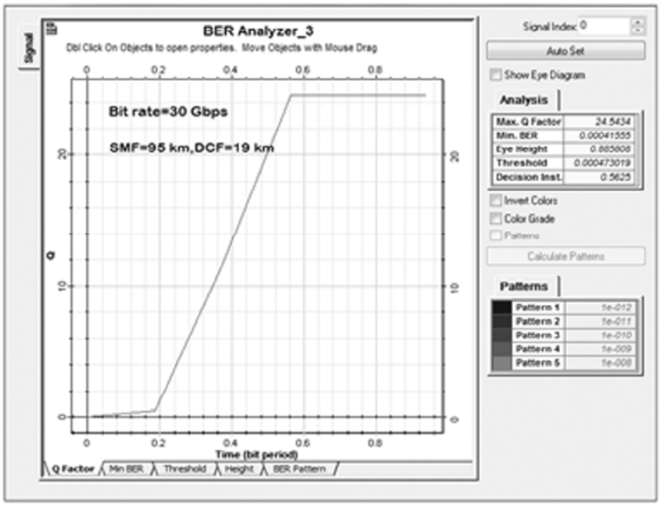


Figure 12a: Time Vs Q factor

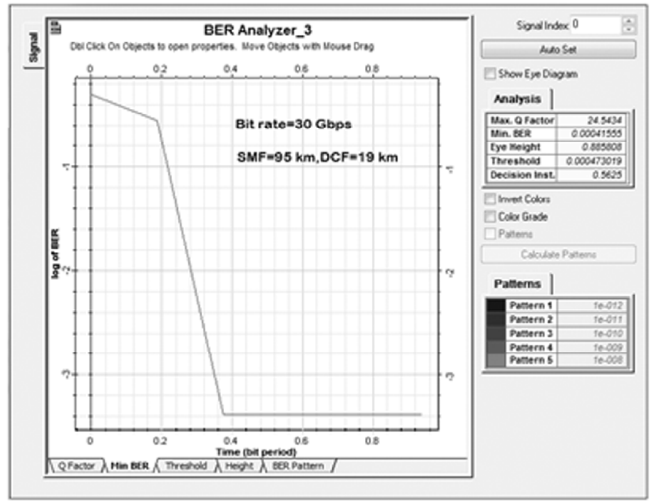


Figure 12b: Time Vs Min BER

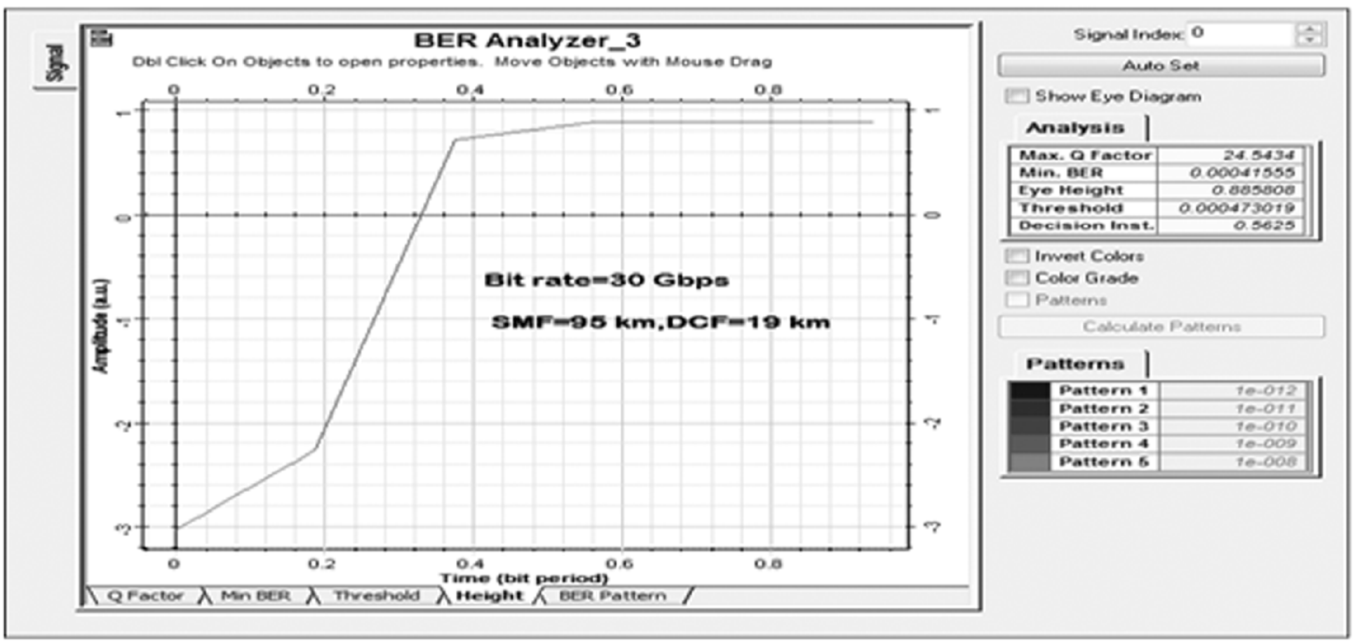


Figure 12c: Time Vs Amplitude

At the ONU de-multiplexed signal is detected using coherent detector circuit shown in fig12 which incorporates a local oscillator. Coherent detection block which has four balanced PIN Photo detectors. The optical signal from optical fiber link is received by four balanced photo detector to perform the I/Q optical to electrical detection [4].

The detected signal is demodulated using OFDM demodulator in order to remove the guard interval. OFDM demodulator which has the parameter number of subcarrier as 128, position array as 64 and number of FFT points is 256.

3. RESULT AND DISCUSSION

After that, the resulting signal is decoded using the 4-QAM sequence decoder constellation diagram shown in fig. 13 and is analyzed using the BER analyzer, from that BER, Quality factor and Eye height is calculated.

Table 2
Tabulation for BER of different ONU at different distances (bitrate =30 Gbps)

Distance (Km)		Bit Error Rate (Bit Rate = 30gb/S; Power = –4dbm)					
SMF	DCF	ONU 1	ONU 2	ONU 3	ONU 4	ONU 5	ONU 6
90	18	1.0389e-4	6.2333e-5	2.0778e-5	2.0778e-5	4.1556e-5	2.0778e-5
95	19	4.7788e-4	4.5712e-4	4.3633e-4	3.9477e-4	4.3633e-4	4.5712e-4
100	20	2.2439e-3	2.3271e-3	2.5764e-3	2.5141e-3	2.6803e-3	2.8050e-3
105	21	9.3499e-3	8.872-e-3	8.8304e-3	9.0798e-3	9.4953e-3	9.1213e-3
110	22	2.2419e-2	2.2835e-2	2.3312e-2	2.2980e-2	2.3229e-2	2.3105e-2
115	23	4.4277e-2	4.4505e-2	4.5150e-2	4.4963e-2	4.5108e-2	4.4630e-2
120	24	7.5173e-2	7.5028e-2	7.5485e-2	7.4612e-2	7.5921e-2	7.5422e-2

Table 3
Tabulation for Q-Factor of different ONU at different distances (bitrate = 30Gbps)

Distance(km)		Q-FACTOR (Bit Rate = 30GB/s; power = –4dBm)					
SMF	DCF	ONU 1	ONU 2	ONU 3	ONU 4	ONU 5	ONU 6
90	18	49.2981	64.2505	155.132	155.132	77.5588	155.132
95	19	22.994	23.4685	24.0952	25.2295	23.9278	23.3703
100	20	10.5213	10.3353	9.8125	9.9351	9.6196	9.4026
105	21	5.0982	5.2379	5.2576	5.1780	5.0579	5.1646
110	22	3.2263	3.1947	3.1601	3.1845	3.1654	3.1747
115	23	2.2159	2.2090	2.1907	2.1960	2.1918	2.2054
120	24	1.6113	1.6132	1.6070	1.6192	1.6012	1.6078

Table 4
Q Factor and BER for WDM vs WDM/OFDM PON

POWER (dBm)	WDM PON Bit Rate = 20GB/s SMF = 30Km	WDM/OFDM PON Bit Rate = 20GB/s SMF = 30Km, DCF = 6Km	WDM PON Bit Rate = 20GB/s SMF = 30Km	WDM/OFDM PON Bit Rate = 20GB/s SMF = 30Km DCF = 6Km
	Q factor	Q factor	BER	BER
0	6.68447	5.05e+049	1.15692e-011	0
-1	6.3875	5.05e+049	8.42748e-011	0
-2	5.73158	5.05e+049	4.97109e-09	0
-3	5.40622	5.05e+049	3.21572e-008	0
-4	4.73672	5.05e+049	1.08391e-006	0
-5	3.99463	5.05e+049	3.22625-005	0
-8	0	5.05e+049	1	0
-12	0	5.05e+049	1	0
-13	0	31.0163	1	0.00028
-13.5	0	14.4456	1	0.00119704
-14	0	8.7245	1	0.00330761
-14.5	0	5.82921	1	0.00721373
-15	0	3.97019	1	0.01512

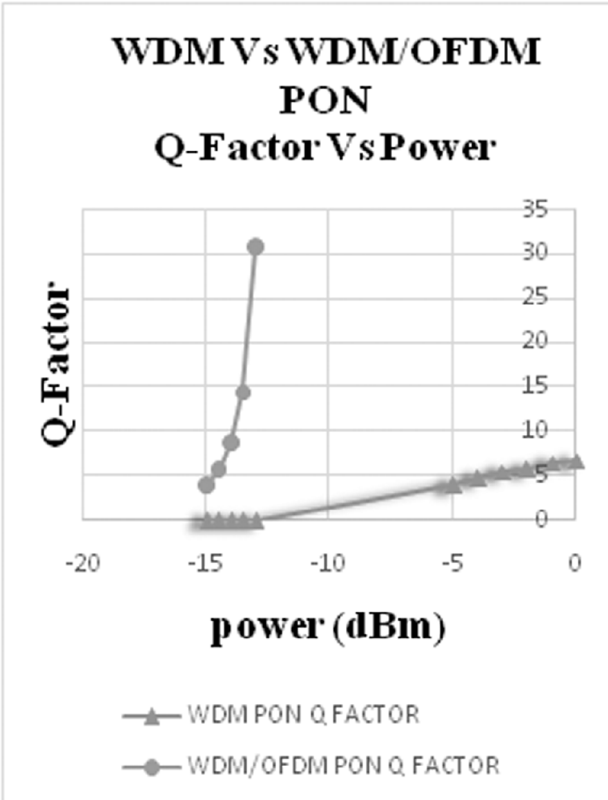


Figure 13: Q-Factor Vs Power for WDM

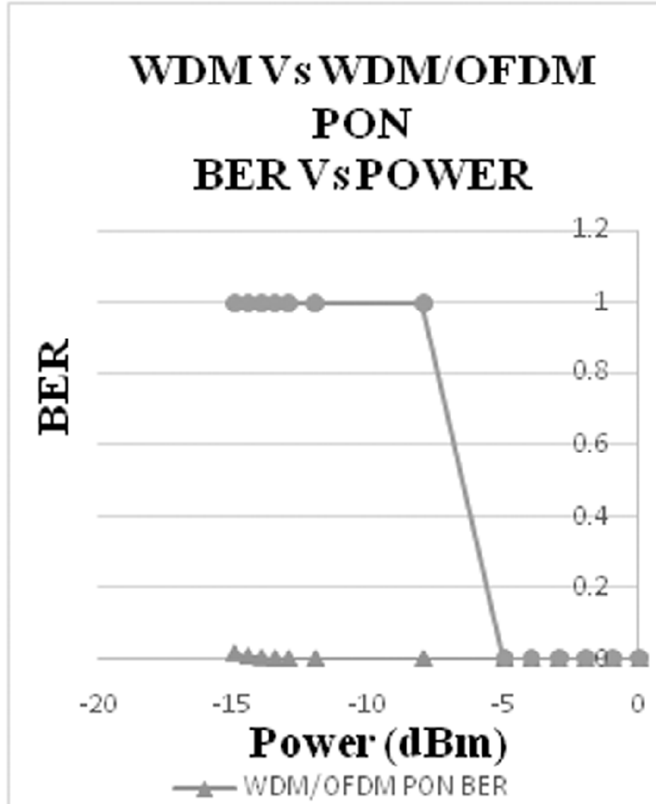


Figure 14: BER Vs Power for Vs WDM/OFDM

4. CONCLUSION

In this paper, we have proposed and enhanced the QoS in cost and energy efficient WDM/OFDM PON system. The WDM/OFDM PON system supports number of ONU and also flexible for sub channel bandwidth allocation. In the proposed system, we used the bit rate as 30Gbps, and it supports the transmission distance of about108 km to126 km effectively with better BER and Q factor. This can be achieved by using the post dispersion compensation technique, coherent detection method. It reduces the chromatic dispersion which is a major issue in the single mode fiber, then signals travels for a long transmission distance.

The Cost efficiency can be achieved by using the AWG and unpowered passive optical devices. The BER obtained is 1.039e-4 for 108 km. We achieved Q factor as 6.3 in WDM/OFDM PON system for power 14.45dBm.

Whereas the same Q factor achieved in WDM PON for power -1dBm at 30km shown in table4. From this, it is clear that the WDM/OFDM PON system consumes very less power when compared to the WDM PON system. At the power -4dBm we have attained the better Q factor at the distance 108 to 126km. So, we can attain the WDM/OFDM PON is an energy efficient system.

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