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Design and Analysis of WDM OFDM System Using Optisystem

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Abstract: Orthogonal frequency division multiplexing (OFDM) is a modulation technique which is now used in most new and developing broadband wired and wireless communication systems. We propose WDM OFDM design to reach a data rate of 40 Gbps over 240 km optical fiber. 40 Gbps signal is generated by multiplexing four OFDM with 10 Gbps data rate for each OFDM. We present the performance of single OFDM system by measuring the BER and the constellation diagram. We will also check the performance of the CO-OFDM WDM system for 240 km by measuring the BER and constellation diagram.

Keywords: OFDM, WDM, BER, QAM, Optical Communication.

1. INTRODUCTION

Now a days communication is an important factor and requirement high data rate for the communication and also require the error free environment. So for these entire requirements we use OFDM. OFDM is used for both wired and wireless communication. OFDM belongs to a broader class of multicarrier modulation (MCM) in which the data information is carried over many lower rate subcarrier [2]. OFDM is a solution of intersymbol interference (ISI). ISI is caused by dispersive channel.

As higher data rate requirement for this OFDM is very important and for the subcarrier modulation using the different type of modulation technique such as Quadrature Amplitude Modulation (QAM) or Phase Shift Keying (PSK) [3]. The Inverse Fast Fourier Transform (IFFT) and the Fast Fourier Transform (FFT) are very effectively use in OFDM transmitter and receiver. These algorithms are very important for the OFDM to prove higher scalability above the channel dispersion and the data rate [4].There are so many restrictions in optical fiber communication like modal dispersion, Chromatic Dispersion (CD), Polarization Mode Dispersion (PMD) [5]. OFDM play important role to eliminate these restriction by using different modulation technique. Coherent optical OFDM (CO-OFDM) is an important technique for high data rate. CO-OFDM eliminates the Chromatic Dispersion (CD) and the Polarization Mode Dispersion (PMD)[6].

Theoretical Necessity for OFDM

The electrical signal is modulated by the OFDM modulation technique. A multicarrier modulation (MCM) signal at transmitter is [2]

$$s(t) = \sum_{i=-\infty}^{+\infty} \sum_{k=1}^{N} c_{ki}\, s_k(t - iT_s) \qquad (1.1)$$

$$s_k(t) = \prod(t) e^{2\pi j f_k t} \qquad (1.2)$$

$$\prod(t) = \begin{cases} 1, 0 < t \le T_s \\ 0, \text{otherwise} \end{cases} \qquad (1.3)$$

s_k denotes the subcarrier and c_k denotes the information of k_{th} subcarrier. N denotes the subcarrier number. f_k denotes the subcarrier frequency. $\prod(t)$ and T_s represents the function of pulse shaping and symbol period respectively. The m_{th} sample of s(t) when sampling period is T_s/N is [2]

$$s_m = \sum_{k=1}^{N} c_k e^{j2\pi f_k (m-1)T_s/N} \qquad (1.4)$$

There is a number of frequencies of subcarrier are chosen for each subcarrier are orthogonal. For the orthogonality equation is

$$f_k = \frac{(k-1)}{T_s} \qquad (1.5)$$

Put the value of f_k from the equation (1.5) to equation (1.4)

$$s_m = \sum_{k=1}^{N} c_k e^{j2\pi (m-1)(k-1)/N} \qquad (1.6)$$

So s_k is the Inverse Fourier Transform of the signal c_k . $\hat{c_k}$ is the Fourier transform of $\hat{s_k}$,this is a received signal[2]

$$\hat{c_k} = \frac{1}{\sqrt{n}} \sum_{k=1}^{N} \hat{s_k}\, e^{-j2\pi (m-1)(k-1)/N} \qquad (1.7)$$

After analyzing the equation 1.6 can say that OFDM signal is a summation of lots of signals. So OFDM signal having more peak to average power ratio (PAPR) than single carrier signals [2].

$$\text{PAPR} = \frac{\max\{|s(t)|^2\}}{E\{|s(t)|^2\}},\ t \in [0, T_s]$$

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2. SYSTEM DESIGN

In our study, we design a system which have three parts OFDM transmitter, optical fiber link and OFDM receiver which is shown in Figure 1 [1]. We use wavelength division multiplexing (WDM) to reach high data rate with four channel spaced with 50 Ghz and each OFDM signal with 10 Gbps data rate to reach 40 Gbps data rate. We use optisystem v.14 to analysis the WDM OFDM system. And we use some parameter for system work properly which is shown in table 1.

Table 1: Simulation global parameter

Sequence length	16384
Samples per bit	8
Number of samples	131072

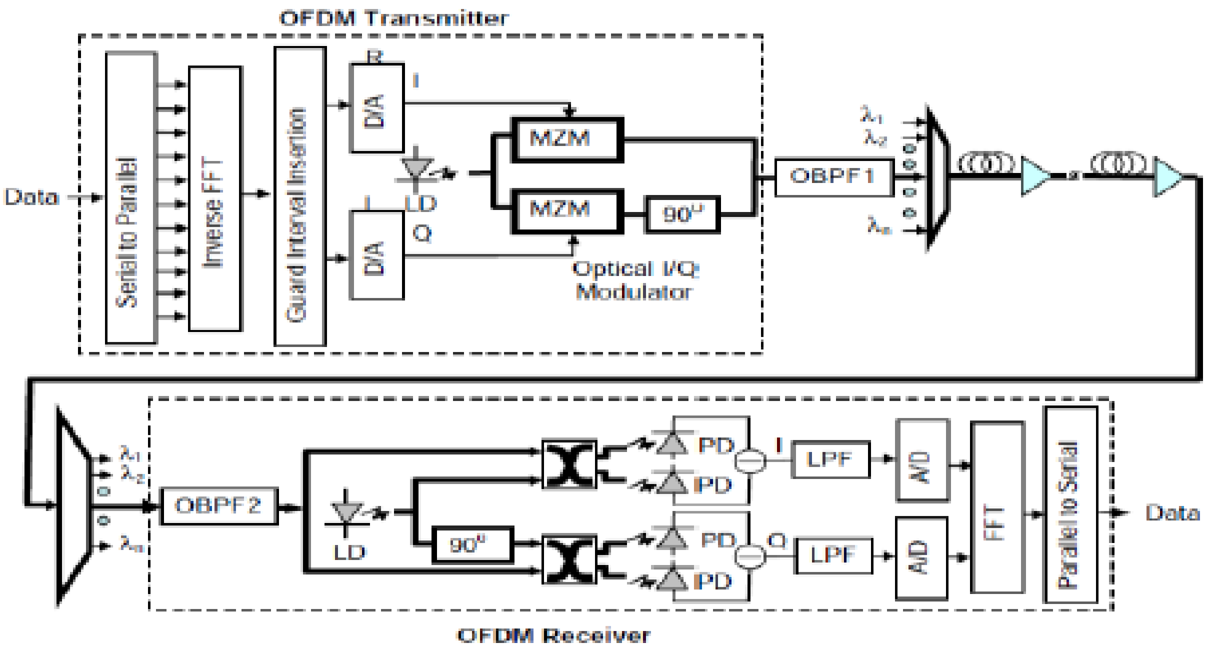

Figure 1: OFDM WDM system design

Transmitter

First part of our system which is shown in figure 2 is OFDM transmitter. Input signal is generated by the pseudo random bit sequence generator followed by the NRZ pulse generator. Input signal is passed through 4- QAM sequence generator and then signal is modulated by OFDM modulator which has OFDM subcarrier 512, FFT points 1024. That signal is passed through the direct I/Q modulator, having optical power splitter, power combiner and Mach-Zehnder Modulators (MZMs) [6]. Mach-Zehnder Modulator converts RF data to optical data. And those signals from the MZMs are combining and transmitted to optical fiber link [7-8].

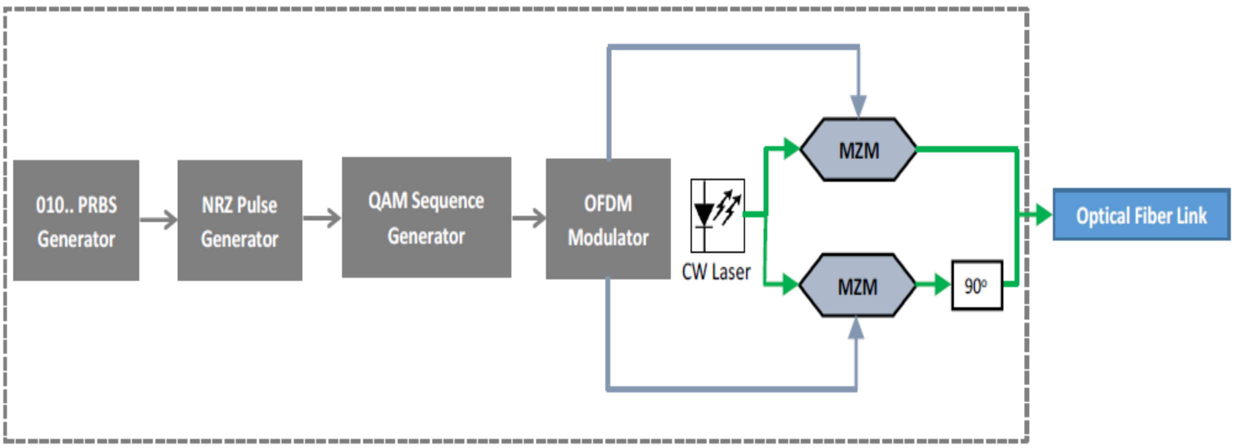

Figure 2: OFDM transmitter

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Optical Fiber Link

As the data from the transmitter is transmitted is passed through WDM. WDM multiplexed four OFDM signals and then passed through optical fiber link consisting 240 km single mode fiber (SMF). SMF configuration is given in Table 2. Dispersion is compensated by optical filter. EDFA is used to compensate the loss in optical fiber link.

Table 2: SMF Parameter

Attenuation	0.2 dB/km
Dispersion	16 Ps/nm/km
Dispersion Slope	0.08Ps/nm^2/km

Receiver

As the data from the optical fiber link passed through receiver before that data launched to wavelength division DE multiplexing. Figure 3 shows the OFDM receiver. Receiver has 4 PIN photo detectors and a laser.

We give the same frequency as the transmitter so synchronized the frequency with the transmitter. And then signal passing through the OFDM demodulator and resulting signal passed through the QAM sequence generator.

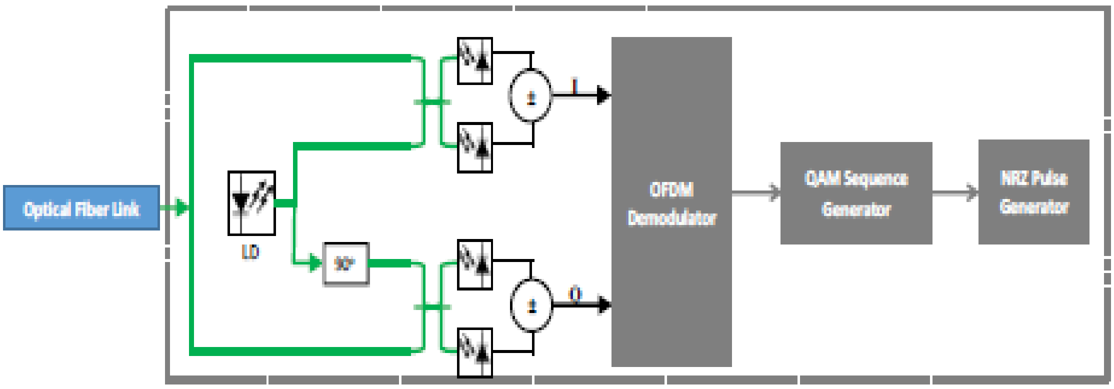

Figure 3: OFDM receiver

3. RESULT AND DISCUSSION

In Figure 4 shows undistorted RF spectrum. RF spectrum reading took from the transmitter which has power -12dBm. Now take the reading from the coherent receiver before this signal spread over 240 km optical fiber. Power is decreased to -69 dBm shown in Figure 5.

This is decrease in power due to attenuation increase as fiber length increase.

- Spectrum after WDM

Now we take the reading after WDM Figure 6 shows the four OFDM spectrums. Four WDM channels start from 193.05 THz to 193.2 THz with 50 GHz channel space.

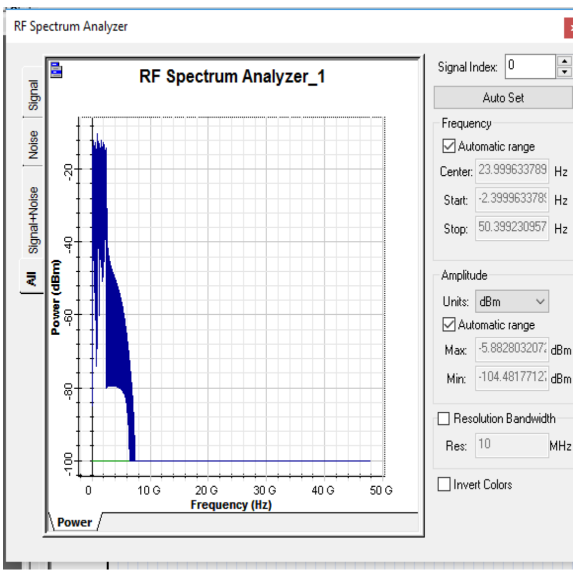

Figure 4: RF spectrum at transmitter

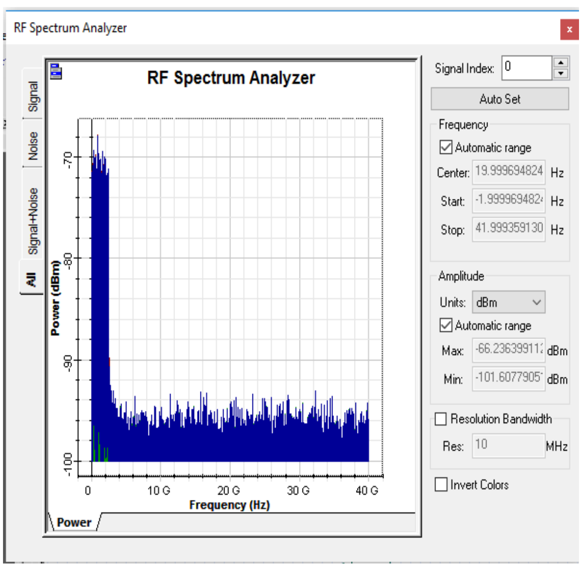

Figure 5: RF spectrum at receiver

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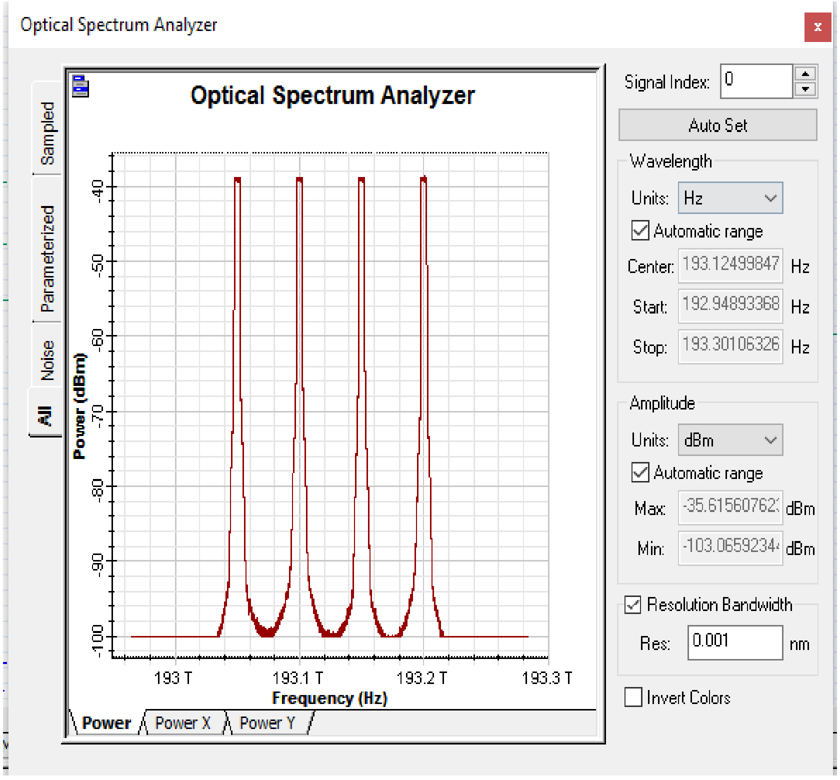

Figure 6: optical spectrum of 4 OFDM signals

Now we see the constellation diagram at the transmitter which is shown in figure 7. This is constellation diagram for 4-QAM modulator.

Now we connect transmitter with receiver without optical fiber and see the constellation diagram at receiver side which is shown in Figure 8.connect the optical fiber between transmitter and receiver and analysis the resulting Figure 9 shows the constellation diagram after 240 km and data rate 40 Gbps. Figure 10 shows the BER analyzer which shows bit error rate is very high.

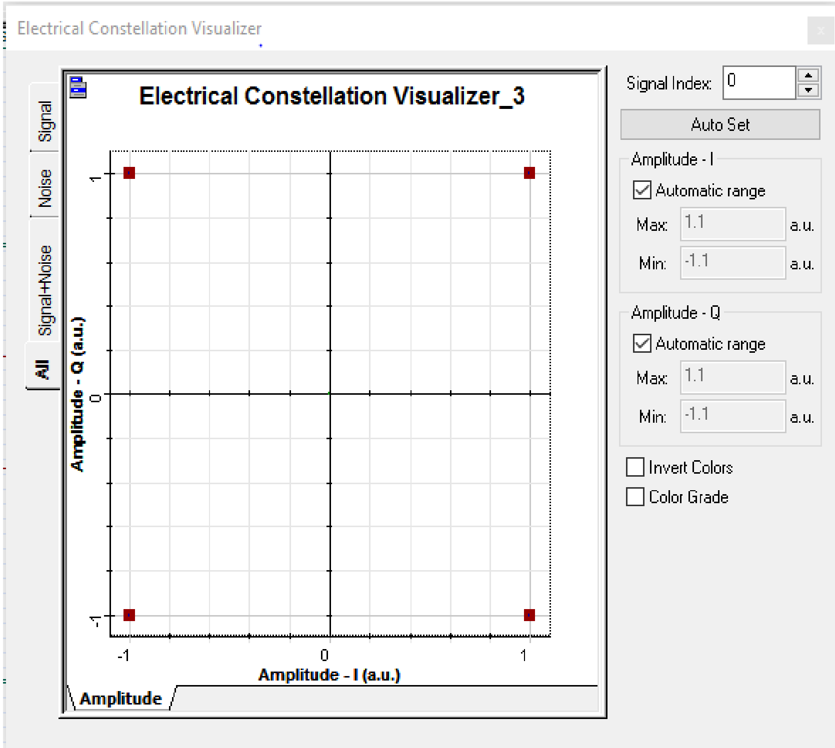

Figure 7: Constellation diagram at OFDM transmitter

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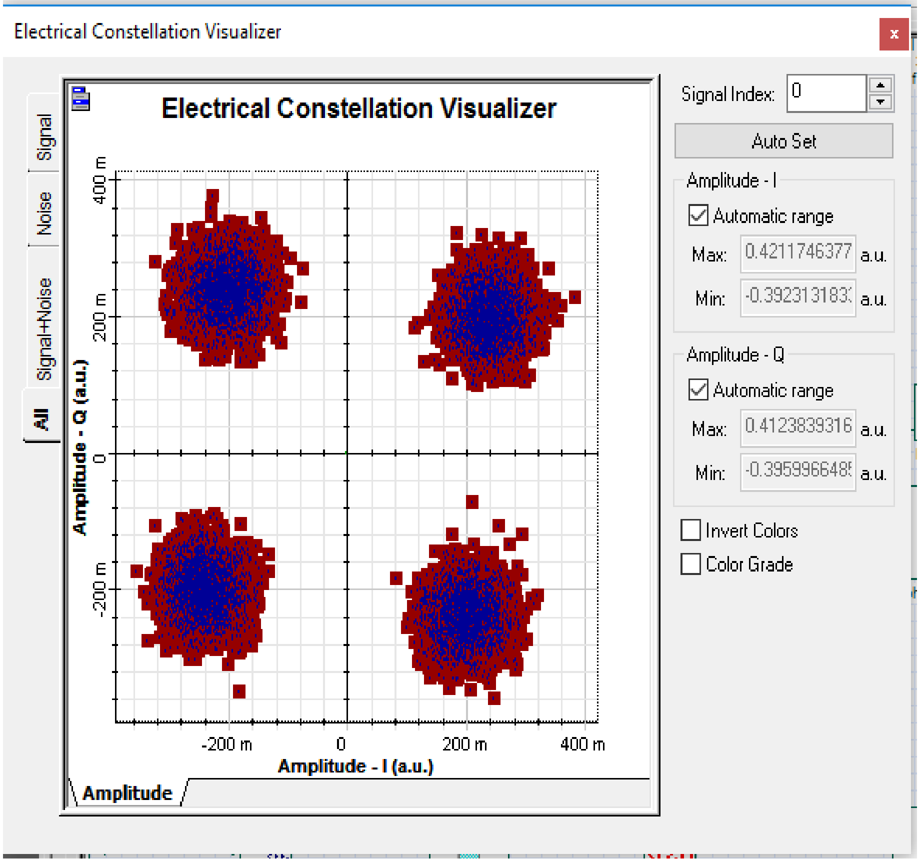

Figure 8: Constellation diagram at receiver without optical fiber

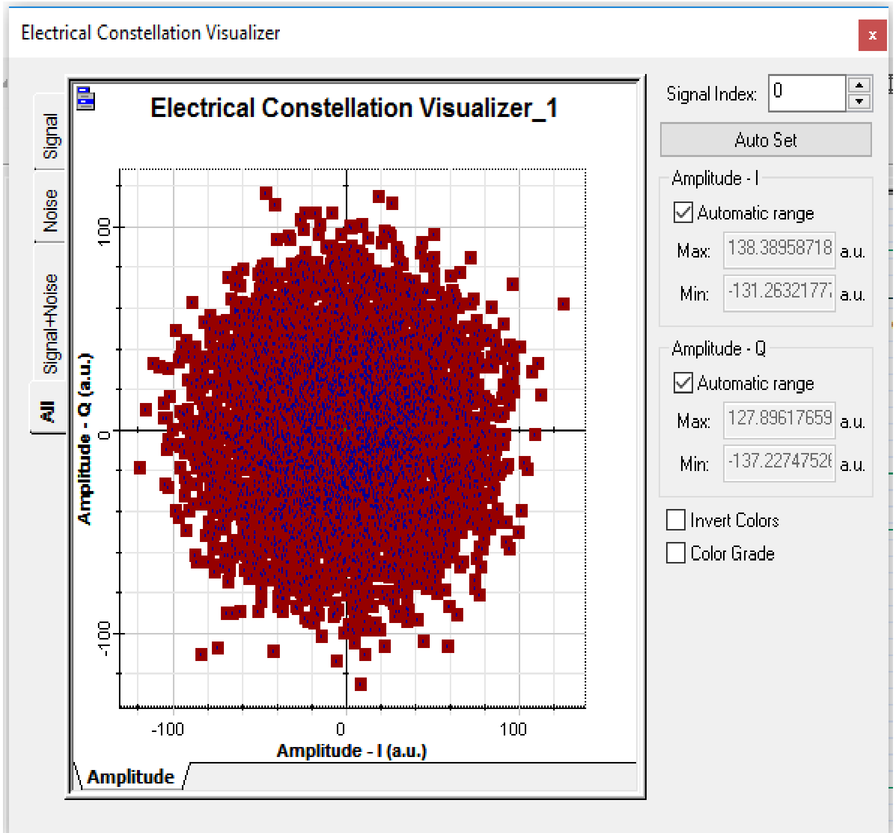

Figure 9: constellation diagram at receiver after 240 km and before using optical filter

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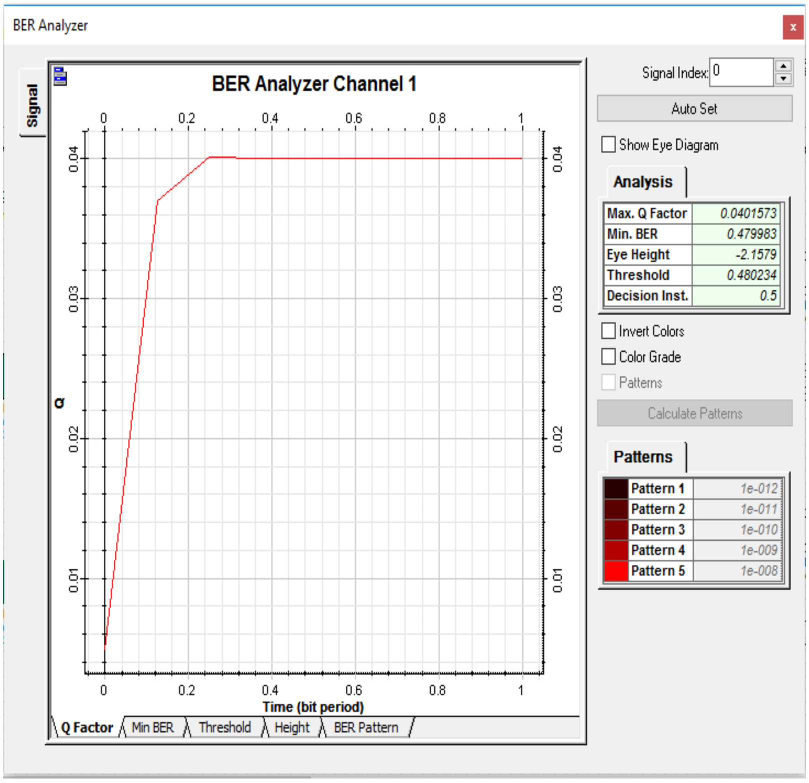

Figure 10: BER analyzer without optical filter

Now we take the reading for OFDM system at 40 Gbps as shown in the figure 11. Constellation diagram shows very high distortion. Now take the reading OFDM WDM system at 40 Gbps.

To compensate the dispersion use optical filter and analysis the output. Figure 12 shows the constellation diagram and Figure 13 shows the BER analyzer. So it is clearly seen that distortion of signal is very less and transmitted signal receive with very less bit error rate and less loss of the signal. And can recover the original signal easily.

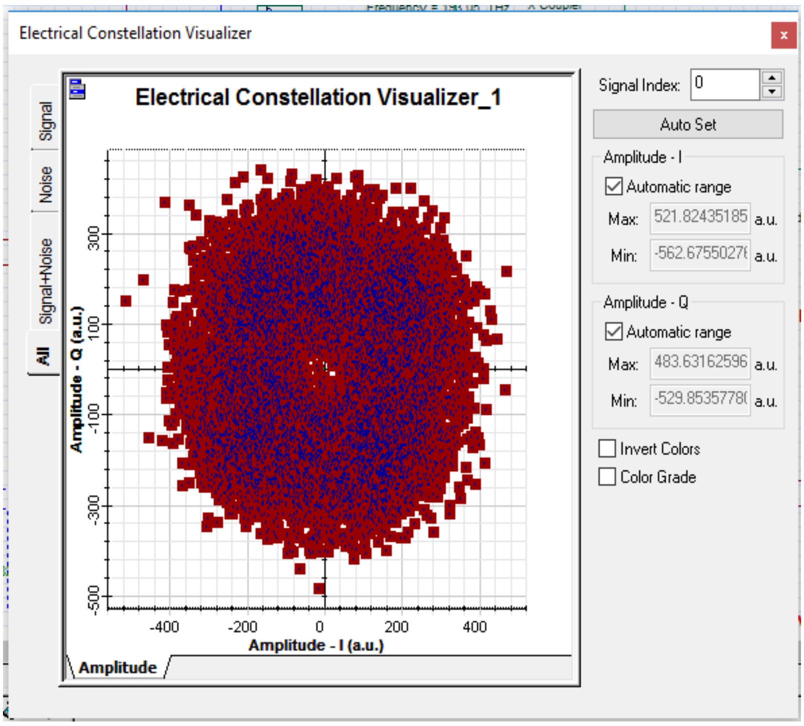

Figure 11: Constellation diagram of single OFDM at receiver at 40 Gbps

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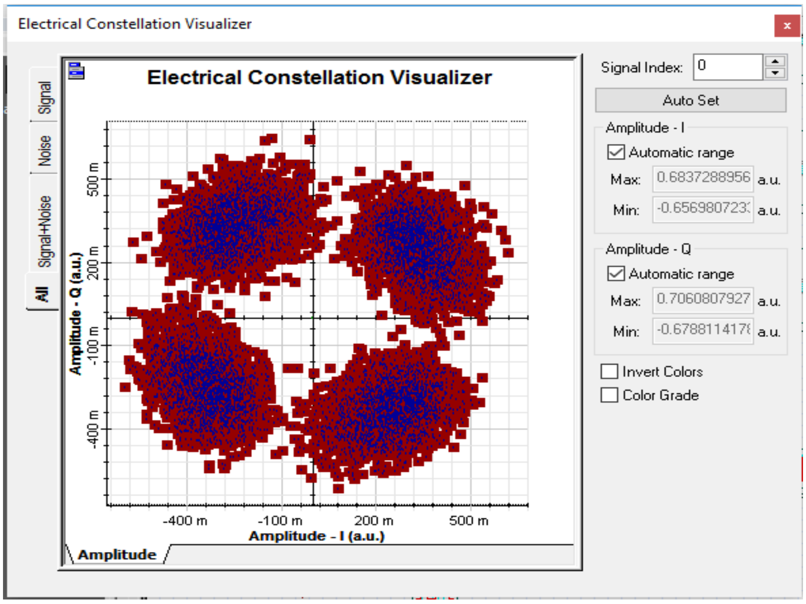

Figure 12 : Constellation diagram at receiver after using optical filter at 40 Gbps

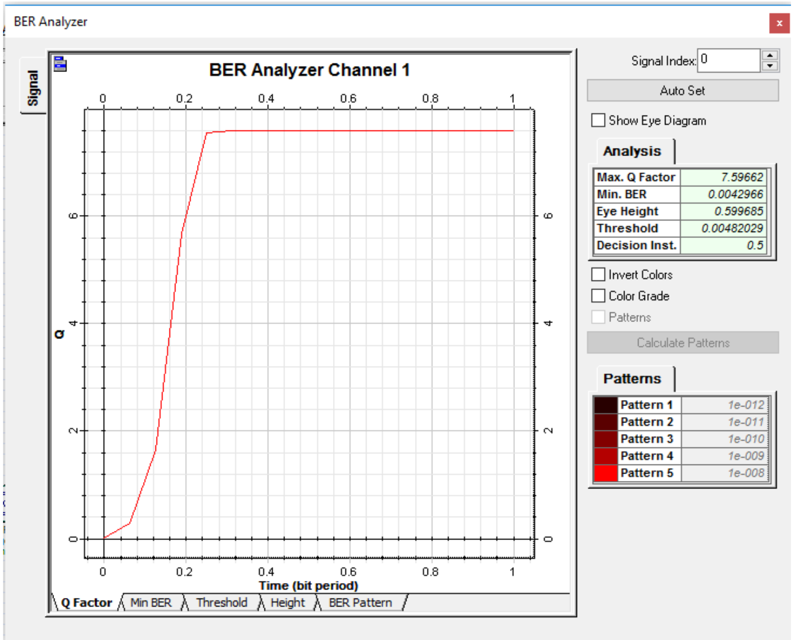

Figure 13: BER and Q factor at receiver after using optical filter at 40 Gbps

4. CONCLUSION

In this paper, OFDM with WDM system has been designed and analyzed. The use of WDM system increases the data rate and to reach data rate 40 Gbps. The system was designed by four channels with 50 GHz each with 10 Gbps to reach data rate 40 Gbps. And also studied single OFDM system and seen that OFDM WDM system is more reliable for the high data rate. The system gives clear result to prove that system is reliable.

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