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To Study Performance Analysis of OFDM Modulation in Optical Fibre Communication

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ABSTRACT

The increasing demand for high-capacity multimedia services in real-time demands a huge bandwidth for effective and efficient communication. Optical Fiber communication provides a long term solution for this ever increasing traffic demand. Optical communication based upon digital modulation provides greater information capacity, compatibility with multiple digital data services, and also provides higher data security, better quality communication. In this proposed work we have designed and analyzed a QAM encoded OFDM modulated optical communication link. We have also evaluated the performance of the designed network using OPTISYSTEM simulator.

Keywords: Quadrature amplitude modulation (QAM), MZM, BER , OFDM

I. INTRODUCTION

An Optical Fiber is a thin fiber of glass or plastic that carries light from one end to the other. Optical Fiber is a flexible, transparent fiber made by drawing glass or plastic to a diameter slightly thicker than that of a human hair. Optical fibers are used most often as a means to transmit light between the two ends of the fiber and find wide usage in fiber-optic communications, where they permit transmission over longer distances and at higher bandwidths than wire cables. Fibers are used instead of metal wires because signals travel along them with lesser amount of loss. Fig. 1 given below shows a generic block diagram of a typical optical communication system. It consists of a transmitter, a communication channel, and a receiver, the three elements common to all communication systems

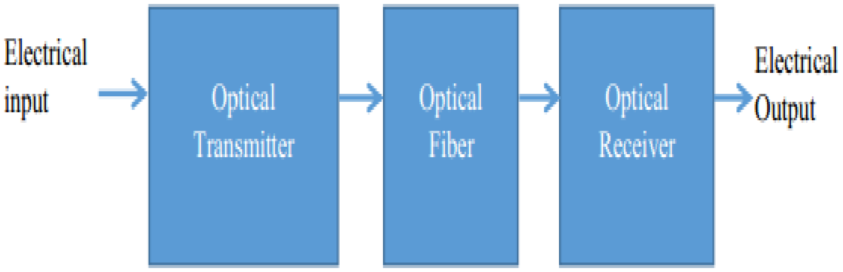


Figure 1: Block diagram of an Optical Communication System.

The optical transmitter is to convert the electrical signal into optical form and to launch the resulting optical signal into the optical fiber. It consists of an optical source, a modulator, and a channel coupler. Semiconductor lasers or light-emitting diodes are used as optical sources. The optical signal is generated by modulating the optical carrier wave.[1] An optical receiver converts the optical signal received at the output end of the optical fiber back into the original electrical signal. It consists of a coupler, a photo detector, and a demodulator. The coupler focuses the received optical signal onto the photo detector. Semiconductor photodiodes are used as photo detectors because of their compatibility with the whole system. The design of the demodulator depends on the modulation format used by the light wave system. The use of frequency-shift keying (FSK) and phase-shift keying (PSK) formats generally requires heterodyne or homodyne demodulation techniques. Most light wave systems employ a scheme referred to as “intensity modulation with direct detection” (IM/DD).[2]

II. DIGITAL MODULATION

Modulation is the process of varying the characteristics of a periodic waveform, called the carrier signal, according to a modulating signal that typically contains information to be transmitted. A modulator is a device that performs modulation. A demodulator performs the inverse of modulation. A modem (from modulator–demodulator) can perform both operations. The next generation wireless communication systems require higher data transmission rates in order to meet the higher demand of quality services. Communicating effectively over a huge distance has always been the challenge for engineers and scientists and with the transition of modulation systems from analog to digital has further complicated the situations.

Digital modulation schemes provide more information carrying capacity, better quality communication, data security and RF spectrum sharing to accommodate more services. The digital modulation schemes are preferred over analog modulation schemes because digital modulation schemes provide larger immunity to noise at the cost of large bandwidth requirements, whereas the requirement of video, audio and data over the computer network or the mobile telephony network termed as the third generation mobile communication poses a serious problem for the bandwidth, so the existing modulation schemes need to be modified for the purpose, where it can handle both the situations of noise and bandwidth efficiency[3][4].

Quadrature Amplitude Modulation (QAM)

QAM is a form of modulation which is widely used for modulating data signals onto a carrier used for radio communications. It is widely used because it offers advantages over other forms of data modulation such as PSK, although many forms of data modulation operate alongside each other. Quadrature Amplitude Modulation, QAM is a signal in which two carriers shifted in phase by 90 degrees are modulated and the resultant output consists of both amplitude and phase variations. In view of the fact that both amplitude and phase variations are present it may also be considered as a mixture of amplitude and phase modulation.[8]. Figure 8 shows the block diagram of a QAM modulator and demodulator.

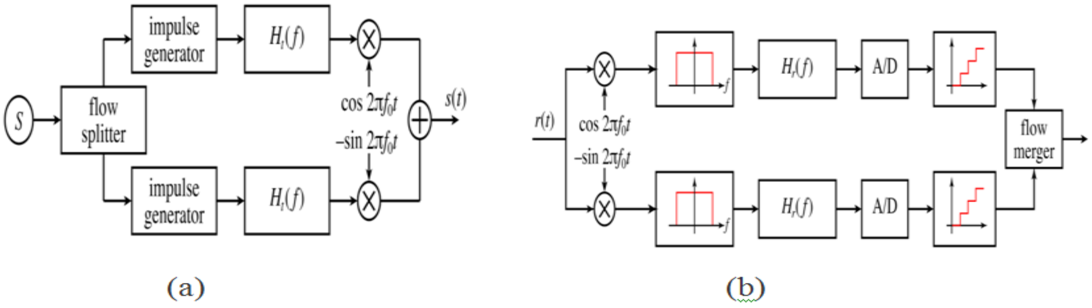


Figure 2: Block Diagram of (a) QAM Modulator, (b) QAM Demodulator

The above figure shows the ideal structure of a QAM transmitter, with a carrier center frequency and the frequency response of the transmitter's filter. First the flow of bits to be transmitted is split into two equal parts: this process generates two independent signals to be transmitted. They are encoded separately just like they were in an amplitude-shift keying (ASK) modulator. Then one channel (the one "in phase") is multiplied by a cosine, while the other channel (in "Quadrature") is multiplied by a sine. This way there is a phase of 90° between them. They are simply added one to the other and sent through the real channel. The receiver simply performs the inverse operation of the transmitter. [10][11]

Multiplying by a cosine (or a sine) and by a low-pass filter it is possible to extract the component in phase (or in Quadrature). Then there is only an ASK demodulator and the two flows of data are merged back. In practice, there is an unknown phase delay between the transmitter and receiver that must be compensated by synchronization of the receiver's local oscillator (i.e. the sine and cosine functions in the above figure). In mobile applications, there will often be an offset in the relative frequency as well, due to the possible presence of a Doppler shift proportional to the relative velocity of the transmitter and receiver. Both the phase and frequency variations introduced by the channel must be compensated by properly tuning the sine and cosine components, which requires a phase reference, and is typically accomplished using a Phase-Locked Loop (PLL)

III. OFDM

Orthogonal frequency division multiplexing (OFDM) is a modulation technique which belongs to a broader class of multicarrier modulation (MCM) in which the data information is carried over many lower rate subcarriers. Two of the fundamental advantages of OFDM are its robustness against channel dispersion and its ease of phase and channel estimation in a time-varying environment. OFDM is now used in most new and emerging broadband wired and wireless communication systems because it is an effective solution to intersymbol interference caused by a dispersive channel. Very recently a number of researchers have shown that OFDM is also a promising technology for optical communications.

Orthogonality is considered as a property that allows multiple information signals to be transmitted perfectly over a common channel and detected without interference. OFDM achieves Orthogonality in the frequency domain by allocating each of the separate information symbols onto different orthogonal subcarriers. OFDM signals are generated from a sum of sinusoids, with each corresponding to a subcarrier as shown in Figure 3.

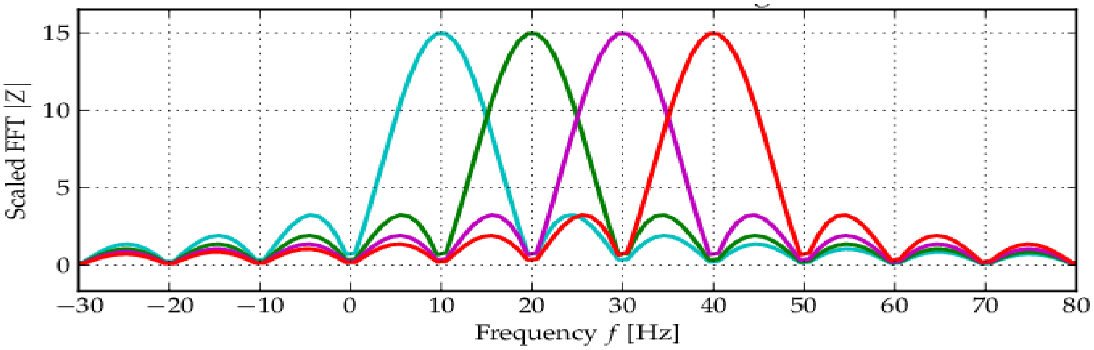


Figure3: Spectrum of Orthogonal OFDM subcarriers

Figure 4 shows the block diagram of transmission system using OFDM. The high rate digital data stream is split into N parallel streams. Each stream is mapped to a symbol stream using some modulation scheme (QAM, PSK, etc). The symbols are modulated onto the subcarriers using the inverse discrete Fourier transform (IDFT). IDFT operation is a transformation of the OFDM. Symbol from the frequency domain to time domain. The inverse fast Fourier transform (IFFT) performs the same operation as an IDFT, except that it is much more computationally efficiency. After the IDFT operation, a cyclic prefix is added to the OFDM symbol prior to digital- to-analogue converter (DAC).

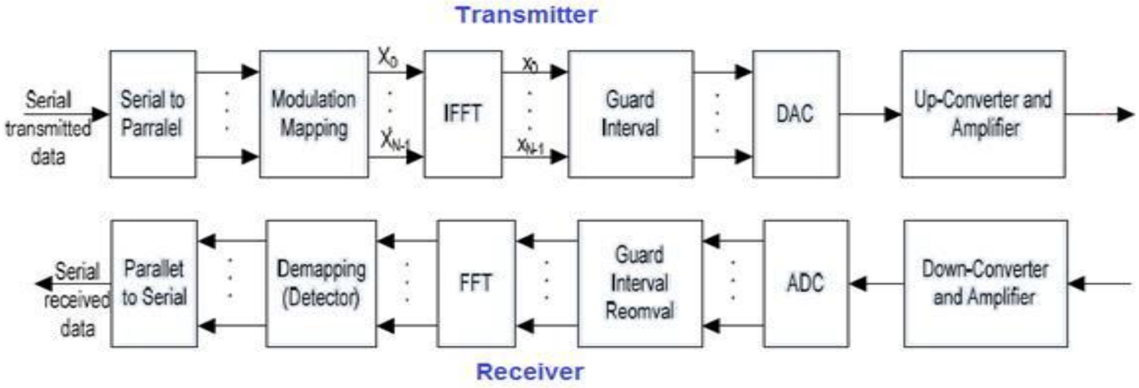


Figure 4: Block Diagram Showing a Basic OFDM System

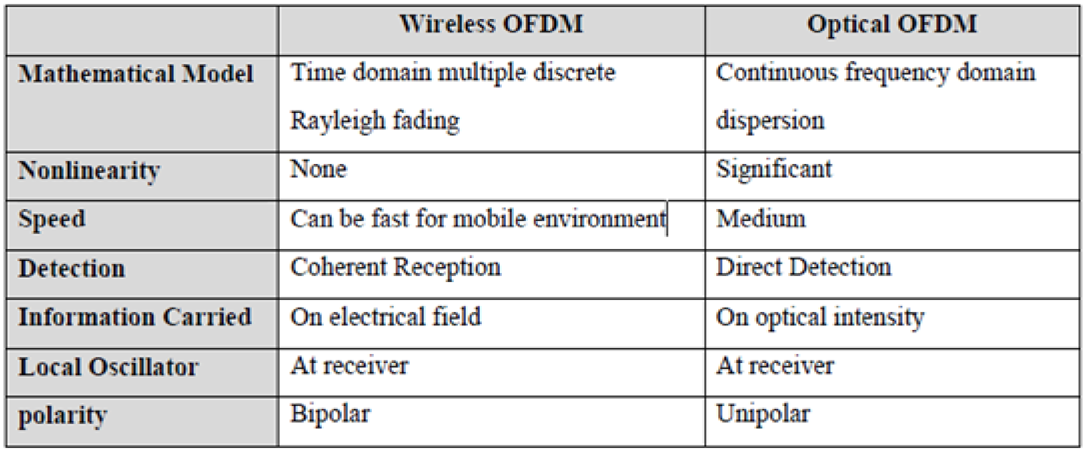
The DAC output is a baseband analog signal which is then up-converted in frequency and Transmitted. At the receiver as shown in Figure 4, the received signal is down-converted to baseband. Then the signal is converted from analog to digital using an analogue-to digital converter (ADC). After removing guard interval, the samples are fed into the discrete Fourier transform (DFT) to be converted to frequency domain. Finally, the data is detected.

IV. OPTICAL OFDM

OFDM is an attractive modulation format that recently received a lot of attention in the fiber-optic community. The main advantage of optical OFDM is that it can cope with virtually unlimited amount of ISI. In high-speed optical transmission systems, ISI is caused for instance by chromatic dispersion and polarization mode dispersion (PMD). Table 1 show the comparison between wireless OFDM and Optical OFDM. As discussed basics of OFDM, the division of a high bit rate data stream into several low bit rate streams, which are simultaneously modulated onto orthogonal subcarriers. In general, the subcarriers are generated in the digital domain; therefore these systems typically consist of many subcarriers. In these systems, channel estimation is realized by periodically inserting training symbols. In fiber-optic transmission systems, the

OFDM systems where the subcarriers are generated in the optical domain are also proposed. Optical OFDM solutions can be divided into two groups. The first group includes techniques for multi modes are received, for instance optical wireless and multimode fiber systems. The second group includes techniques for single mode fiber, where only one mode of the signal is received.

Table 1 Comparison Between Wireless and Optical OFDM.



	Wireless OFDM	Optical OFDM
Mathematical Model	Time domain multiple discrete Rayleigh fading	Continuous frequency domain dispersion
Nonlinearity	None	Significant
Speed	Can be fast for mobile environment	Medium
Detection	Coherent Reception	Direct Detection
Information Carried	On electrical field	On optical intensity
Local Oscillator	At receiver	At receiver
polarity	Bipolar	Unipolar

V. ADVANTAGES and DISADVANTAGES OF OFDM

OFDM has several advantages such as high spectral efficiency; tuned sub-channel receiver filters are not required, low sensitivity to time synchronization errors, Efficient implementation using FFT, can easily adapt to serve channel conditions without complex equalization. Robust against narrow-band co-channel interference and robustness against intersymbol interference and fading caused by multipath propagation. Along with these advantages, OFDM also has certain inherent disadvantages too such as high Peak-to-Average-Power Ratio (PAPR), Sensitive to Frequency Synchronization Problems, Sensitive to Doppler Shift.

VI. PROPOSED WORK

In this proposed work we have simulated an OFDM based optical communication network with QAM modulation .The PRBS generate a bit rate which is modulated by a 4-QAM modulator in electrical domain ,then the signal is applied to an OFDM modulator in electrical domain. The output of OFDM modulator id then applied to a MZM modulator based I/Q up converter which process the signal in optical domain and the signal is then transmitted over the communication link.

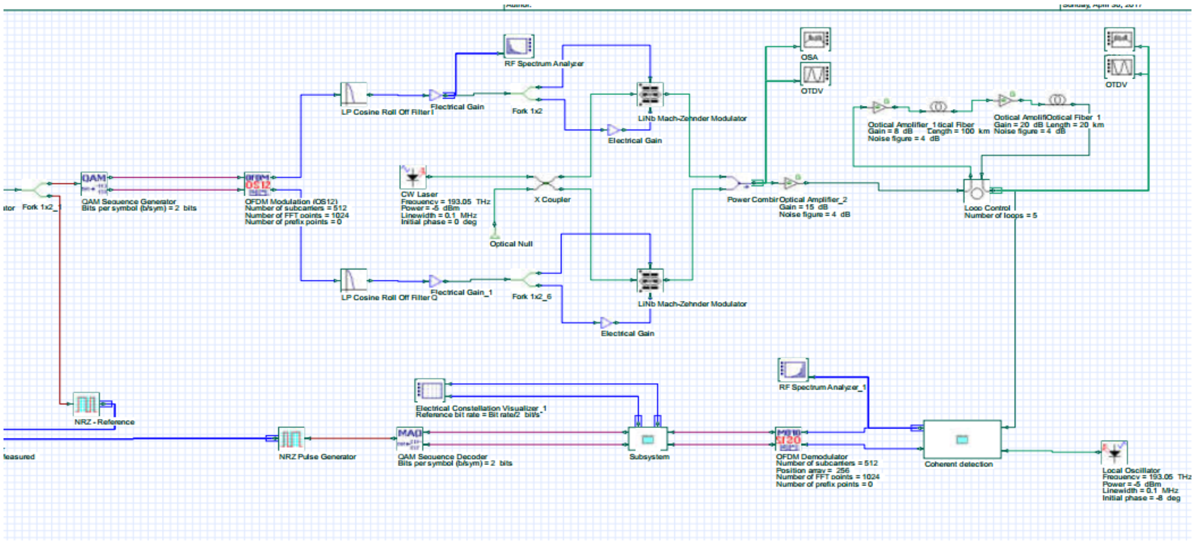


Figure 5 Proposed System layout design in OPTISYSTEM

At the reciever we perform Coherent Detection and after detection the signal is then transmitted to an I/Q downconverter which is then applied to an OFDM demodulator, which demodulates the singal and then the signal is applied to QAM demodulator which demodulates the symbols and we obtan the results at the output.

VII. RESULT ANALYSIS

In this proposed work,, we have simulated the designed system on OPTISYSTEM v14 software over 120,240,360,480 and 600km respectively and following results were obtained.

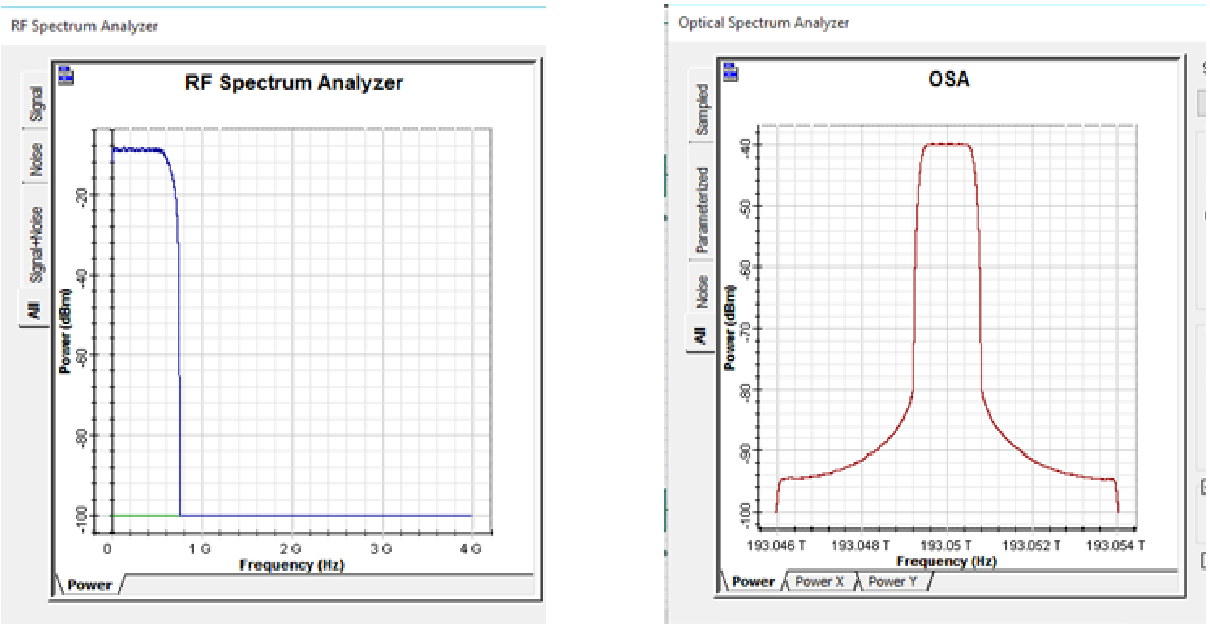


Figure 6 Input RF spectrum and corresponding Optical Spectrum

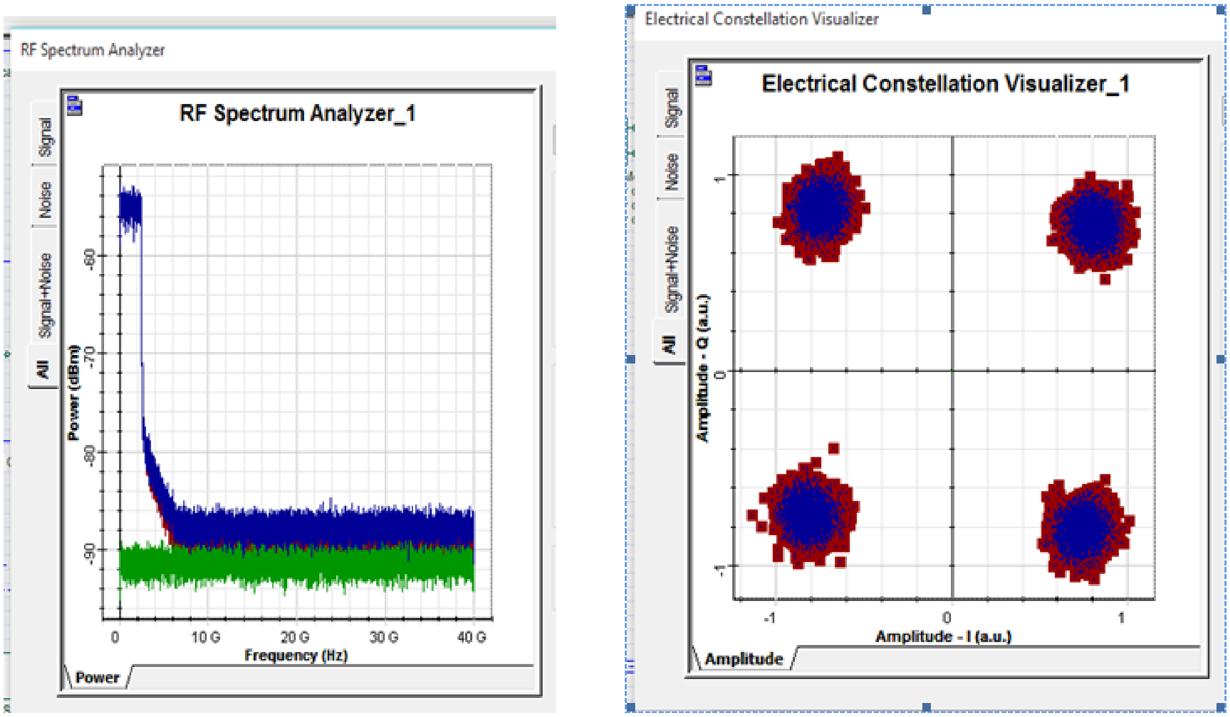


Figure 7 received RF spectrum and constellation diagram at 120km fiber length

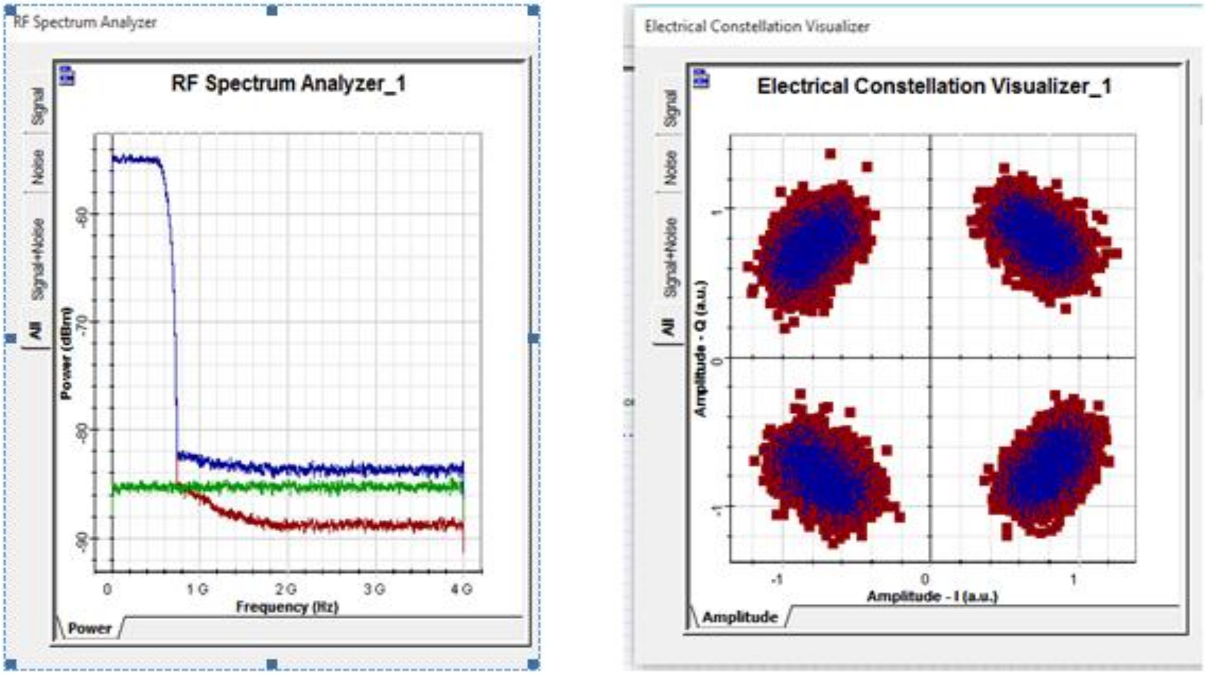
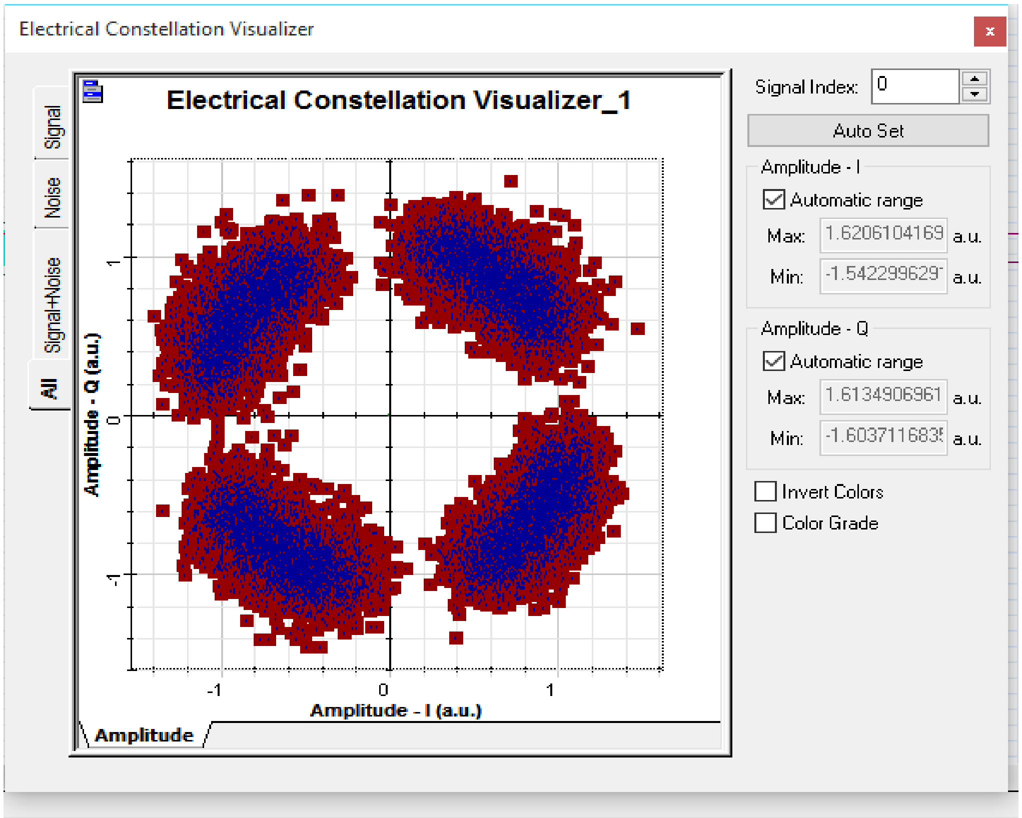


Figure 8. Received RF spectrum and constellation diagram at 240km fiber length

After simulation of the above designed system we found that the Q Factor almost remains same but the constellation diagram shows the ovelapping of spectral points . We further simulated the system over 360,480and 600km of fibre length.And we fond that although the system works reliably but over long range communication the constellation diagram shows distortion and spectral overlapping.



Signal Index: 0

Amplitude - I

☑ Automatic range

Max: 1.6206104169 a.u.

Min: -1.542299629 a.u.

Amplitude - Q

☑ Automatic range

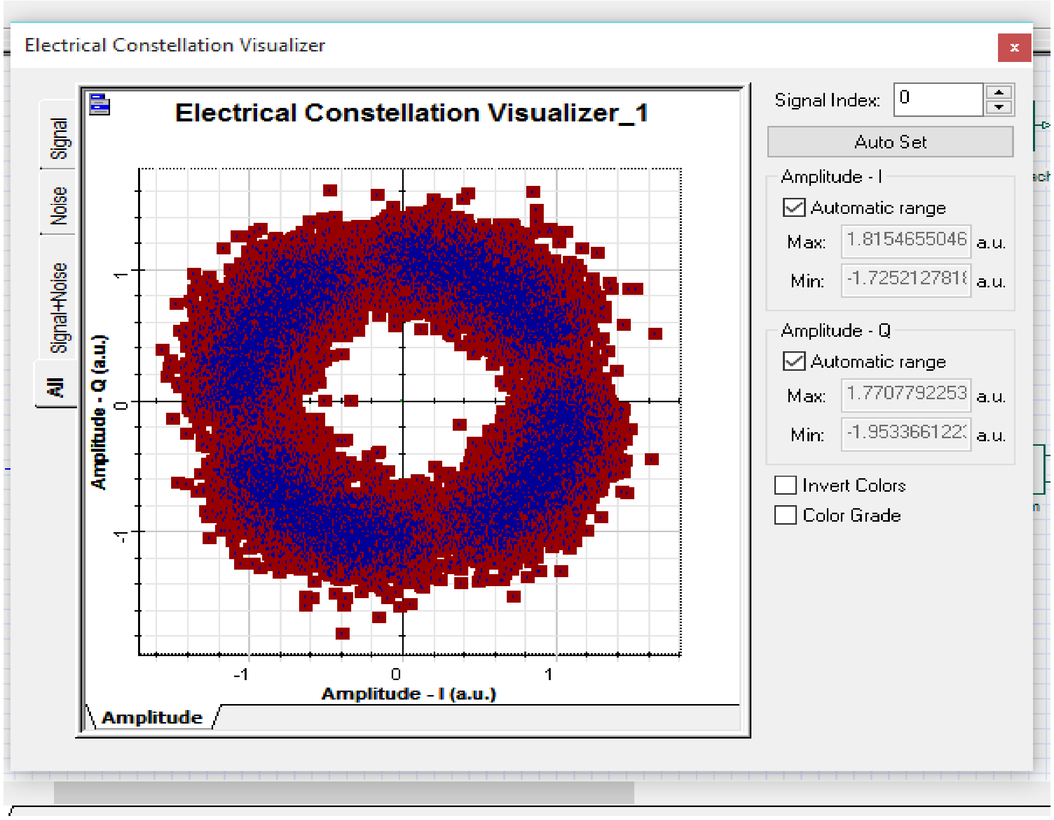
Max: 1.6134906961 a.u.

Min: -1.603711683 a.u.

☐ Invert Colors

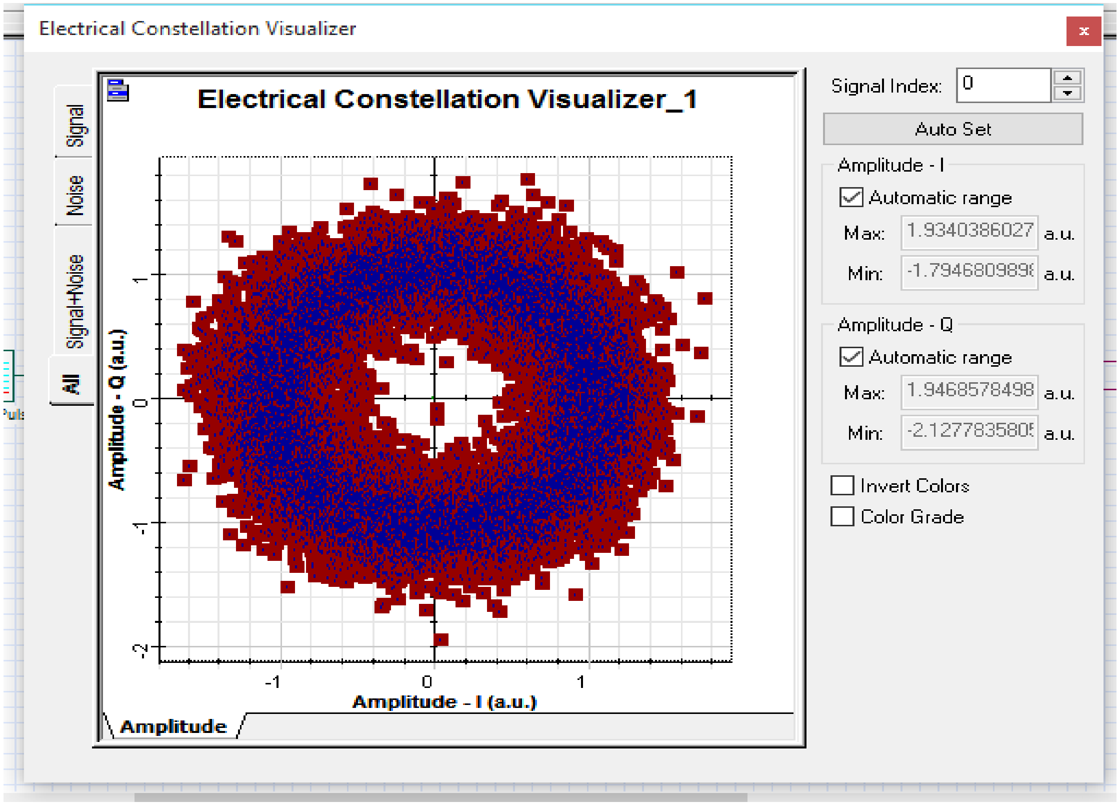
☐ Color Grade

Figure 9. Constellation diagram at 360km fiber length



Signal Index: 0
Amplitude - I
☑ Automatic range
Max: 1.8154655046 a.u.
Min: -1.725212781 a.u.
Amplitude - Q
☑ Automatic range
Max: 1.7707792253 a.u.
Min: -1.953366122 a.u.
☐ Invert Colors
☐ Color Grade

Figure 10 Constellation diagram at 480 km fiber length



Signal Index: 0
Amplitude - I
☑ Automatic range
Max: 1.9340386027 a.u.
Min: -1.794680989 a.u.
Amplitude - Q
☑ Automatic range
Max: 1.9468578498 a.u.
Min: -2.127783580 a.u.
☐ Invert Colors
☐ Color Grade

Figure 11 Constellation diagram at 600 km fiber length

CONCLUSION

In this proposed work we have presented a uniform simulation approach for numerical and graphical value analysis of optical networks. After simulation of the above designed system we found that the Q Factor almost remains same but the constellation diagram shows the ovelapping of spectral points . We further simulated the system over 120,240,360,480and 600km of fibre length.And we fond that although the system works reliably but over long range communication the constellation diagram shows distortion and spectral overlapping.

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