**University of Babylon**

**Faculty of Engineering**

**Electrical Engineering Department**

# Evaluation of the performance of 5G Optical Communication

A Project Submitted in Partial Fulfillment of the Requirements for the Degree of Bachelor of Science (B.Sc.) in Electrical Engineering.

By

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Supervisors

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**Academic year 2021/2022**

# <u>Certificate</u>

The project entitled:

**Evaluation of the performance of 5G Optical Communication**

Which is being submitted by

Ali Aziz Muhammed
Ahmed Qassim Khudair
Hussein Alaa Hussein
Shukran Ghani hussien

In the fulfillment of requirement for the award of the B.Sc. degree in Electrical Engineering. This has been carried out under my supervision and accepted for presentation & examination.

Signature :

Supervisor's name :

Date: / / 2022

The Supervisor

## CERTIFICATE

This project entitled

**Evaluation of the performance of 5G Optical Communication**

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Shukran Ghani hussien

In the partial fulfillment of requirement for the award of the B.Sc. degree in Electrical Engineering has been discussed by us and all the suggested recommendations during the discussion are carried out.

**1st Examiner ( The supervisor ):**
**Signature:**

**Name :**
**Date: / / 2022**

**2nd Examiner**
**Signature :**

**Name :**
**Date: / / 2022**

**3rd Examiner**
**Signature:**

**Name :**
**Date: / / 2022**

**4th Examiner**
**signature:**

**Name :**
**Date : / / 2022**

**5th Examiner**

**Signature:**

**Name :**

**6th Examiner**

**signature:**

**Name :**

الرحيم الرحمن الله بسم

﴿قَالُوا سُبْحَانَكَ لَا عِلْمَ لَنَا إِلَّا مَا
عَلَّمْتَنَا إِنَّكَ أَنتَ الْعَلِيمُ الْحَكِيمُ﴾

صدق الله العلي العظيم

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# ACKNOWLEDGMENT

Alhamdulillah, thank to Allah for His divinity and blessing. I have completed my final year project for Bachelor of Electrical Engineering successfully. I would like to thanks my lovely family for their encouragement and support. I also would like to thank my supervisor, Dr. Haider Jabbar, whose patience in supporting, helping and guiding me on my project. Thanks also to my friends and people that has helped me along the course of finishing this project. Thank you all.

# LIST OF SYMBOLS AND ABBREVIATIONS

| | | |
|---|---|---|
| $\lambda$ | - | Wavelength |
| ADC | - | Analog to digital converter |
| ASK | - | Amplitude shift keying |
| BER | - | Bit Error Rate |
| BPSK | - | Binary phase shift keying |
| BS | - | Base Station |
| CATV | - | Cable Television |
| CBS | - | Central base station |
| CO | - | Central Office |
| COFDM | - | Coded OFDM |
| CO-OFDM | - | Coherent Optical - Orthogonal Frequency Division Multiplexing |
| CW laser diode | - | Continuous wave laser diode |
| DAC | - | Digital to analog converter |
| DFA | - | Doped fiber amplifier |
| DPSK | - | Differential phase-shift keying |
| DWDM | - | Dense Wavelength Division Multiplexing |
| E/O | - | Electrical to optical |
| EDFA | - | Erbium Doped Fiber Amplifier |
| FDM | - | Frequency Division Multiplexing |
| FFT | - | Fast Fourier Transform |
| FM | - | Frequency modulation |
| FSO | - | free space optical |
| I/Q | - | I - in phase; Q - quadrature (90 degree phase shift) |
| ICI | - | Inter-carrier Interference |
| IF | - | Intermediate Frequency |
| IFFT | - | Inverse Fast Fourier Transform |

| | | |
|---|---|---|
| ISI | - | Inter-symbol Interference |

| | | |
|---|---|---|
| LAN | - | Local Area Network |
| LiNbO3 | - | Lithium noibate |
| MCM | - | Multicarrier Modulation Method |
| MSC | - | Mobile Switching Centre |
| MZM | - | Mach-Zehnder modulator |
| NRZ | - | Non return-to-zero |
| O/E | - | Optical to electrical |
| OFDM | - | Orthogonal Frequency Division Multiplexing |
| OOK | - | On-off keying |
| OTDM | - | Optical Time Division Multiplexing |
| OTR | - | Optical-to-RF down-conversion |
| PBRS | - | Pseudo-random bit sequence |
| PM | - | Frequency modulation |
| PON | - | Passive optical network |
| PSK | - | Phase-shift keying |
| QAM | - | Quadrature amplitude modulation |
| QPSK | - | Quadrature Phase-Shift Keying |
| RAP | - | Radio access point |
| RAU | - | Remote access unit |
| RF | - | Radio Frequency |
| RoF | - | Radio over Fiber |
| RS | - | Remote Site |
| RTO | - | RF-to-optical up-conversion |
| RZ | - | Return-to-zero |
| SC | - | Switching Centre |
| SMF | - | Single-Mode Fiber |
| WDM | - | Wavelength-Division Multiplexing |
| WLAN | - | Wireless Local Area Network |

# CHAPTER ONE

# INTRODUCTION

## 1.1 Introduction

Free-space optical system (FSO) refers to the transmission of modulated visible or infrared, IR beams through the atmosphere to achieve broadband communications. The theory of FSO is exactly the same as that of the fiber optical transmission system. The difference is that the energy beam is collimated and sent through clear air or space from the source to the destination, rather than guided through an optical fiber [1].
It has drawn attention in telecommunication industry, due to its cost effectiveness easy installation, quick establishment of communication link especially in the disaster management scenario, high bandwidth provisioning and wide range of applications. With FSO communication, maximum data transfer rates up to 2.5 Gbps is possible, unlike the maximum data transfer rates of 622Mbps offered by RF communication systems [2]. Another appealing characters are, the optical spectrum is unlicensed and a modulation technique like on-off keying which is simple in implementation finds much importance in high bandwidth and in physical layer connection where there is protocol transparency [3]. The main limitation of FSO link is due to atmospheric attenuations (i.e., rain, fog, snow). Attenuation created by rain plays a major role and reduces the power level at the receiver limiting the FSO link availability over a distance. The availability of FSO link is estimated based on the threshold value of LM .For telecommunication (carrier class) applications, the link availability is generally considered to be 99.999% while for the LAN applications (enterprise class) it is over 99% [4].

The estimation of LM in different places for different distances based on the statistical data of rain fall distribution and for different attenuations is been evaluated. An FSO network is considered with an adaptive LM based RWA Technique is proposed for maximum Link reliability even for the worst scenarios .The network performance metrics have been calculated for different conditions .

## 1.2 Organisation of Work

In chapter one the introduction of optical wireless and it’s Contents has been done in chapter one. In chapter two “Free space optical (FSO) communication Network" definition of all optical wireless has been reviewed . In chapter three the propose system design has been done . In chapter four all the Results and discussion has been determind. Finally In chapter five The Conclusion of work where is presented.

## 1.3 Problem Statement

- Free Space Optical (FSO) communication is one of the most promising access methods.
- when the laser passes through the atmospheric channel, it will be subject to the interference of the dust, smoke, fog, water and other solid, liquid and gas suspended particles in the channel.
- The scattering effect of the atmosphere on the laser signals is related to the number and size of the particles, the number of particles increases, and the scattering attenuation is more serious.
- With the weather changes of cloud, rain, snow and fog, the scattering attenuation caused by the particles in the atmosphere is also different.
- In different weather conditions, the amplitude and phase noise of the signals are brought to a different extent. This will affect the communication quality, shorten the communication distance, and even lead to the communication interrupt .

## 1.4 Objective Of The Work

The objectives of this research can be summarized as follows :

- To investigate the performance of Optical wireless Communications based on different modulations Schemes
- To study the atmospheric, geometric and other effected factors on the optical transmitted signal to increase the transmission range and maximum Q-factor.
- To inhance the FSO network we have been used different types of modulation and filters.
- To perform the performance of optical transmission system in term of BER,Q-factor , SNR and link range .

# CHAPTER TWO

## Free space optical (FSO) communication Network

### Challenges for 5G:
### Following are the key challenges that need to tackle in the implementation of 5G communication system;

IoT and increased number of connections: IoT will be main promising thing in 5G communication system and because of IoT there is expected to be a huge number of increment in number of devises in network. Increased number of devises means increasing demand of total data volume and increasing demand of management of huge number of devices. There is a limit in current 3Gpp based networks control plane which will not be able to handle the increased number of connection load so there is a need to develop new control plane for increased number of connection in 5G communication system.Data volume: 5G is expected to provide UHD video quality with high resolution and virtual reality/ augmented reality. Because of this data consumption volume will increasing 25-50 % every year and this is expected to be continue. Some researcher have predicted that in 5G communication system data consumption volume will reach upto 25 exabytes per month upto 2020 which is 10 times more than present consumption which is 2.5 exabytes per month. So the data capacity will be a main challenge in 5G communication system.

Increasing capacity without increasing cost: In the present scenario users want to use more data but they don't want to pay more times for their bills compares to their previous bills. In the development of 5G communication system this is one of the major challenge to increase data capacity without increasing the cost for operation so that users don't have to pay more for their increased data capacity. To resolve this issue macro cell and small cell concept is being developed in 5G system. Fast and flexible deployment of architecture: Development of fast and flexible architecture for 5G communication system is challenging. C-RAN concept is being adopted and implemented in 5G communication system in which some of the functions from RAN will be moved towards base band unit (BBU) cloud. This can provide scaling, economy, flexibility and easier reconfiguration because of centralized processing unit.Network densification: 5 To increases capacity and speed 5G system is divided into several layers from macro cells layer to localized layer for high speed connectivity. Increasing number of layers have given network coordination challenge to network designer. Low latency: The vision for 5G communication system is to provide ultra-low (< 1 ms) latency communication system which is the most challenging part in network designing. Various fast speed communication technologies have to be evolved and used in 5G communication system for achieve to reach this goal.

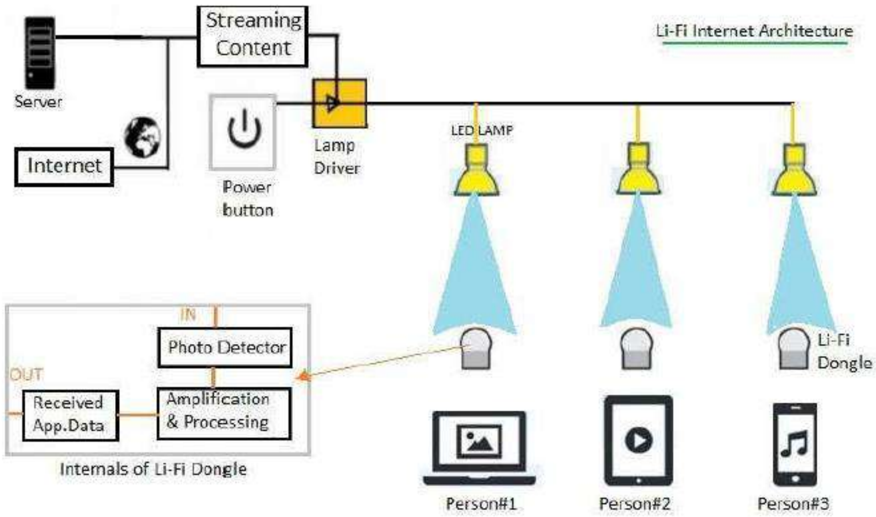
4. Promising wave bands for 5G: Millimetre wave band: This band ranges from wavelength 1mm –10 mm or in frequency 300 GHz – 30 GHz. In wave band is very interesting for recent research interest because of its short wavelength signal, components for this band can be smaller and compact compare to microwave system. Also huge unlicensed bandwidth availability makes it useful to be used in 5G for high data rates. Besides all advantages mm wave band suffers from huge attenuation loss and absorption loss while propagation in free space also it cannot pass through obstacles coming on its way.

Optical wave band: This band ranges from wavelength 390 nm to 750 nm. Due to huge bandwidth availability this band is also a promising wave band for 5G communication to increase the data rate and capacity. Moreover recently developed photonic mm wave transceiver making it more important because it can bridge both photonic and mm wave technologies for 5G system

5. Promising optical network technologies for 5G: Due to the huge bandwidth availability and licence free spectrum in the visible and IR range in the optical domain, photonic networking technologies are expected to play important role in 5G communication system. Some of the promising optical network technologies for 5G are listed below:

**7. Light Fidelity (LiFi):**

is a visible light communication system (VLC) and very similar to WiFi uses radio waves to transmit data but LiFi uses visible light from LEDs with special chip to transmit signal. Due to the high bandwidth availability in the visible spectrum LiFi can be used to high speed and high capacity network. The coherence length of white light generated by LEDs have very small coherence length that is the interference is very less in LiFi compare to WiFi and thus LiFi can be used in a more dense network environment. High switching speed, highenergy efficiency, longer life span, compactness, lower heat generation, reduced usages of harmful materials in design of LED, low cost of LED and huge spectrum availability have made LiFi technology very promising solution for 5G communication system [16].




Fig(2): shows the LiFi internet architecture which can be used in 5G communication system. The internet and server is connected to the LED lamp driver, the lamp driver modulate the electric current according to data content and according to current the LEDs

get ON/OFF. In the receiver side the photo detector is used to detect the modulated LED light and then the amplification and processing can be done to retrieve the data and then the data stream can be transmitted Table 1 LiFi v/s WiFi to a mobile or computer [17]

In the experimental environment LiFi has shown the 224 Gbps speed which is 100 times more than the WiFi can provide. This has become possible because of far more spectrum available for LiFi than WiFi also the visible spectrum is unlicensed which make LiFi very cost efficient technology for 5G communication system. Moreover the required components for LiFi is very less compared to WiFi which makes it very useful for communication networks. Table 1 shows the comparison between LiFi and WiFi in different aspects. The main down side of LiFi is that it cannot travel through walls or opaque media which makes it very short rage technology in 5G. Another limiting factor in LiFi technology is the LED need to be continuously on to transmit data although there is a possibility to dim LED light lower that human visibility. In short we can say that LiFi is not a replacement for WiFi but the LiFi and WiFi can work together in 5G communication system for better performance [18]. LiFi system can be mainly useful for indoor environment similar to WiFi but in some cases like street lamp to vehicle communication, traffic signal to vehicle communication, LiFi can be also used for outdoor environment.

**8. Optical camera communication (OCC):**

Optical camera communication (OCC) system is very similar to LiFi except that OCC uses image sensor instead of photo detector as in LiFi. Fig. 3 shows the working principal of OCC, in which in the transmitter side according to input data stream the LED driver modulates the LED light and in the receiver side mobile camera's image sensor can be used as detector. Then the received signal from sensor can be demodulate using signal and image processing algorithms and the output data can be extracted [19].

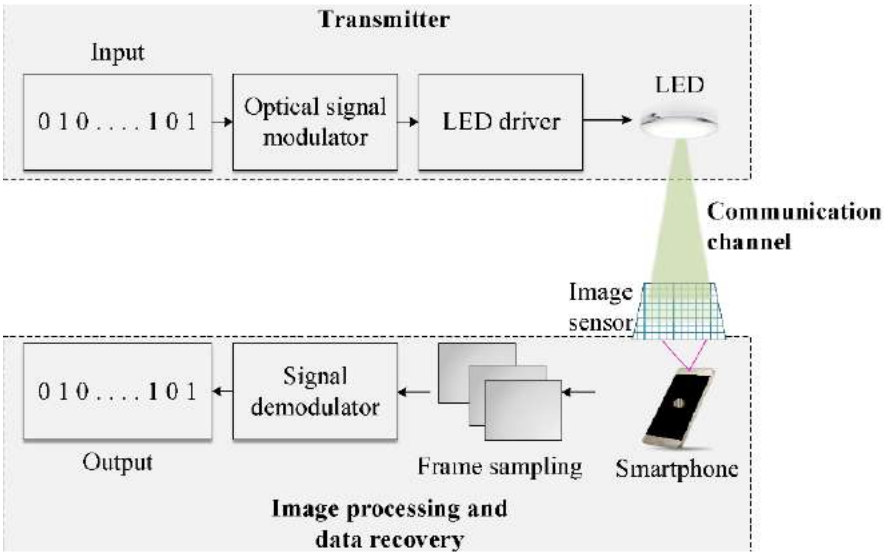



Fig (3):The main advantage of using image sensor as a detector in the OOC communication system

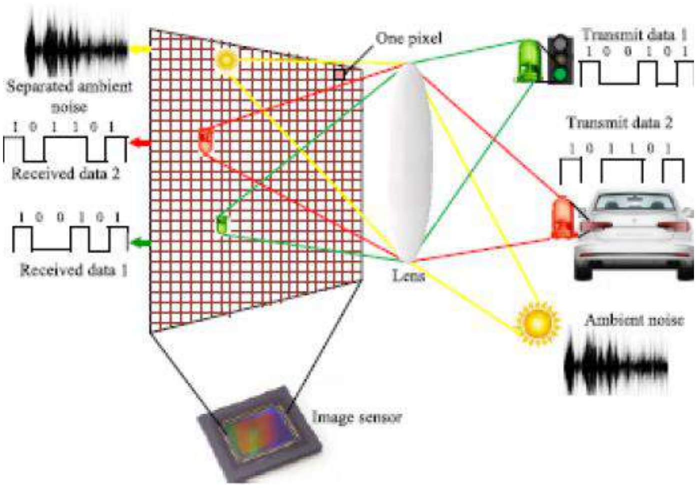



Figure (4): Operation principal of OCC

As shown in Fig if we use a lens in-front of image sensor in OCC we can separate different incoming signals in the detection side. Different signals and ambient noise will be focused at different pixels on the image sensor side, in this way noise can also be removed from the signal with some image and signal processing. The main advantage of OCC is, the SNR is very high compare to the single photo detector system. The OCC can also be used as LiFi in different applications in the 5G communication system [20].

# CHAPTER THREE

## Proposed Free Space Optical (FSO) Communication Design

### 3.1 Introduction :

Free space optical (FSO) communication is a technique of using laser beam as an information carrier, to realize point-to-point or point to multi-points transmission . Its advantages such as large capacity, good security, strong anti-interference ability, no frequency applications permission, make FSO become a flexible system for broadband access. Therefore, FSO has been widely concerned in the fixed wireless broadband access technology. However , the different weather conditions will affect the transceiver performance.

One of the fundamental considerations needed to deploy OWC technologies, is the communication distance. Based on the communication distance, OWC applications can be classified into ultra- short range, short range, medium range, long range, ultra- long range. The description of the fso channel is shown in the figure 3.1

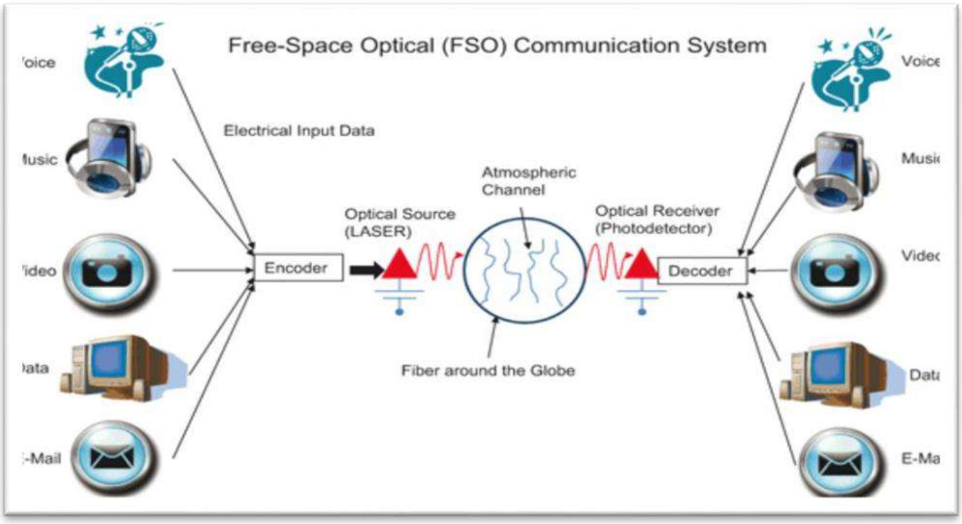



**Fig 3.1 Fundamentals of Free-Space Optical (FSO)**

## 3.2 Theoretical Description of FSO channel :

The FSO has known for its remarkable successes in data rates and security, cheeping network installation, and license-free spectrum. In addition, it has a high-level immunity from electromagnetic interference since it cannot be detected using the RF meter, it is neither visible nor health hazardous. Furthermore, it can easily achieve very low (Bit Error Rate) BER, dissimilar from RF antennas it doesn't have side lobes, and also the deployment is fast and inexpensive. However, despite all mentioned the FSO is often prone to atmospheric absorption, beam dispersion, rain, fog, snow, and Shadows, . In general, the wireless optical link consists of the transmitter, atmospheric channel, and receiver as presented in Fig.3. 2.
Utilizing the optical modulator, the transmitter part transmits the signal in the wireless media by converting the electrical signal into the optical one. Next, the optical signal propagates via the wireless medium and it is collected by the receiver and converted into a beneficial electrical signal. The pulse generator, line coder, modulator, optical power meter, spectrum analyzer, switching system, and optical amplifiers constitute the transmitter subsystem. Information in an electrical form is carried by pulses that are generated via a pulse generator. The modulator converts the baseband signal into a high frequency that is suitable for transmission

The major signal attenuation happens in the wireless channel. This is because the atmospheric effects can significantly attenuate the signal. The overall attenuation is calculated as :

$$\alpha_{Total} = \alpha Fogy_{\gamma} + \alpha Snow_{\gamma} + \alpha Haze_{\gamma} + \alpha Rainy_{\gamma} + \alpha Mist_{\gamma},\ dB/km$$

Where, α is the attenuation and γ is the operational wavelength in μm .

the BER analyzer determines the accuracy of the received signal. The BER averages the probability of correctly received bits out of the total transmitted bits.

$$BER = \frac{Number\ of\ errors}{Total\ number\ of\ bits\ sent}$$

A tight approximation for BER bellow

$$\mathrm{BER} = \frac{N_{\mathrm{s}}}{G_{\mathrm{GC}} \log_2(M)} Q\left(d_{\mathrm{s}} \sqrt{\log_2(M) \Gamma_{\mathrm{b(elec)}}}\right).$$

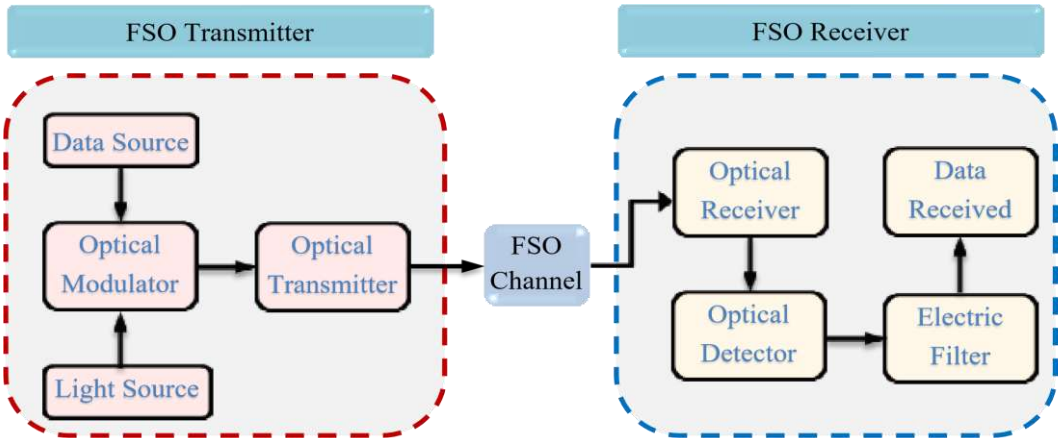
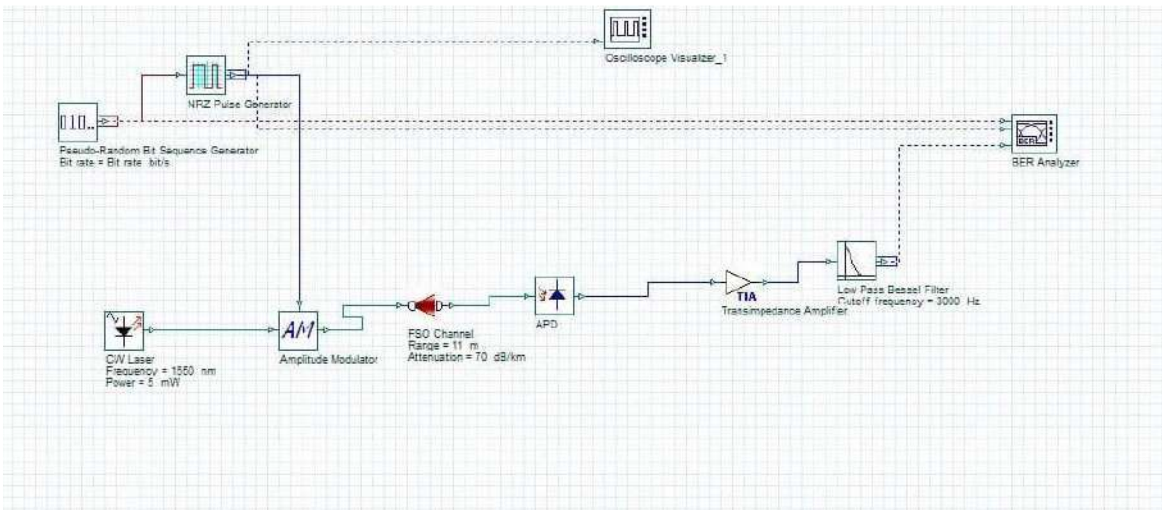



**Fig 3.2. Free space optical channel**

## 3.3 Proposed System Design :

In this work, a circuit was designed using optisystem




**Proposed System Design Fig(3.3)**

## 3.4 Circuit design elements :

**The circuit consists of the following:**

### 1. Pseudo random bit sequence generator : ( PRBS )

A pseudorandom number generator (PRNG), also known as a deterministic random bit generator (DRBG), is an algorithm for generating a sequence of numbers whose properties approximate the properties of sequences of random numbers. The PRNG-generated sequence is not truly random, because it is completely determined by an initial value, called the PRNG's seed (which may include truly random values). Although sequences that are closer to truly random can be generated using hardware random number generators, pseudorandom number generators are important in practice for their speed in number generation and their reproducibility.

### 2. CW laser :

A continuous wave or continuous waveform (CW) is an electromagnetic wave of constant amplitude and frequency, typically a sine wave, that for mathematical analysis is considered to be of infinite duration. Continuous wave is also the name given to an early method of radio transmission, in which a sinusoidal carrier wave is switched on and off. Information is carried in the varying duration of the on and off periods of the signal .

In laser physics and engineering, "continuous wave" or "CW" refers to a laser that produces a continuous output beam, sometimes referred to as "free-running," as opposed to a q-switched, gain-switched or modelocked laser, which has a pulsed output beam.

The continuous wave semiconductor laser was invented by Japanese physicist Izuo Hayashi in 1970.[citation needed] It led directly to the light sources in fiber-optic communication, laser printers, barcode readers, and optical disc drives, commercialized by Japanese entrepreneurs, and opened up the field of optical communication, playing an important role in future communication networks. Optical communication in turn provided the hardware basis for internet technology.

### 3. Amplitude modulation (AM) :

Is a modulation technique used in electronic communication, most commonly for transmitting messages with a radio wave. In amplitude modulation, the amplitude (signal strength) of the carrier wave is varied in proportion to that of the message signal, such as an audio signal. This technique contrasts with angle modulation, in which either the frequency of the carrier wave is varied, as in frequency modulation, or its phase, as in phase modulation**.**

## 4. Photodetector APD :

An avalanche photodiode (APD) is a highly sensitive semiconductor photodiode detector that exploits the photoelectric effect to convert light into electricity. From a functional standpoint, they can be regarded as the semiconductor analog of photomultipliers. The avalanche photodiode (APD) was invented by Japanese engineer Jun-ichi Nishizawa in 1952. However, study of avalanche breakdown, microplasma defects in Silicon and Germanium and the investigation of optical detection using p-n junctions predate this patent. Typical applications for APDs are laser rangefinders, long-range fiber-optic telecommunication, and quantumsensing for control algorithms.

APD applicability and usefulness depends on many parameters. Two of the larger factors are: quantum efficiency, which indicates how well incident optical photons are absorbed and then used to generate primary charge carriers; and total leakage current, which is the sum of the dark current, photocurrent and noise. Electronic dark-noise components are series and parallel noise. Series noise, which is the effect of shot noise, is basically proportional to the APD capacitance, while the parallel noise is associated with the fluctuations of the APD bulk and surface dark currents.

## 5. Transimpedance amplifier (TIA) :

A transimpedance amplifier (TIA) converts current to voltage. Transimpedance amplifiers can be used to process the current output of photodiodes, pressure transducers, accelerometers, and other types of sensors to a voltage formatted as a useable signal output. TIAs provide simple linear signal processing using an operational amplifier and a resistor for dissipating current.

## 6. Filters :

We used three types of filters:

- Low Pass Bessel filter
- Measured filter
- Gaussian filter

## 7. Modulaters :

we used three types of modulaters :

- NRZ pulse generator
- Rz pulse generator
- Gaussian pulse generator

## 3.5 System design parameters

All parameters of the simulation system are in the table (1) and FSO atmospheric conditions and the corresponding signal attenuation magnitudes. in table (2)

**Main parameters of the simulation system table (3.1)**

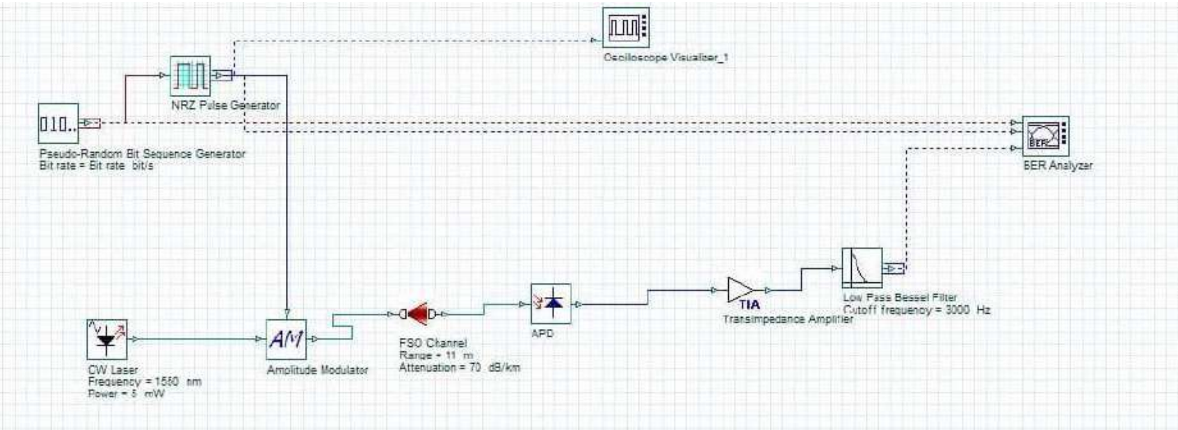
| Devices | Parameters | Settings |
|---|---|---|
| **Cw laser** | Frequency Power | 14 KH<br>5 mw |
| **Pseudorandom bit sequence generator** | Bit rate<br>Mark probability | 4 kb/s<br>0.5 |
| **OWC Channel** | Range<br>Attenuation<br>Beam divergence<br>Transmitter aperture Diameter<br>Receiver aperture Diameter | 5-11 m<br>Varied<br>170 mrad<br>5 cm<br>4 mm |
| **Photodetector APD** | Responsivity<br>Dark current<br>Thermal noise | 0.7 A/W<br>10 nA<br>1e-22 W/Hz |
| **Low Pass Bessel filter** | Cut-off frequency | 3 KHz |
| **Low Pass Gaussian filter** | Cut-off frequency | 3 KHz |
| **Measurd filter** | Cut-off frequency | 3 KHz |

**FSO atmospheric conditions table (3.2)**

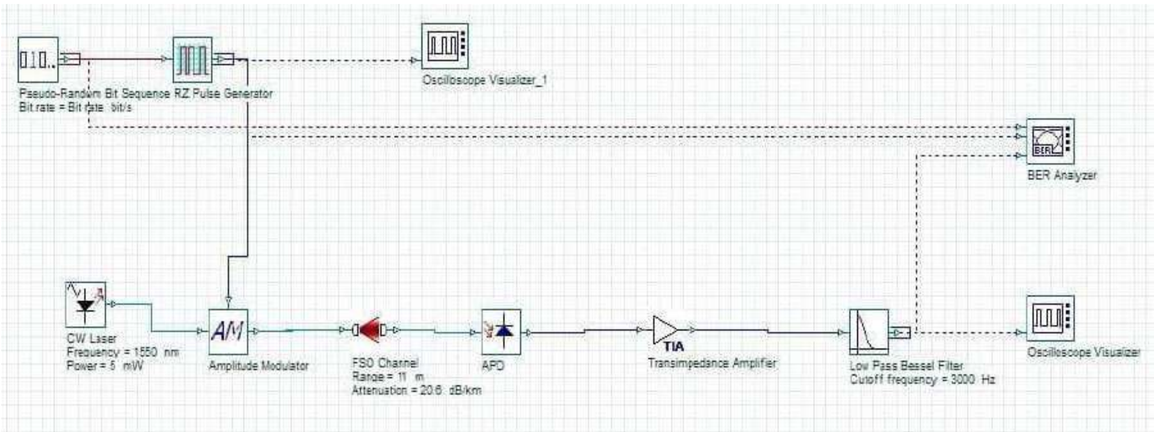
| Atmospheric conditions | Attenuation (dB/km) |
|---|---|
| **Haze** | 10.9-20.6 |
| **Rain** | 6-30 |
| **Mist** | 28.5-31.4 |
| **Snow** | 40 |
| **Fog** | 70 |

## 3.6 Proposed System Design :

in this proposed We used three types of modulaters (NRZ, RZ and Gaussian pulse generator) in each case we used three types of filters (Low Pass Bessel filter , Measured filter and Gaussian filter) .




**Proposed System Design For NRZ pulse generator fig (3.4)**




**Proposed System Design For RZ pulse generator fig (3.5)**

# CHAPTER FOUR

# RESULTS AND DISCUSSIONS

## 4.1 Introduction:

In this chapter, all the simulated results and analysis are discussed. This chapter presents all the results of simulation systems that have been proposed in this project which support the objective of this research. The results obtained can be summarized as follows:

1. The results of the proposed system design under different atmospheric conditions using filters (Bessel, Gaussian and Measured) and using the NRZ pulse generator with different attenuation.

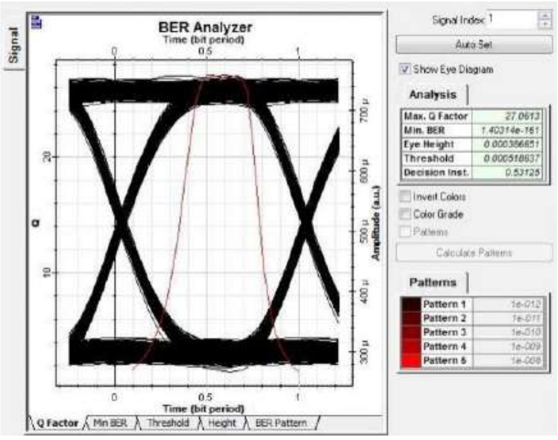
2. The results of the proposed system design under different atmospheric conditions using filters (Bessel, Gaussian and Measured) and using the RZ pulse generator with different attenuation.

3. The results of the proposed system design under different weather conditions using the (Bessel, Gaussian and Measured )filters, and using the Gaussian puls generator with different attenuation.

### 4.2 Results of system design NRZ pulse generator:

### 4.2.1 Results and discussions For Low Pass Bessel filter :

**1- BER tester and oscilloscope at channel Attenuation (Haze( $\alpha$)= 20.68)dB/Km shown in fig(4.1):**

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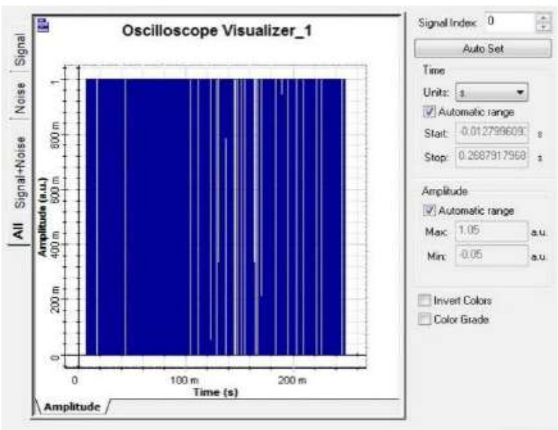


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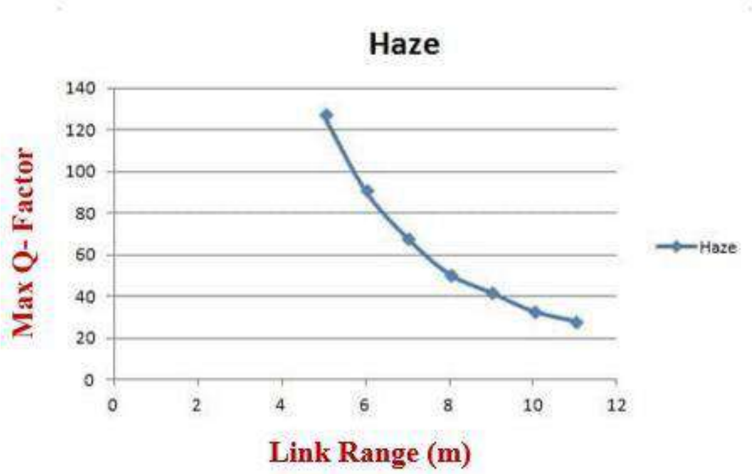
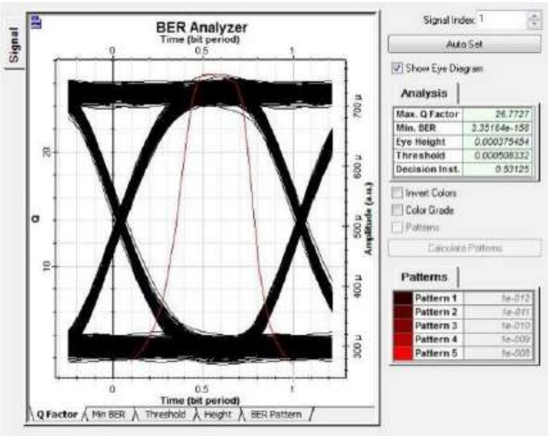



**(c)**

**Fig(4.1):** Results For Low Pass Bessel filter (a) Haze Sweep7,(b) Haze oscilloscope Sweep 7,(c)Quality factor vs optical link rang for weather condition Haze.

**2- BER tester and oscilloscope at channel Attenuation (Rain ( α)= 30)dB/Km shown in fig(4.2)**

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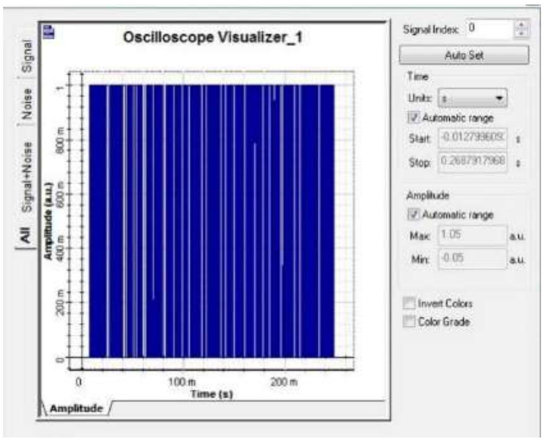


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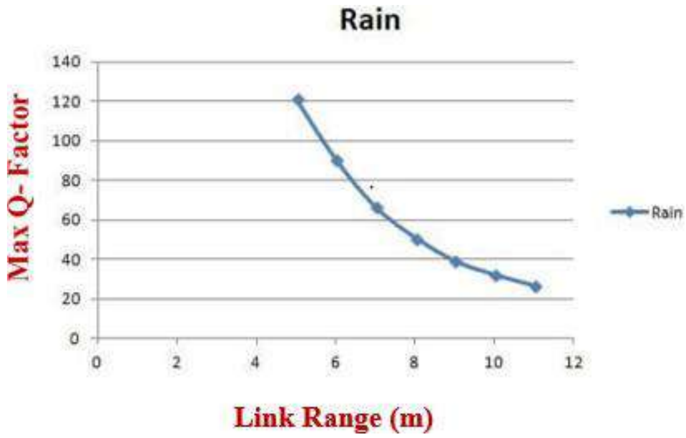
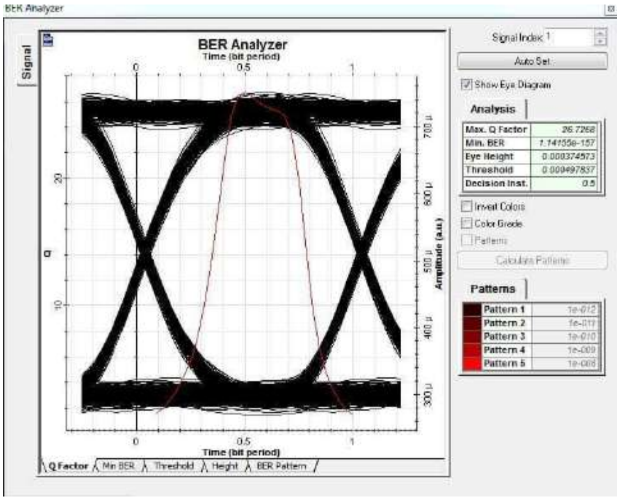
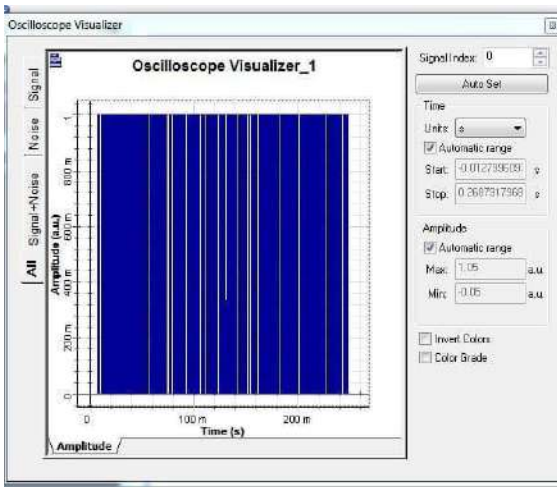



**(c)**

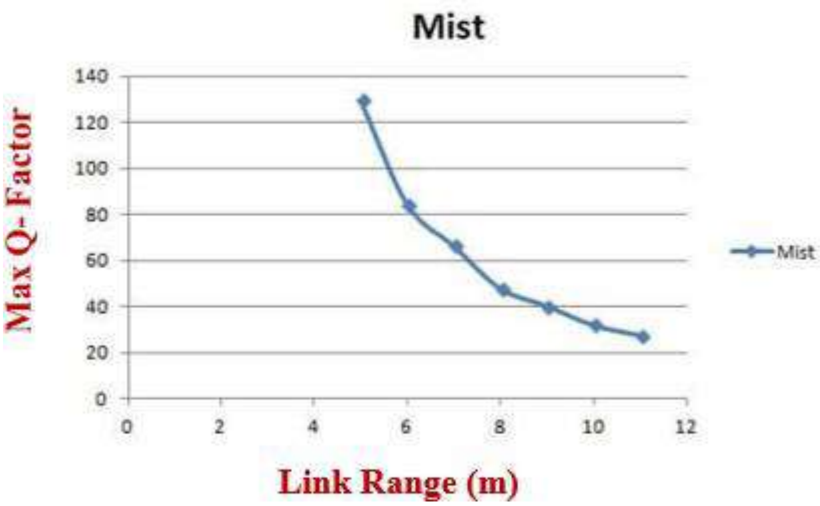
**Fig(4.2):** Results For Low Pass Bessel filter (a) Rain Sweep7,(b) Rain oscilloscope Sweep 7,(c)Quality factor vs optical link rang for weather condition Rain.

**3- BER tester and oscilloscope at channel Attenuation (Mist ( $\alpha$)= 31.4)dB/Km shown in fig(4.3):**



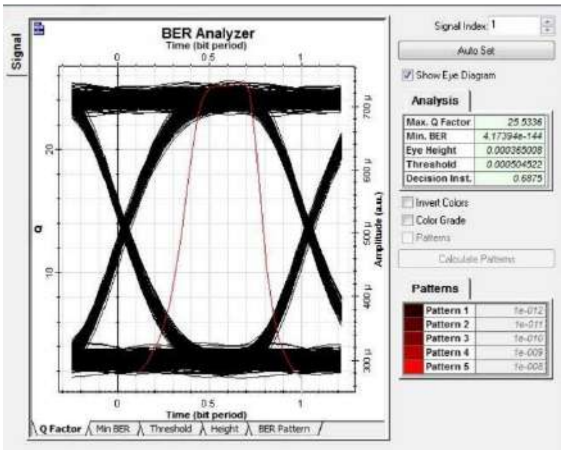

(a) (b)

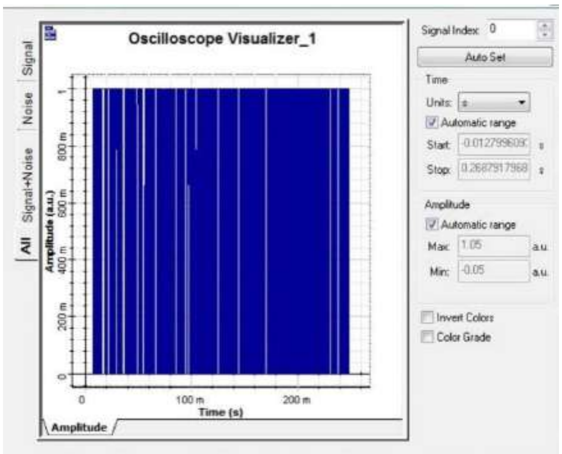



(c)

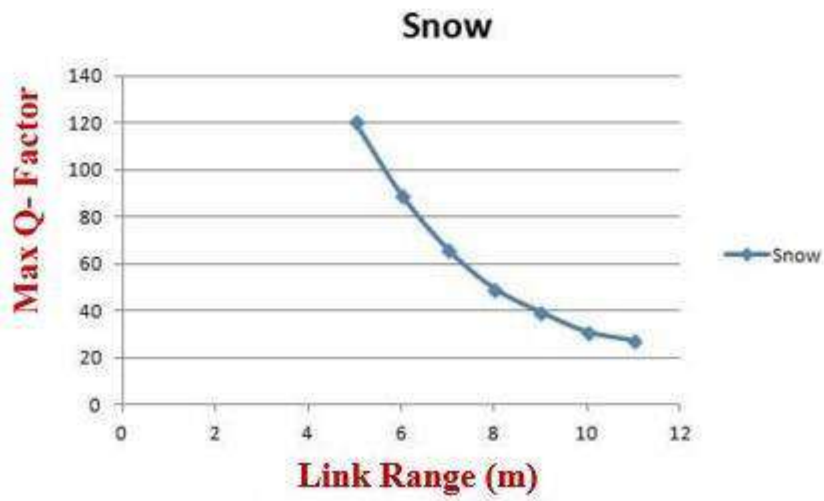
**Fig(4.3):** Results For Low Pass Bessel filter (a) Mist Sweep7,(b) Mist oscilloscope Sweep 7,(c)Quality factor vs optical link rang for weather condition Mist.

**4- BER tester and oscilloscope at channel Attenuation (Snow( $\alpha$)= 40)dB/Km shown in fig(4.4):**





**(a)** **(b)**

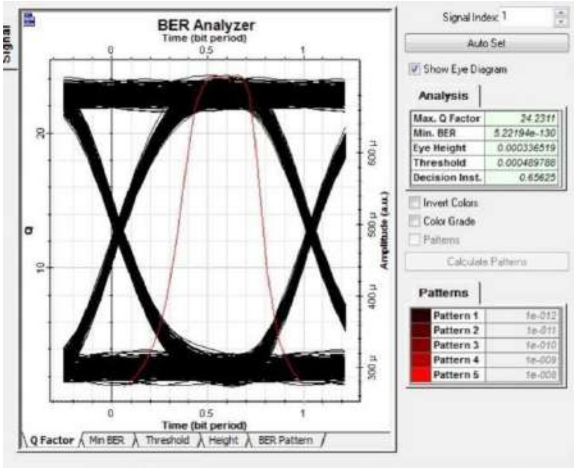



**(c)**

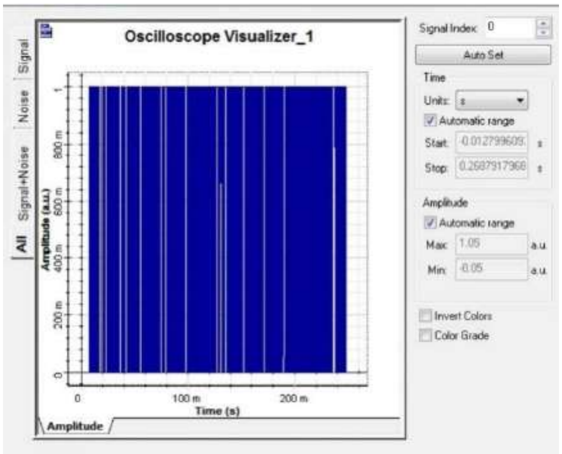
**Fig(4.4):** Results For Low Pass Bessel filter (a) Snow Sweep7,(b) Snow oscilloscope Sweep 7,(c)Quality factor vs optical link rang for weather condition Snow.

**5- BER tester and oscilloscope at channel Attenuation (Fog( α)= 70)dB/Km**

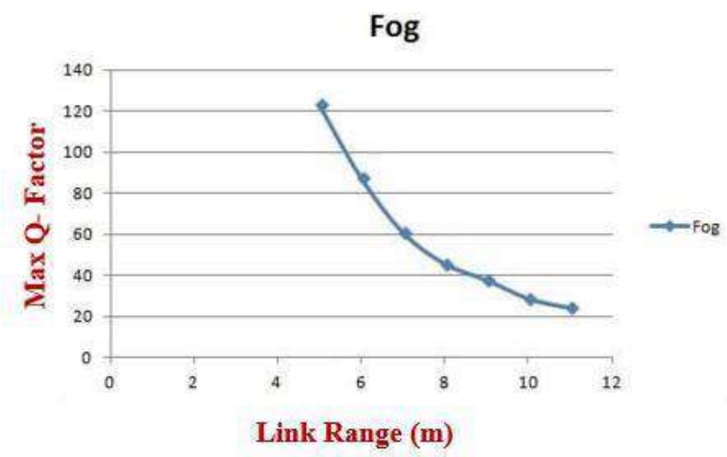
**shown in fig(4.5):**




**(a)**

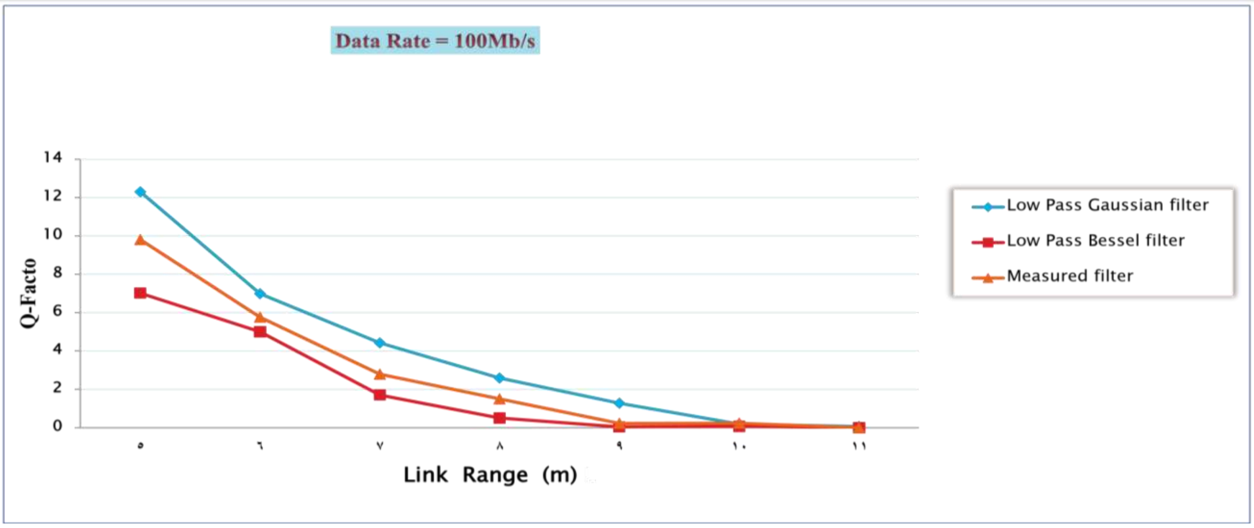



**(b)**




**(c)**

**Fig(4.5):** Results For Low Pass Bessel filter (a) fog Sweep7,(b) fog oscilloscope Sweep 7,(c)Quality factor vs optical link rang for weather condition fog .

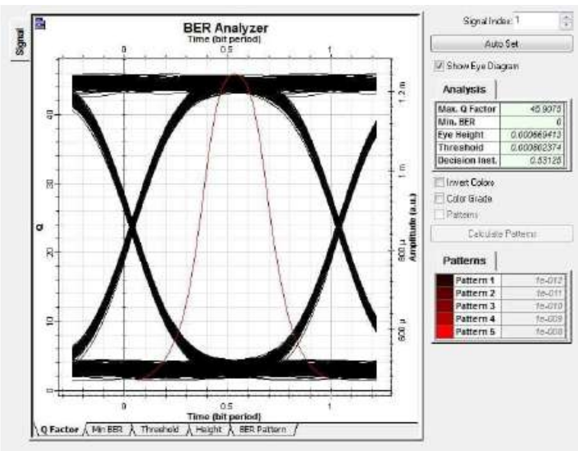



**Fig(4.6)The relationship between factor Q and range**

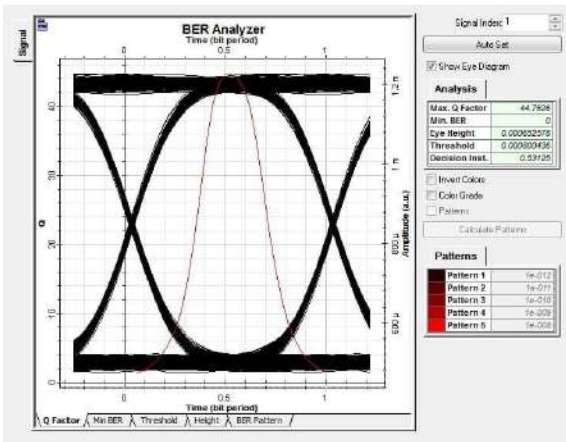
## 4.2.2 Results and discussions for Low Pass Gaussian filter shown in figs(4.7):

**1- BER tester at channel Attenuation (Haze( α)= 20.68)dB/Km**

**2- BER tester at channel Attenuation (Rain ( α)= 30)dB/Km**



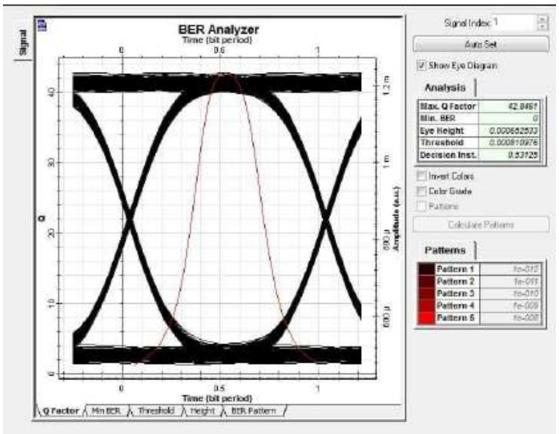

**Haze Sweep 7(a)**



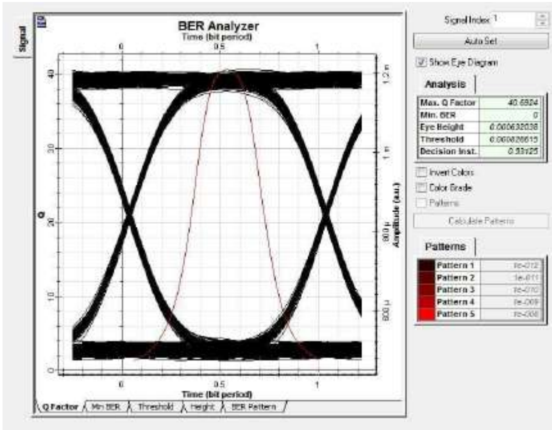

**Rain sweep 7(b)**

**3- BER tester at channel  Attenuation (Mist ( $\alpha$)= 31.4)dB/Km**

**4- BER tester at channel  Attenuation (Snow( $\alpha$)= 40)dB/Km**

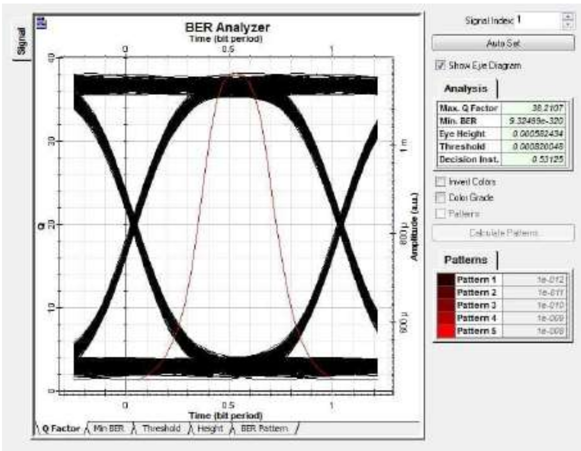



**Mist sweep 7**  (c)




**Snow sweep 7(d)**

**5- BER tester at channel  Attenuation (Fog( $\alpha$)= 70)dB/Km**



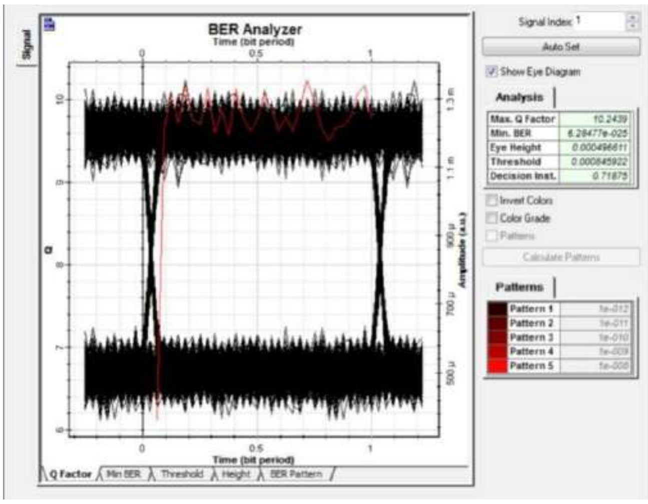

**Fog sweep 7(e)**

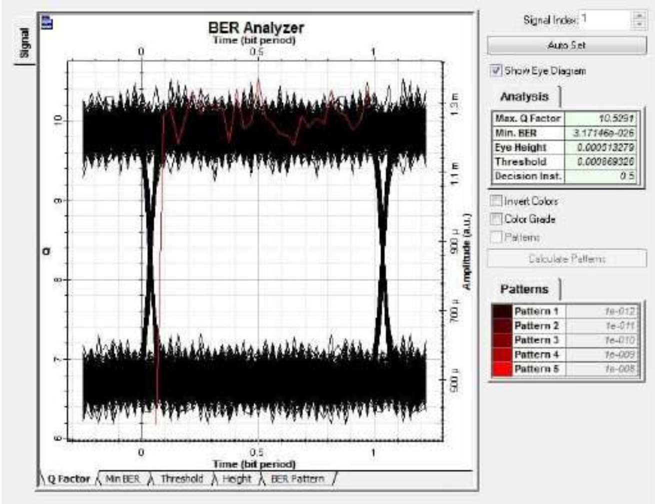
**Figs(4.7):** BER tester at channel  Attenuation for (a)Haze,(b)Rain,(c)Mist,(d)Snow,(e)Fog.

## 4.2.3 Results and discussions For Measured filter shown in figs(4.8): :

**1- BER tester at channel Attenuation (Haze( α)= 20.68)dB/Km**

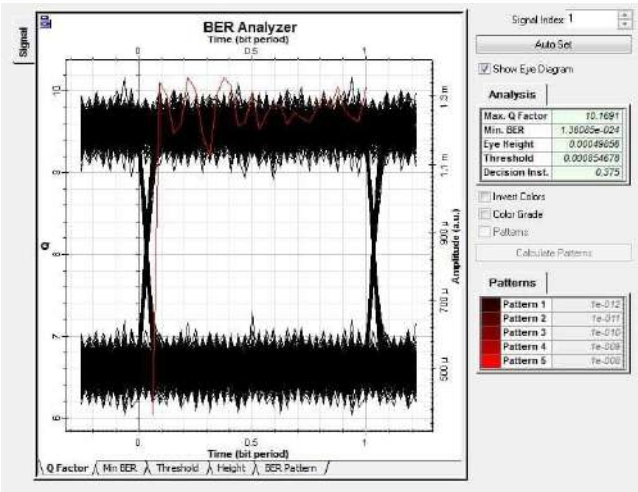
**2- BER tester at channel Attenuation (Rain ( α)= 30)dB/Km**




**Rain sweep 7 (b)** **Haze Sweep 7(a)**

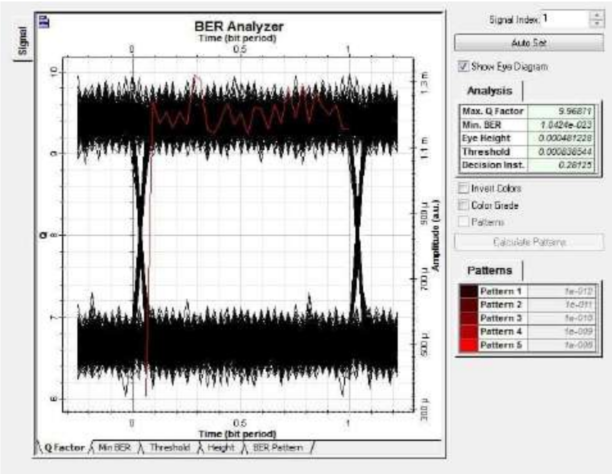
**3- BER tester at channel Attenuation (Mist ( α)= 31.4)dB/Km**



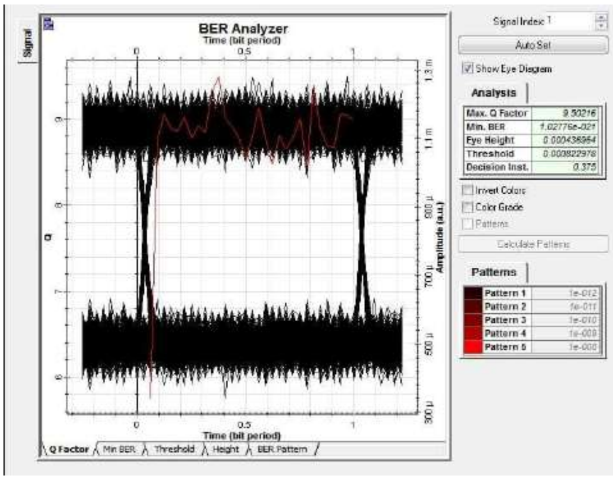

**Mist sweep 7(c)**

**4- BER tester at channel  Attenuation (Snow( α)= 40)dB/Km**

**5- BER tester at channel  Attenuation (Fog( α)= 70)dB/Km**




**Snow sweep 7 (d)**



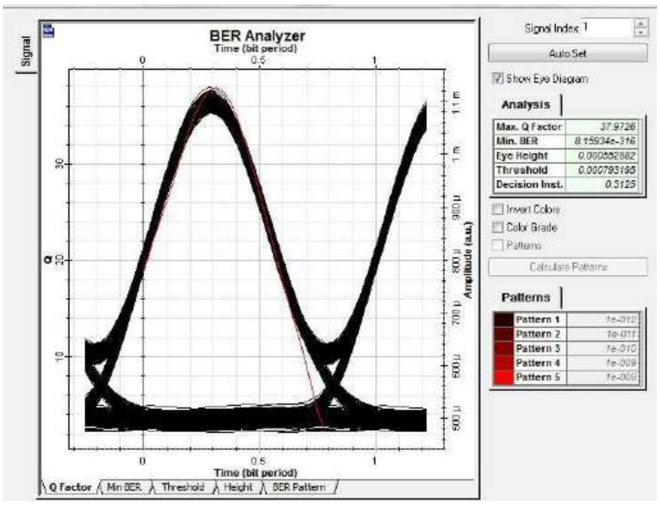

**Fog sweep 7(e)**

**Figs(4.8):** BER tester at channel  Attenuation for (a)Haze,(b)Rain,(c)Mist,(d)Snow,(e)Fog..

## 4.3 Results of system design RZ pulse generator shown in figs(4.9):

## 4.3.1 Results and Discussions For Low Pass Bessel filter :

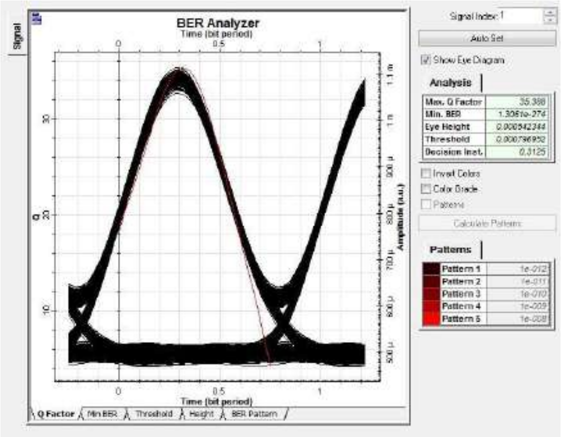
**1- BER tester at channel  Attenuation (Haze( α)= 20.68)dB/Km**



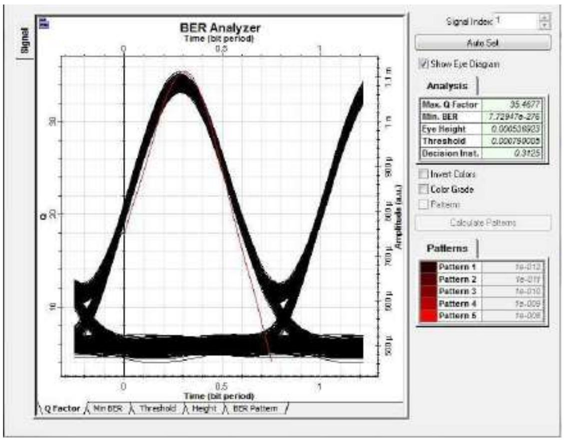

**Haze sweep 7(a)**

**2- BER tester at channel  Attenuation (Rain ( α)= 30)dB/Km**

**3- BER tester at channel  Attenuation (Mist ( α)= 31.4)dB/Km**

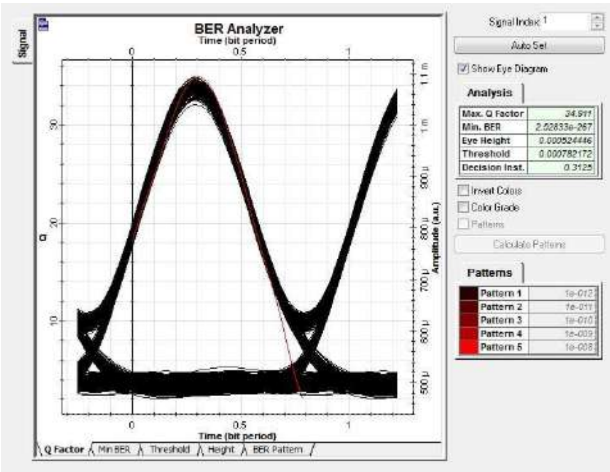



**Mist sweep 7(c)**



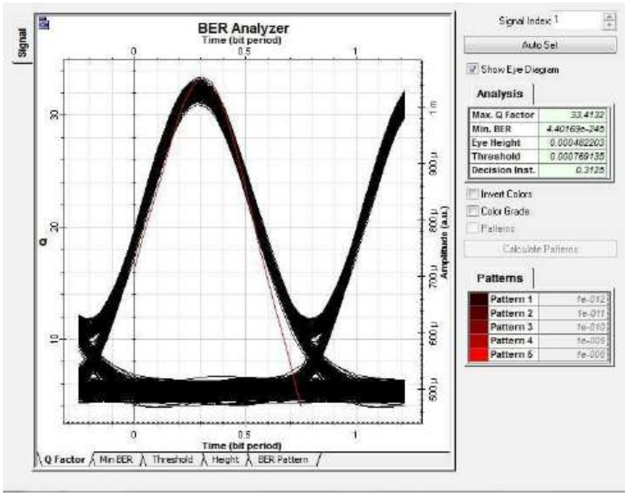

**Rain sweep 7(b)**

**4- BER tester at channel  Attenuation (Snow( α)= 40)dB/Km**




**Snow sweep 7(d)**

**5- BER tester at channel  Attenuation (Fog( α)= 70)dB/Km**

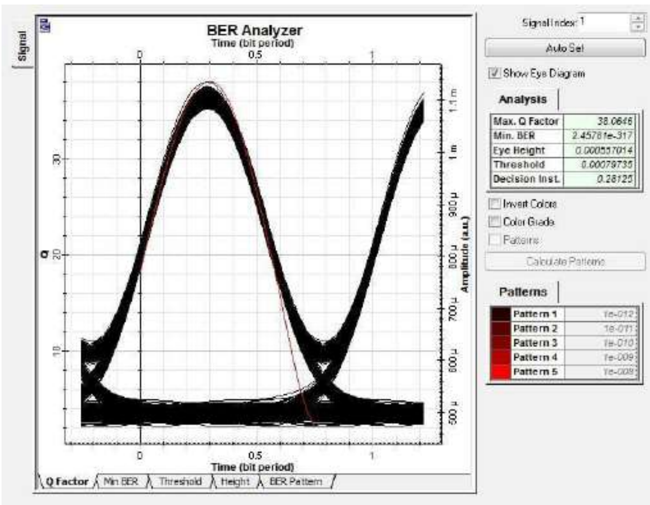



**Fog sweep 7(e)**

**Figs(4.9):** BER tester at channel  Attenuation for (a)Haze,(b)Rain,(c)Mist,(d)Snow,(e)Fog.

## 4.3.2  Results and discussions For Low Pass Gaussian filter shown in figs(4.10):

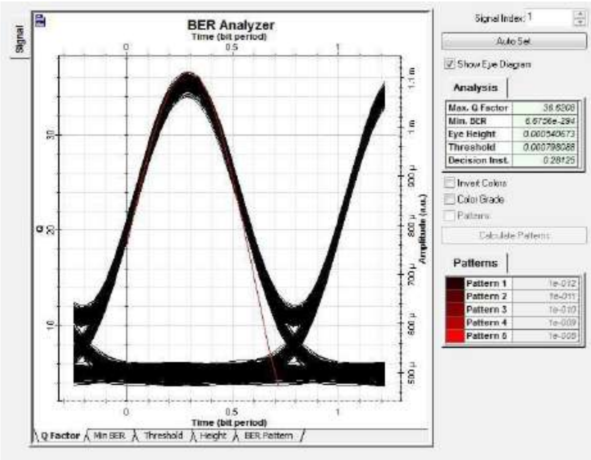
**1- BER tester at channel  Attenuation (Haze( α)= 20.68)dB/Km**

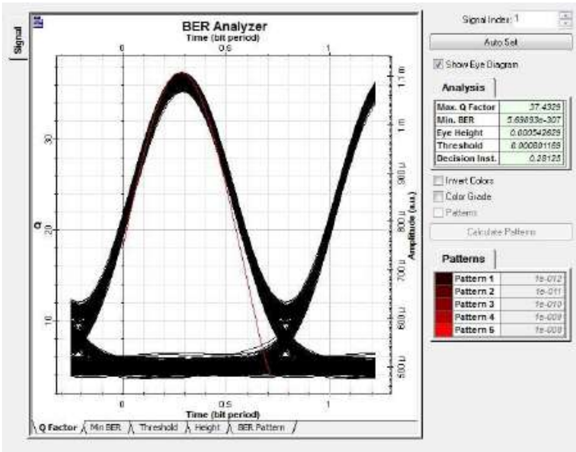



**Haze sweep 7(a)**

**2- BER tester at channel Attenuation (Rain ( α)= 30)dB/Km**

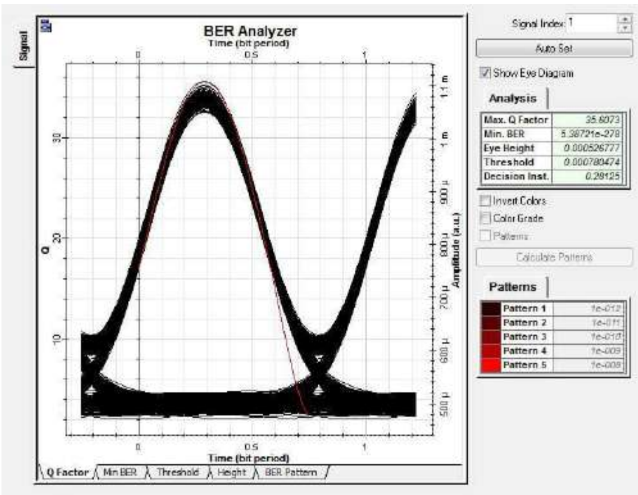
**3- BER tester at channel Attenuation (Mist ( α)= 31.4)dB/Km**



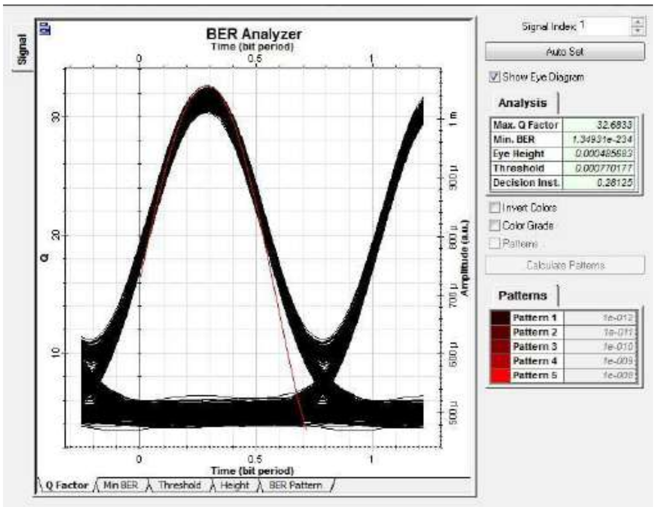

**Mist sweep(c)** **Rain sweep 7(b)**

**4- BER tester at channel Attenuation (Snow( α)= 40)dB/Km**




**Snow sweep7 (d)**

**5- BER tester at channel  Attenuation (Fog( α)= 70)dB/Km**



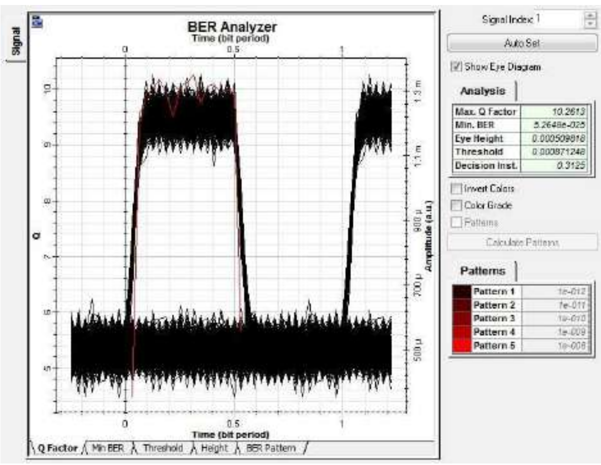

**Fog sweep 7(e)**

**Figs(4.10):** BER tester at channel  Attenuation for (a)Haze,(b)Rain,(c)Mist,(d)Snow,(e)Fog..

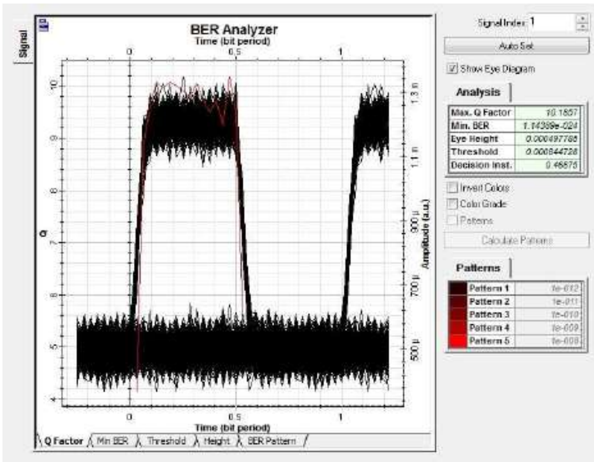
### 4.3.3 Results and discussions for  Measured filter shown in figs(4.11):

**1- BER tester at channel  Attenuation (Haze( α)= 20.68)dB/Km**

**2- BER tester at channel  Attenuation (Rain ( α)= 30)dB/Km**



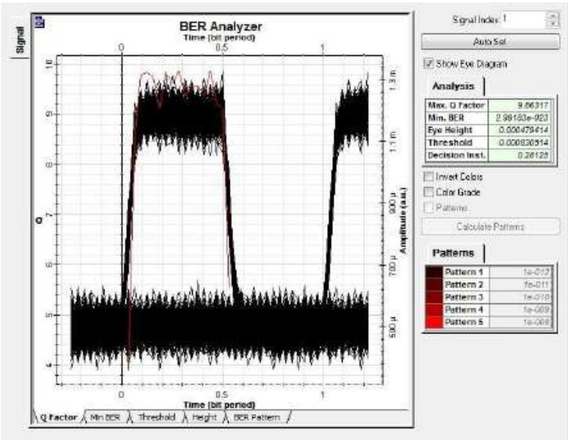

**Haze sweep 7 (a)**



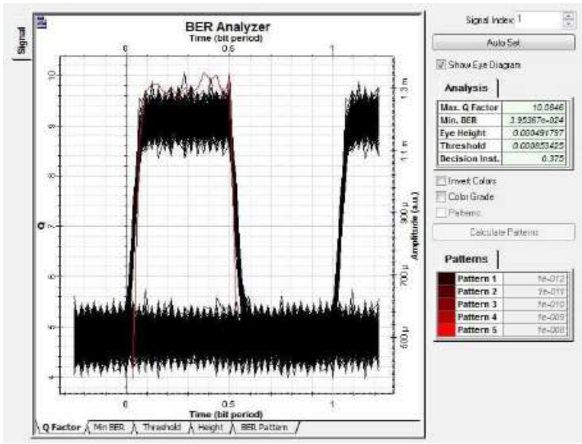

**Rain sweep 7(b)**

**3- BER tester at channel  Attenuation (Mist ( α)= 31.4)dB/Km**

**4- BER tester at channel  Attenuation (Snow( α)= 40)dB/Km**

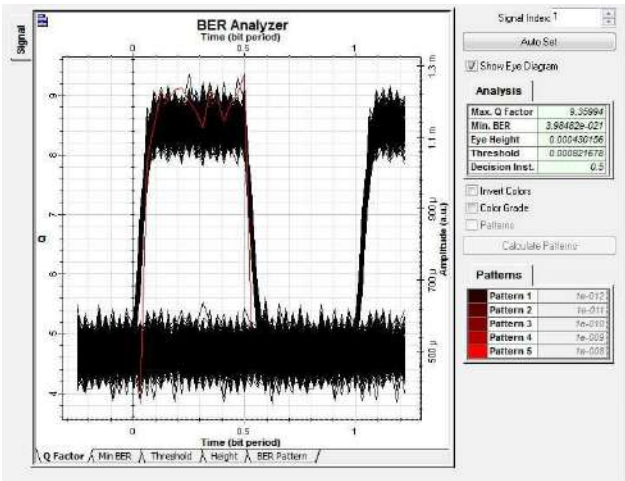



**Snow sweep   (d)**




**Mist sweep 7(c)**

**5- BER tester at channel  Attenuation (Fog( α)= 70)dB/Km**



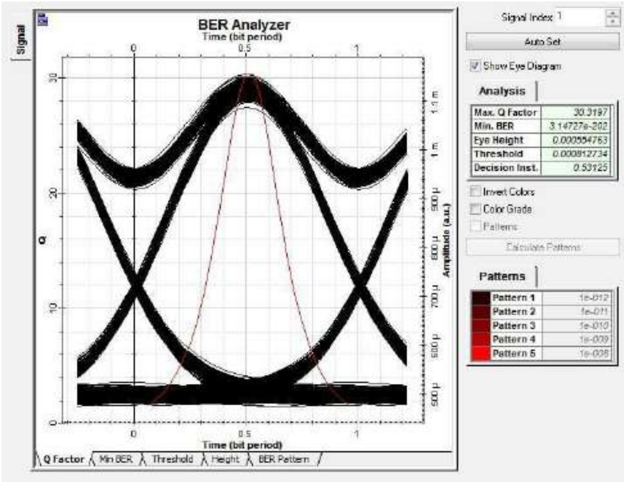

**Fog sweep 7(e)**

**Figs(4.11):** BER tester at channel  Attenuation for (a)Haze,(b)Rain,(c)Mist,(d)Snow,(e)Fog.

## 4.4 Results of system design Gaussian Pulse Generator shown in figs(4.12):

### 4.4.1 Results and discussions For Low Pass Bessel filter :

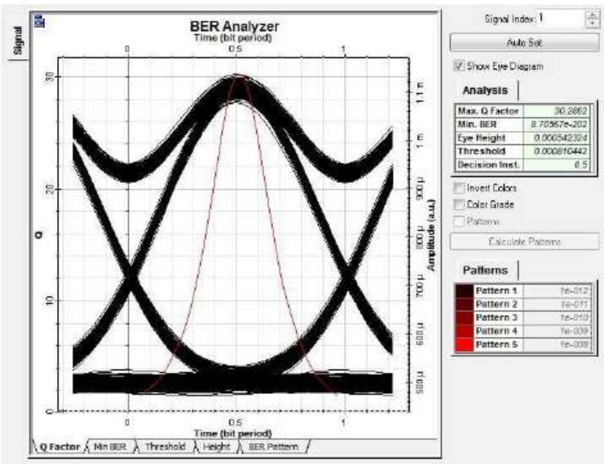
**1- BER tester at channel Attenuation (Haze( $\alpha$)= 20.68)dB/Km**



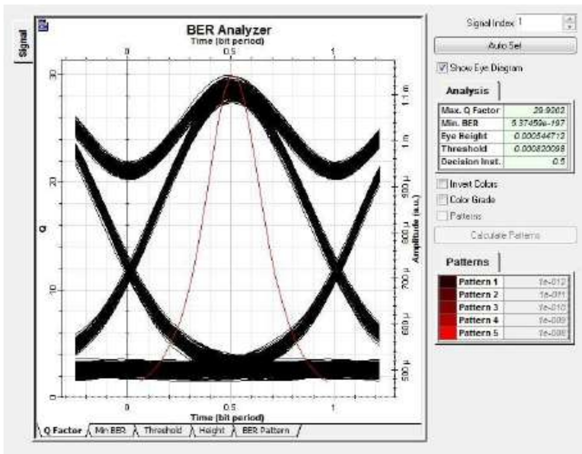

**Haze sweep 7(a)**

**2- BER tester at channel Attenuation (Rain ( $\alpha$)= 30)dB/Km**

**3- BER tester at channel Attenuation (Mist ( $\alpha$)= 31.4)dB/Km**



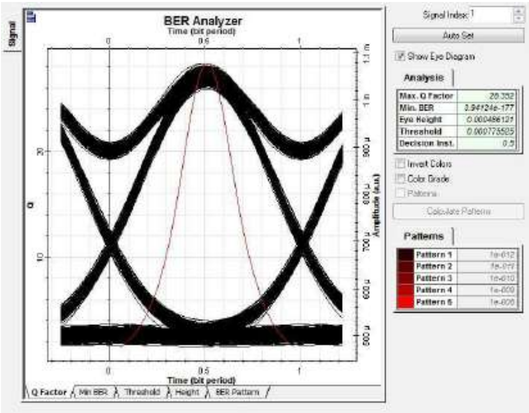

**Rain sweep 7 (b)**



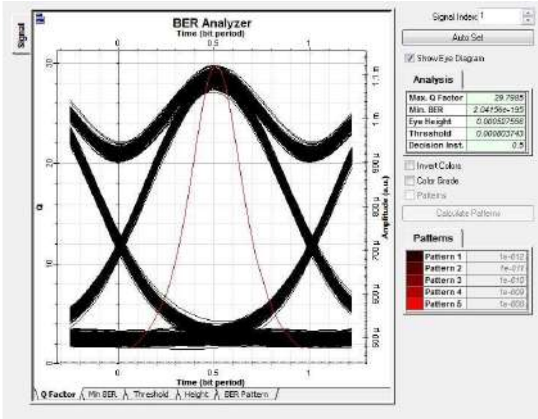

**Mist sweep 7(c)**

**4- BER tester at channel  Attenuation (Snow( α)= 40)dB/Km**

**5- BER tester at channel  Attenuation (Fog( α)= 70)dB/Km**




**Fog sweep 7(e)**

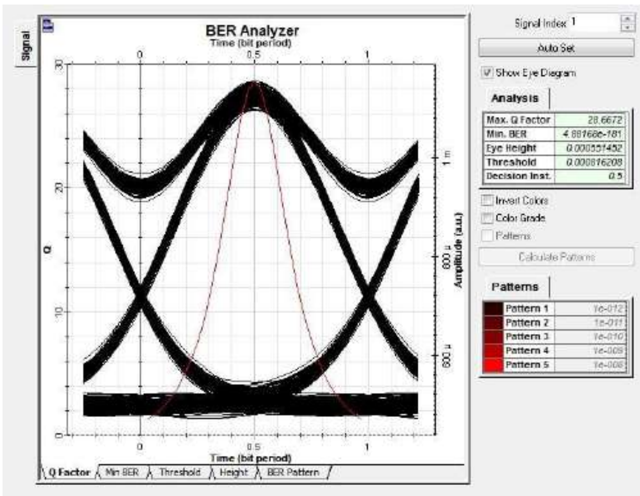



**Snow sweep 7 (d)**

**Figs(4.12):** BER tester at channel  Attenuation for (a)Haze,(b)Rain,(c)Mist,(d)Snow,(e)Fog.

## 4.4.2 Results of System Design For Low Pass Gaussian  filter shown in figs(4.13) :

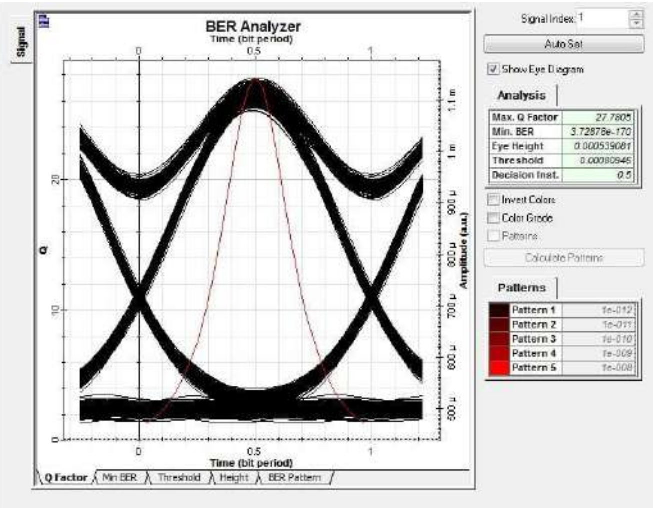
**1- BER tester at channel  Attenuation (Haze( α)= 20.68)dB/Km**

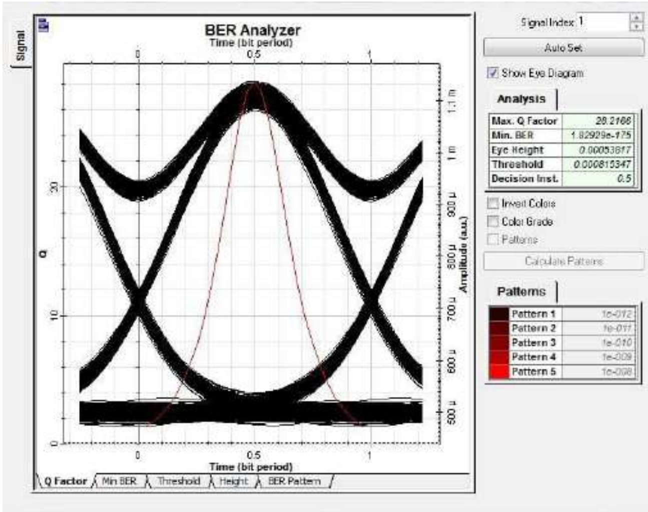



**Haze sweep 7(a)**

**2- BER tester at channel  Attenuation (Rain ( α)= 30)dB/Km**

**3- BER tester at channel  Attenuation (Mist ( α)= 31.4)dB/Km**



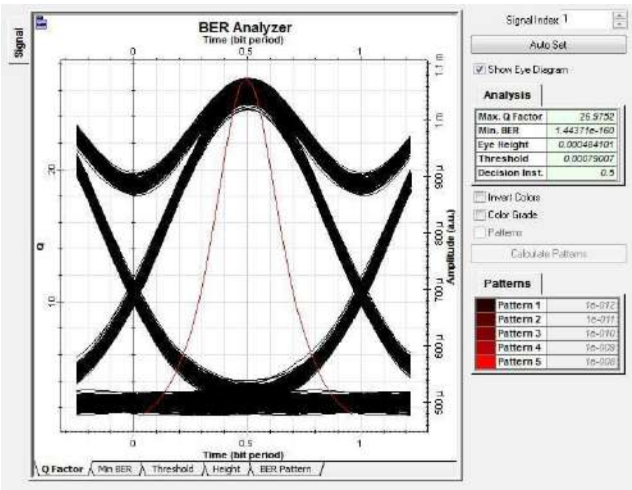



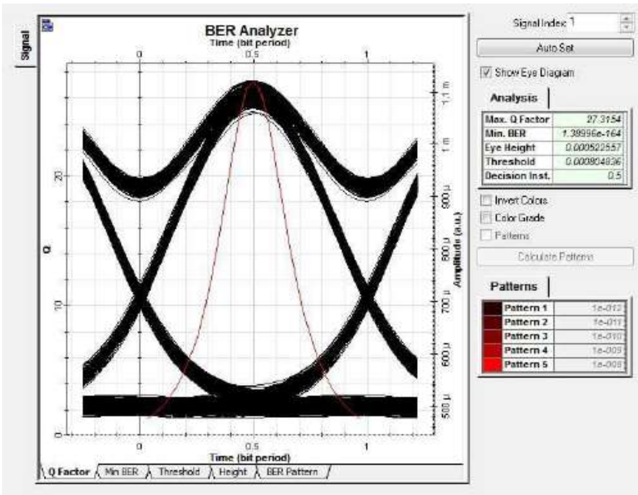

**Mist sweep 7 (c)**

**Rain sweep 7(b)**

**4- BER tester at channel  Attenuation (Snow( α)= 40)dB/Km**

**5- BER tester at channel  Attenuation (Fog( α)= 70)dB/Km**



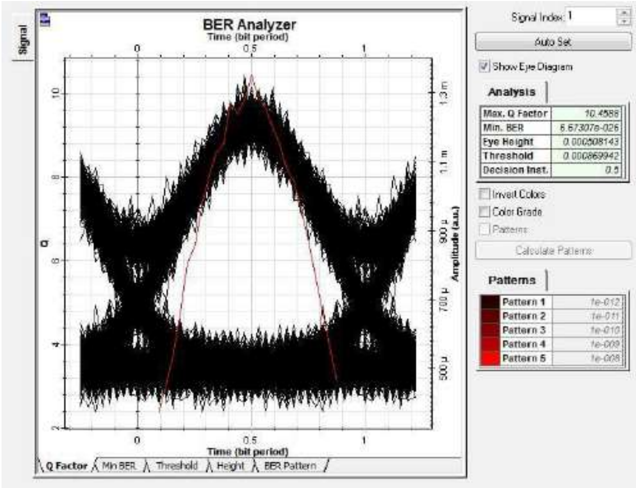

**Fog sweep 7(e)**

**Snow sweep 7(d)**

**Figs(4.13):** BER tester at channel  Attenuation for (a)Haze,(b)Rain,(c)Mist,(d)Snow,(e)Fog.

### 4.4.3 Results of System Design For Measured filter shown in figs(4.14):

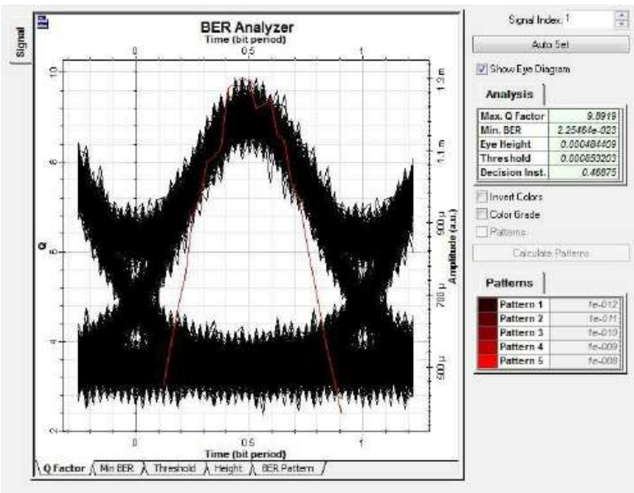
**1- BER tester at channel Attenuation (Haze( $\alpha$)= 20.68)dB/Km**

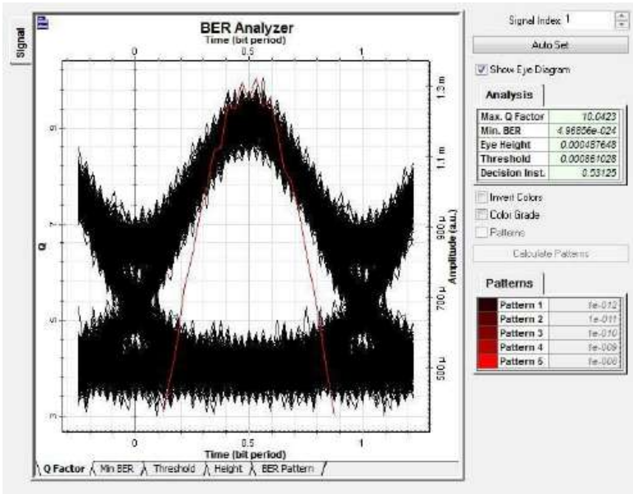



**Haze sweep 7(a)**

**2- BER tester at channel Attenuation (Rain ( $\alpha$)= 30)dB/Km**

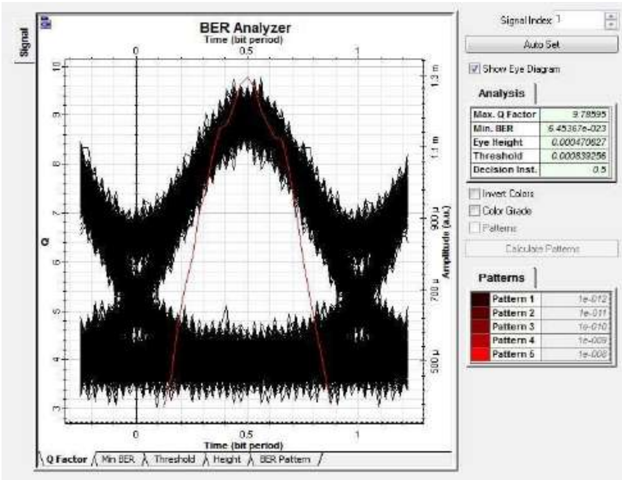
**3- BER tester at channel Attenuation (Mist ( $\alpha$)= 31.4)dB/Km**



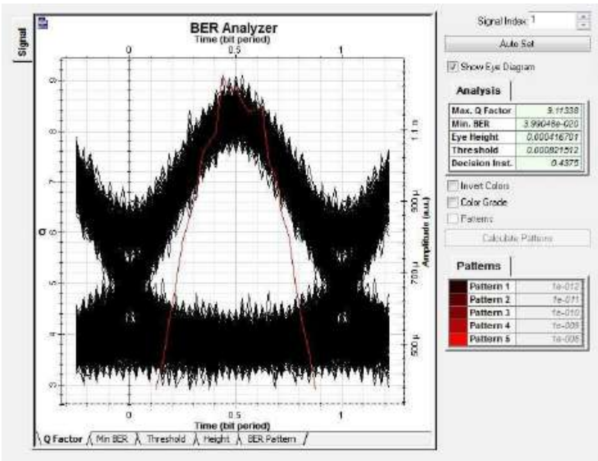

**Mist sweep 7(c)** **Rain sweep 7(b)**

**4- BER tester at channel  Attenuation (Snow( α)= 40)dB/Km**




**Snow sweep 7  (d)**

**5- BER tester at channel  Attenuation (Fog( α)= 70)dB/Km**

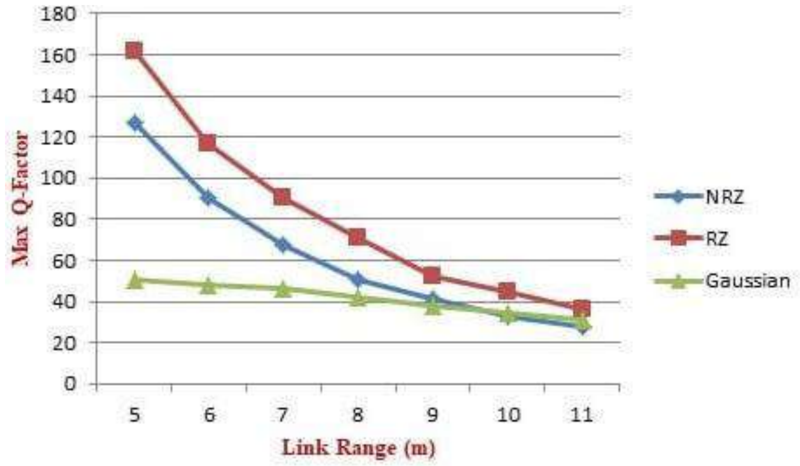



**Fog sweep 7(e)**

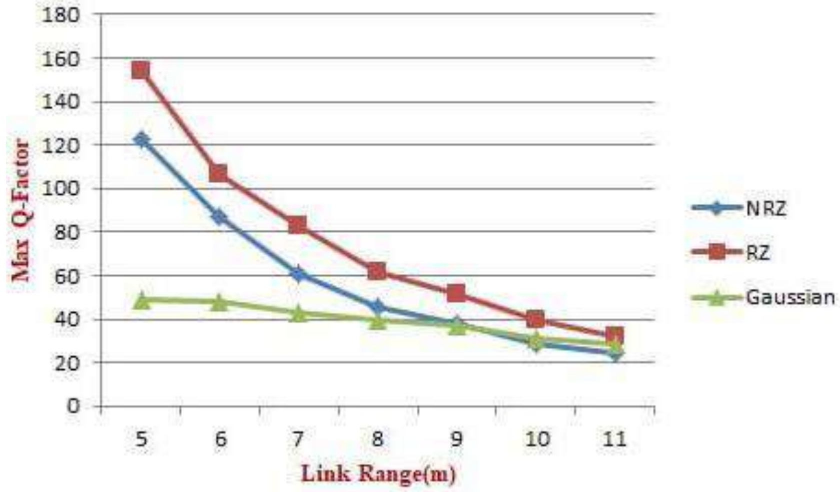
**Figs(4.14):** BER tester at channel  Attenuation for (a)Haze,(b)Rain,(c)Mist,(d)Snow,(e)Fog.

## 4.5 The relationship between Q factor and range :

1- Quality factor vs link range for Bessel filter with the modulators ( NRZ,RZ,Gaussain) for weather condition at Haze and Fog .shown in fig(4.15).



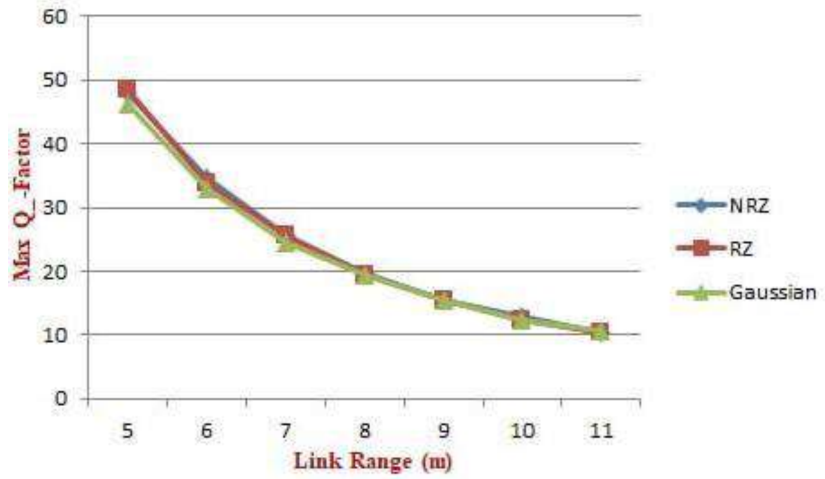

**Haze(a)**



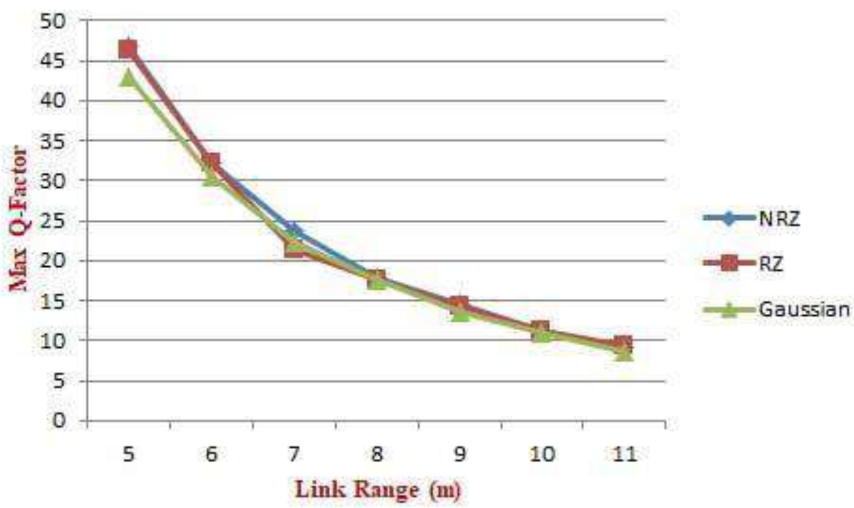

**Fog(b)**

**Figs(4.15):** The relationship between Q factor and range for (a) Haze,(b)Fog.

2-Quality factor vs link range for Measured filter with the modulators ( NRZ,RZ,Gaussain) for weather condition at Haze and Fog.shown in fig(4.16).



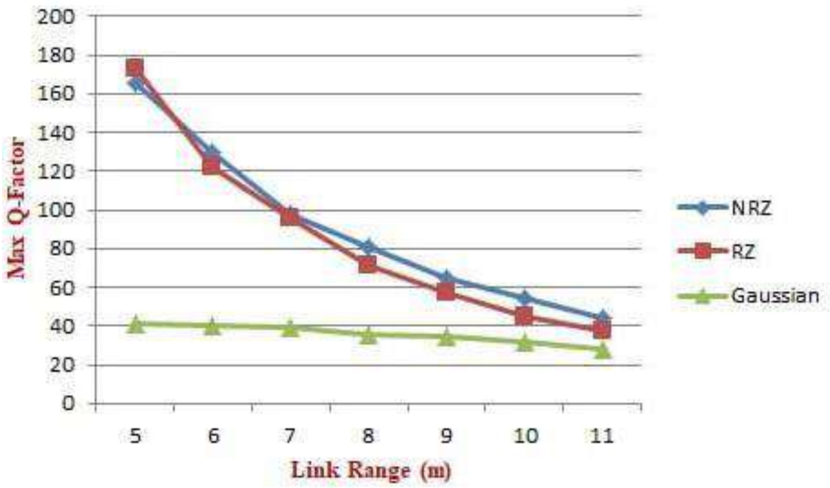

**Haze(a)**



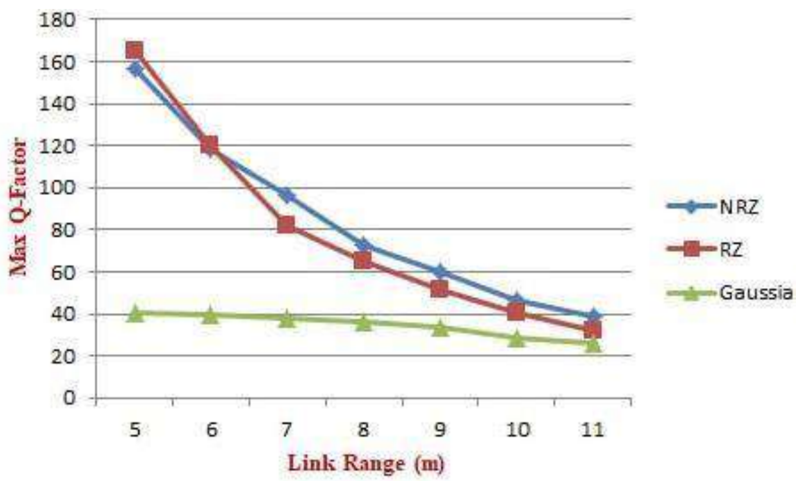

**Fog(b)**

**Figs(4.16):** The relationship between Q factor and range for (a) Haze,(b)Fog.

3-Quality factor vs link range for Gaussian  filter with the modulators ( NRZ,RZ,Gaussain) for weather condition at Haze and Fog shown in fig(4.17) .




**Haze(a)**




**Fog(b)**

**Figs(4.17):** The relationship between Q factor and range for (a) Haze,(b)Fog.

## 4.6 Results summery :

**Table (4.1)**

| MODULATORS | FILTERS | Q Factor | | | | |
|---|---|---|---|---|---|---|
| | | HAZE | RAIN | MIST | SNOW | FOG |
| **NRZ** | **Bessel** | 27.0613 | 26.7727 | 26.7268 | 25.5336 | 24.2311 |
| | **Measured** | 10.5291 | 10.2439 | 10.1691 | 9.96871 | 9.50216 |
| | **Gaussian** | 45.9075 | 44.7626 | 42.8461 | 40.6924 | 38.2107 |
| **RZ** | **Bessel** | 37.9726 | 35.4677 | 35.388 | 34.911 | 33.4132 |
| | **Measured** | 10.2613 | 10.1857 | 10.0646 | 9.86317 | 9.35994 |
| | **Gaussian** | 38.0646 | 37.4329 | 36.6208 | 35.6073 | 32.6833 |
| GAUSSIAN | Bessel | 30.3197 | 30.2862 | 29.9202 | 29.7985 | 28.352 |
| | Measured | 10.4588 | 10.0423 | 9.8919 | 9.78595 | 9.11338 |
| | Gaussian | 28.6672 | 28.2166 | 27.7805 | 27.3154 | 26.9752 |

# CHAPTER FIVE

## CONCLUSION  AND REFRENCES

### 5.1  Conclusion

From the current results we can conclude the following points:

- There is an inverse relationship between the attenuation and Q-Factor where increasing the attenuation leads to degrade the Q and vice versa.
- High Q-Factor appeared under (Haze effect where $\alpha$=20.6 dB/km ) while lower Q-Factor appeared under (Fog  effect wher $\alpha$=70  dB/km )
- In this work , three types of filters were used which are the Bessel filter, Gaussian filter and Measured filter, in the presence of the influencing factors such as haze, rain, snow, mist and fog, and the  Gaussian filter  offered better Q-Factor
- When using a Gaussian filter ,the value of the  Q factor will be higher, and thus we notice an improvement in the circuit’s performance and a decrease in the attenuation value.
- The best modulator was RZ pulse generator , which gave the best result and the highest Q-factor value .

# الملخص

بصريات الفضاء الحر (FSO) هي ثورة في تكنولوجيا الاتصالات التي تستخدم الضوء في الفضاء الحر للإرسال. تُستخدم أنظمة FSO للتواصل بمعدل بيانات مرتفع بين موقعين نائيين عبر مسافات تصل إلى عدة كيلومترات. ويستخدم في مجالات التطبيقات الخارجية مثل النسخ الاحتياطي ، واتصال LAN- إلى LAN ، والتعافي من الكوارث ، وإعادة توصيل الشبكات الخلوية اللاسلكية ، والتلفزيون عالي الدقة والمراقبة / المراقبة بالفيديو اللاسلكي ، إلخ.

أدى الطلب على أنظمة الاتصال عالية السرعة لنقل كميات كبيرة من البيانات إلى تطوير تقنيات جديدة بالإضافة إلى إعادة زيارة التقنيات القديمة. على الرغم من أن أنظمة Free Space Optical (FSO) لديها الكثير من المشاكل ، إلا أنها تجذب المزيد من الاهتمام بسبب توفر كميات كبيرة من النطاق الترددي غير المنظم. كان تطوير أنظمة FSO سريعًا.

تعتمد موثوقية الوصلة بشكل كبير على الظروف الجوية التي تضعف قوة الإشارة. ومن ثم ، فإن تركيز هذه الدراسة هو تحسين القناة الضوئية بناءً على تحسين المضخمات والمرشحات الضوئية المختلفة. في هذا المشروع ، تم استخدام ثلاثة أنواع من المرشحات وهي مرشح Bessel و Gaussian Filter و Measured ، في ظل وجود العوامل المؤثرة مثل الضباب والمطر والثلج والضباب والضباب ، وقدم مرشح Gaussian مرشحًا أفضل عاملQ

عند استخدام مرشح Gaussian ، ستكون قيمة عامل Q أعلى ، وبالتالي نلاحظ تحسنًا في أداء الدائرة وانخفاض في قيمة التوهين.

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**قسم الهندسـة الكهربائيــة**

# تقييم أداء الاتصالات البصرية G5

قــدم هــذا المشروع لإستكمال جزء من متطلبات الحصول على درجــة البكالوريوس في الهندسة الكهربائية

قـــدم من قبــل :


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