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Simulation Underwater wireless optical communication system using the Opti system

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ABSTRACT

In this research, the underwater optical wireless systems with the OPTISYSTEM system were identified, and what distinguishes it as a system in comparison with other underwater communication methods, where the elements affecting the spread of the light beam within the water channel were studied, and the necessary optical receivers and transmitters for that were identified, and the A transmission and reception system using a square signal from a pulse generator at different frequencies by simulating the system using OPTISYSTEM, by simulating a 1-meter long water channel, where two pairs of transmitters and receivers were developed with a speed of up to 100 Mbps, based on low-cost TO56 packages. , 520 nm LDS laser diodes, and 100 Mbps UWOCS two-way wireless optical communications system display modules. The effects of six types of seawater on the performance of the proposed communications system were qualitatively analyzed, which include pure seawater, deep seawater, coastal seawater, turbid seawater, and turbid seawater. The simulation results showed that the system relies on X-ray technology. Infrared or laser sends optical signals through water, allowing large amounts of data to be transmitted quickly and safely, as the error rate across the environment has reached 2%. Also, the higher the Q value, the better the SNR value; thus, the possibility of errors decreases. In the transmitted and received bits

محكاه نظام الاتصالات الضوئية اللاسلكية تحت الماء باستخدام نظام Opt

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الكلمات المفتاحية:
تحت الماء
بصري لاسلكي
قناة

الملخص

في هذا العمل ، تم استكشاف أنظمة الاتصالات اللاسلكية البصرية تحت الماء باستخدام أداة المحاكاة OPTISYSTEM، مع التركيز على ميزاتها مقارنة بطرق الاتصالات تحت الماء الأخرى. تناول البحث العوامل التي تؤثر على انتشار حزم الضوء داخل القنوات المائية، وتم تحديد المرسلات والمستقبلات البصرية اللازمة. تم تطوير نظام إرسال واستقبال يستخدم إشارة مربعة من مولد نبضات عند ترددات مختلفة، مع محاكاة قناة مائية بطول متر واحد ،تم إعداد زوجين من المرسلات والمستقبلات، محققين معدلات نقل تصل إلى 100 ميجابت في الثانية، باستخدام حزم TO56 منخفضة التكلفة، وثنائيات ليزر بطول موجي 520 نانومتر، ونماذج عرض لنظام اتصالات لاسلكية بصرية ثنائي الاتجاه تحت الماء ، كما تم تقييم أداء النظام المقترح تحت ستة ظروف مختلفة من مياه البحر، شملت المياه البحرية النقية، المياه البحرية العميقة، المياه الساحلية، ونوعين من المياه البحرية العكرة. أظهرت نتائج المحاكاة أن النظام يعتمد على تقنيات الأشعة السينية، الأشعة تحت الحمراء، أو الليزر لإرسال الإشارات الضوئية عبر الماء، مما يتيح نقل كميات كبيرة من البيانات بسرعة وأمان، مع معدل خطأ وصل إلى 2% عبر البيئة. بالإضافة إلى ذلك، أظهر ارتفاع قيمة عامل Q ارتباطًا بتحسن نسبة الإشارة إلى الضوضاء (SNR)، مما يقلل من احتمالية الأخطاء في البيانات المرسلة والمستقبلة.

1. Introduction

Communications are concerned with delivering information in electronic form from one place to another and include a series of operations including transmission, reception, modification, and signal processing [1]. Communications systems began in the eighteenth century, beginning with the telegraph, and after several years the telephone was used in the early nineteenth century as a result of the World War. Second, the needs of armies for communications between themselves, and the interest of countries in research. A great development in means of communication emerged. The discovery of vacuum tubes (valves) and their use in amplifying sound signals was credited with transmitting telephone signals via wires to long distances. Wireless communications (radio) also appeared, then semiconductors appeared and were the invention of the transistor and integrated circuits, and the appearance of satellites, thus the doors to

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the development of communications systems became wide open.[2] Optical communication is one of the latest methods of communication, as it was achieved after the invention of lasers and optical fibers. The year 1970 can be considered the beginning of the practical emergence of optical communications. Since 1975, communications technology that uses light waves has advanced by all standards and at a great speed. The frequency of the light waves used in optical communications is of the order HZ. 1014 The bandwidth of the optical signal can reach more than 10 GHz [3]., one of the types of wireless communications systems that provide investors with a low cost, as these systems operate in frequency ranges that do not require a license. They are also easy to install and maintain and can reach long distances. They provide high transmission speeds and high confidentiality as the transmission and reception process It is carried out using a narrow beam of light so that spying or stealing the signal is physically prevented. It is one of the reliable systems because it transmits information honestly, as it is difficult for the electromagnetic spectrum to influence or disturb the laser signal [2]., the means of transmitting information on the surface of the Earth since time immemorial, represented by his use of smoke signals, light signals, flames, mirrors, signs, and flags, long before the invention of the telegraph and telephones and after the appearance of the Internet in our lives as an indispensable communication tool that connects tens of billions of devices around the world, and communication technology. Wireless network that carries the sin of Wi-Fi [4], scientists began to explore the possibility of developing underwater communication technologies, but there have always been many obstacles to achieving this ambition, and the emergence of optical fibers, the computer, and the Internet gave a very great impetus to communications systems, which led to the whole world becoming One village where events are transmitted with sound and video at the time. Perhaps the best answer to the question: Why is there a need to develop better underwater communications? It is a review of the incident of the giant passenger ship "Titanic" that sank in the ocean in April 1912, and its exact location remained a mystery until 1985, when a cable-connected imaging vehicle, affiliated with the Woods Hole Institute, found the wreckage of the ill-fated ship. Since that time, scientists have been looking to develop better underwater communications systems, especially those that do not require any cables [5]. For now, it will not be commercially available until researchers overcome several hurdles, The first is to improve the link quality and transmission range with faster electronic components [9], the light beam must remain perfectly aligned with the receiver in moving water [1], the receiver must be spherical and can capture light from all angles [1], fourth: Moderately turbulent water can knock a beam off the path and cause it to be lost to the receiving end [16], and water absorbs and scatters small parts of the light wave, and fluctuations in the variation of density, salinity, and temperature across the environment directly affect the communication path [11]. . As for visible light, it can travel far, carrying with it a lot of data, but its narrow rays require a clear line of sight between transmitters and receivers. Based on this hypothesis, the team of researchers from KAUST succeeded in developing an underwater wireless system, called “Aqua-Fi.” It supports Internet services, such as sending multimedia messages using either light-emitting diode (LED) technology or laser beams. It is worth noting that the term “Wi-Fi” refers to a local wireless network technology that uses electromagnetic waves just like televisions and radios [4]. In Hong Kong University conducted a study on an underwater optical wireless communication system using fiber optics. They used a system that uses lasers to send light signals through the water. They conducted experiments over short distances, and they showed that this technology can be effective in Underwater data transmission [8]. In University of California developed an underwater optical wireless communication system that uses fiber optics and ultrasound. They used this system to send optical signals through water and have shown that it can be used in applications such as controlling underwater robots and collecting data [6]. “Designing an Underwater Optical Wireless Communication System Using Light Wave Mining Technique,” was conducted by researchers at the University of California, Santa Barbara. They used a light wave mining technique to improve the performance of an underwater optical wireless communication system [10], and a study, “The effect of distortion on the performance of underwater fiber optic communications,” was conducted by researchers at Harvard University. They studied how distortion affects the performance of underwater fiber optic communications and had useful results on how to improve communication quality [15], in a study of “Encrypted Optical Signals for Underwater Communications,” conducted by researchers at Stanford University. They used cryptographic techniques to secure optical signals transmitted underwater and improve communication security [2], “Designing an Underwater Optical Wireless Communication System Using Fiber Optic Networks” was conducted by researchers at the University of California, Los Angeles. They used fiber optic networks to develop an effective underwater optical wireless communication system [16]. The objective of this paper is to design and simulate the communications system underwater by using OPTISYSTEM

2. UNDERWATER OPTICAL BEAM PROPAGATION

The increase in the complexity of designing and analyzing optical communications systems daily has led to the need for advanced software tools to analyze these systems and improve their performance [1]. OPTISYSTEM is a simulation package for innovative optical communications systems, which designs, tests, and virtually improves the optical link quality at the physical layer of optical networks. It is a stand-alone product that does not depend on other simulation frameworks and has a new and powerful simulation environment and a hierarchical definition of components and systems [1]. Comprehensive libraries of active and passive components include parameters based on realistic wavelengths. Scanning these parameters allows you to verify the effect of the devices and elements used on the system's performance. This simulator was also created to meet the needs of research centers, communications engineers, and other groups of users, as it meets the demand The advanced optics market provides powerful, easy-to-use tools for designing optical communications systems [4], Evaluating the sensitivity of the parameter that helps in determining the tolerance specifications for the design, Reducing the risks of investing in marketing, Visual representation of design options and scenarios to present to potential users [10], OPTYSYSTEM includes an extensive library of optical design samples and over 200 files that can be used as templates for optical design papers or for learning purposes [14]. The propagation of the optical beam underwater is a major obstacle. The reason is the difference in different water surfaces, from shallow waters to the depths of the oceans. It requires a comprehensive understanding of the difficult physical and chemical nature of the aquatic environment. The characteristics of water surfaces vary about the geographical location, from deep blue waters to coastal waters near land, with the need for analysis. And focus on dissolved materials [12]. Optical properties are called latent when the practical values of the point studied in the medium are constant with the distribution of radiation in the fact and depend on the medium, especially its composition and the materials suspended in it. The properties include both the coefficients (scattering - absorption - attenuation) and the volumetric tripping function used to determine the link budget.) at UWOC, the properties are of great importance when it is considered that we are transmitting a high-quality and resolution image through ocean water [7].

3. SYSTEM LAYOUT DESIGN

A model of an underwater wireless optical communication system was built, Figure .1, shows the basic elements that make up this system

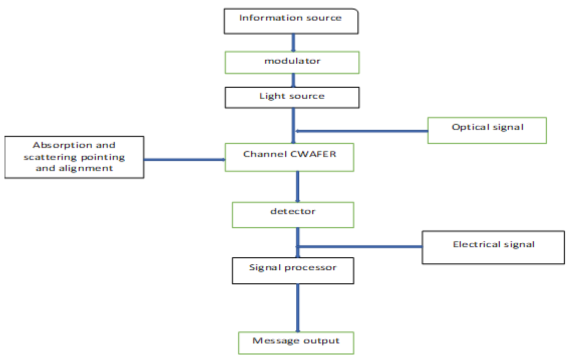

Figure .1, Block diagram of an underwater wireless optical communications system

Figure .2 shows the practical design applied in this work, where a green laser was used and is considered appropriate for such applications, as was indicated in previous studies. The most important components of the system are Laser Diode, Photo Detector, Optical Power Meter, Oscilloscope Visualizer, Optical Spectrum Analyzer, Pulse Generator.

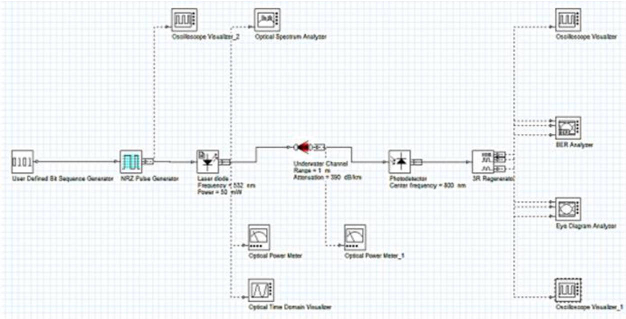

Figure .2, Practical diagram for designing an optical communications system.

Where two strings of binary daughters were generated in the first box, then we reshaped them into pulses (pulse shaping) using a pulse generator encoding NRZ to obtain a unipolar signal from the pulses, which in practical part represents the signal resulting from the frequency generator or the data to be sent from the computer and the stage of converting the signal to TTL.

3. RUSTLES AND DISCASING

The first series data was 111111, it is obtained the shape of this signal after the pulse reshaping phase of this series and applied to the input of the laser diode via the signal oscilloscope. Likewise, the second series was 000000001111, notice that as the time increases, the amplitude decreases, and there is no signal except in the last four bits as shown in Figure .3

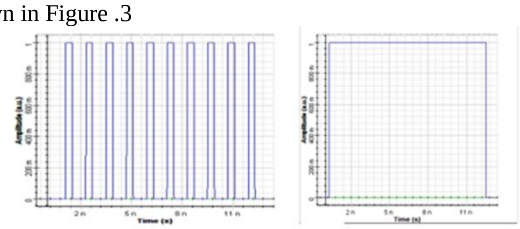

Figure .3, Generating the two strings (111111) and (000000001111)

For the second stage, (LD) with a wavelength of 532nm with a power of 50mW, the light it emits is modified with the previous data (which represents the OOK modification used in our design). Then the optical power was measured on the output of (LD) using an optical power meter. The results are shown in Figure 4, which calculates the average power for the entire series. The output power of this system is the Optical power on the laser output at the message 111111 4.70x10^(-3) w,16.785dBm, and the Optical power on the laser output at message 000000001111 is 16.305x10^(-3) w,12.123dBm , a decrease in power can be observed in the second case because LD did not emit light except in the last four phases. the spectrum was plotted of the optical signal at the laser output in the frequency domain using Optical Spectrum Analyzer. As the wavelength increases, the energy decreases. The message's wavelength was equal to 111111, 531.8 nm, and the power was between -50, -80. As for the message 000000001111, 531.8 nm, the strength was between -70, -90, or the results were as shown in Figure .5

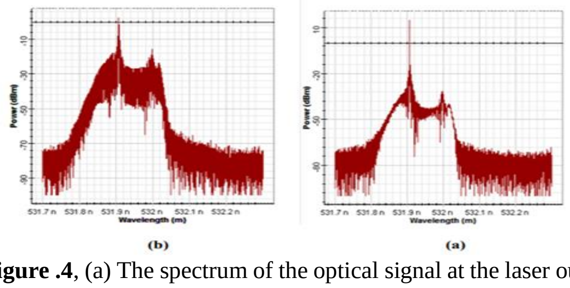

Figure .4, (a) The spectrum of the optical signal at the laser output for the message (111111)

(b) The spectrum of the optical signal at the laser output of the message (000000001111)

The modified optical signal in the time domain was also studied by the Optical Time Domain Visualizer, where Figure .5, shows this, The Opti system environment does not support underwater wireless channels, so a free-space optical (FSO) channel was used with parameters specific to the water channel characteristics.

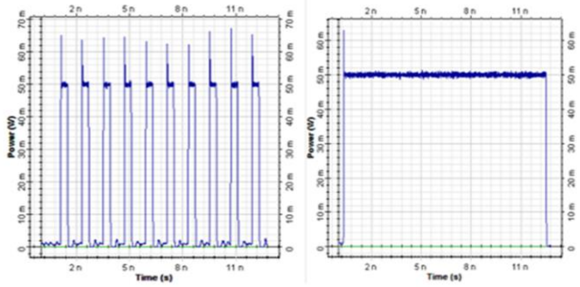

Figure .5, (a) The optical signal at the laser output for the message (111111)

(b) The optical signal at the laser output of the message (000000001111)

Three cases were studied for each bit string: the first case, where the medium was considered to be pure ocean water with an attenuation factor of 0.39 dB/m, while for the second case, the medium was coastal ocean water with an attenuation of 5.4 dB/m, and the third case was in water. Shallow and damped 11db/m. The channel length was considered to be 1m as is the case in the implementation procedure. The optical power was measured at the channel output (at the detector) and the results were shown in Figures .6 and 7,8,9, the power decreases with the increase in the damping factor for each of the previous three types of water, Table 1, shows that the Optical power at the detector output for the message 111111, for (a) In clear oceans (b) Coastal waters (c) Turbid waters and Table .2, for the message 000000001111

Table .1 Optical power at the detector output for the message (111111) for (a) In clear oceans (b) Coastal waters (c) Turbid waters

Power dBm	Power(w) $^{-3}$	
12.313	17.033	(a)
7.303	5.374	(b)
1.707	1.480	(c)

Table. 2 Optical powers at the detector output for the message (000000001111) for (a) In clear oceans (b) Coastal waters (c) Turbid waters

Power dBm	Power(w) $^{-3}$	
7.650	5.822	(a)
2.641	1.837	(b)
2.959	505.920	(c)

When moving to the detection stage, it is possible to use a photodetector with a dark current of 100nA and a maximum sensitivity at the wavelength 800nm, as is the case in the practical circuit, and then plot the received signal at the detector and plot the noise signal for each case:

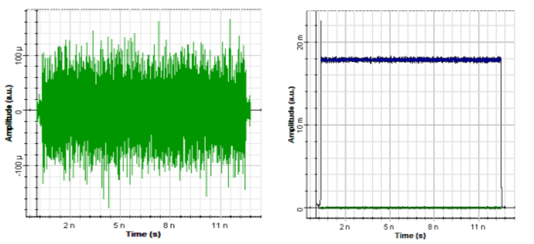

Figure. 6 The received signal at the detector and the noise signal of ocean water for message (111111)

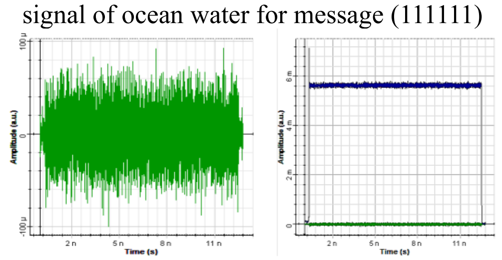

Figure.7 The received signal at the detector and the coastal water noise signal for message (111111)

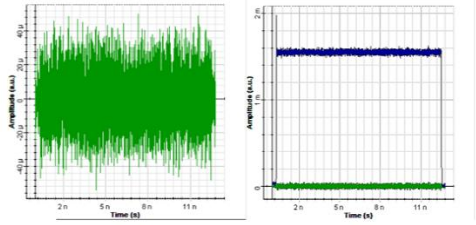

Figure.8, The received signal at the detector and the coastal water noise signal for message (111111)

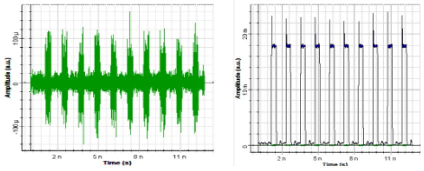

Figure.9 The signal received at the detector and the noise signal of pure ocean water for the message

To analyze the system's performance, we used (BER Analyzer) and drew the Q curve, the quality factor that measures the quality of the analog signal in terms of the signal-to-noise ratio (SNR). It takes into account the physical impairments of the signal, including noise, chromatic dispersion, polarization, and the effects of non-linearity, which reduce the quality of the signal. Ultimately, this leads to female errors. The higher the Q value, the better the SNR value, and thus the lower the probability of female errors occurring, notice that (a) the signal quality is better and the Q value is between 60 and 59. Figure 10 and 11,12,13 , shows the Q curve for the three water cases and both messages:

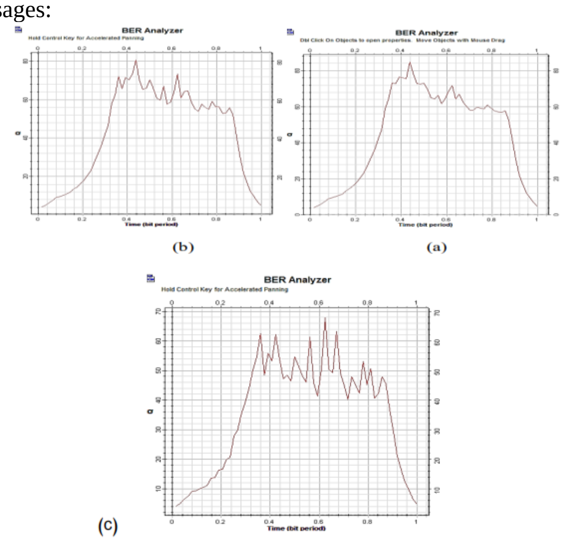

Figure .10 Q curves for different types of water at the message (111111) (a) In clear oceans (b) Coastal waters (c) Turbid waters

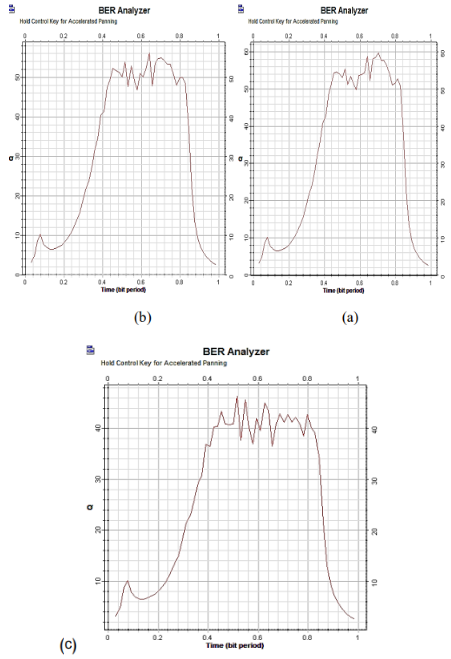

Figure .11 Q curves for different types of water at message (00000001111) (a) In clear oceans (b) Coastal waters (c) Turbid waters

also see (BER) curves as a function of (Bit Period) for all previous cases:

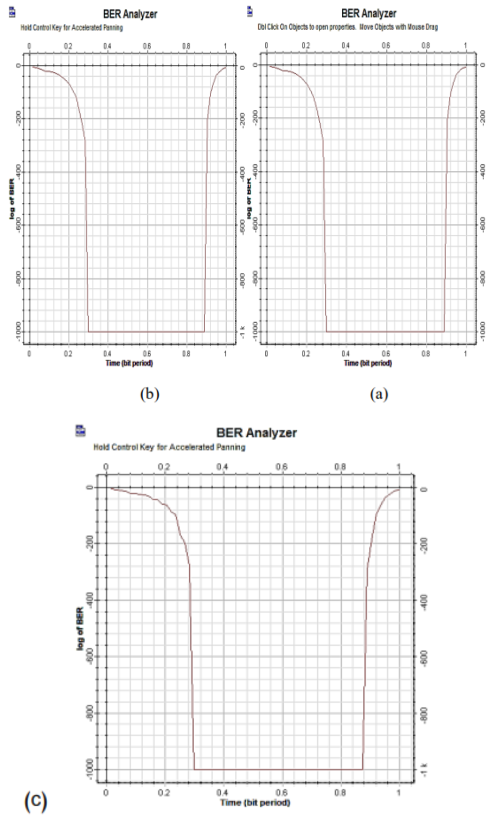

Figure .12, BER curves for different types of water at message (111111) (a) In clear oceans (b) Coastal waters (c) Turbid waters

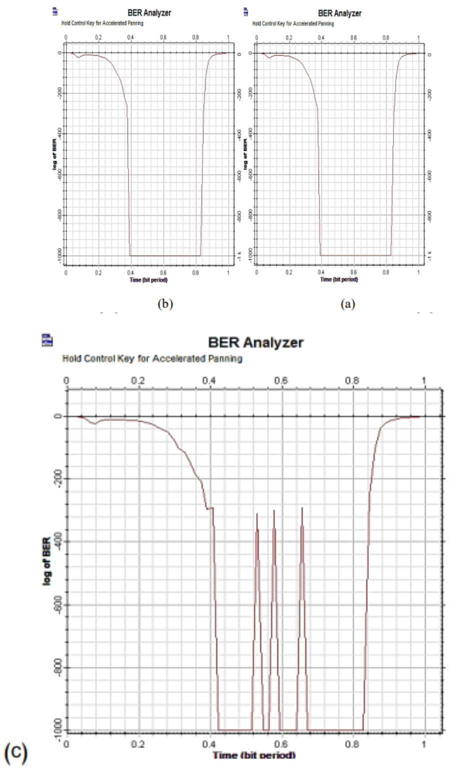

Figure. 13, BER curves for different types of water at the message (00000001111) (a) In clear oceans (b) Coastal waters (c) Turbid waters

The BER Pattern for the previous cases is given in Figure. 14

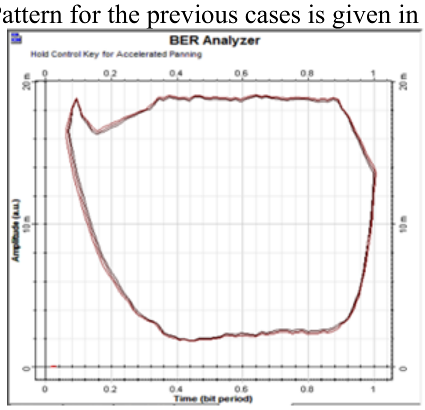

Figure .14, BER Pattern curves at letter (111111) in pure oceans

The eye analysis of the automatic validity of the highest factor was 84.7423, the lowest was 0, the eye height was 0.0168683, the threshold was 0.00917433, and the decision founder was 0.296875, which is the best. Eye Diagram: It is a methodology that gives us an analysis of high-speed digital signals. The eye diagram is formed from the digital form of the wave by folding the part of the wave corresponding to each bit into a single graphic curve whose vertical axis is the amplitude of the wave while the horizontal axis is time and by repeating this Processing several wave samples, the resulting curve will provide the statistical average of the signal, which will resemble an eye in shape. Eye Height refers to the signal-to-noise ratio by closing the eye-opening. While the Eye Crossing Percentage indicates duty cycle distortion and pulse symmetry problems. The Figure.15, shows the eye diagram for each of the previous cases:

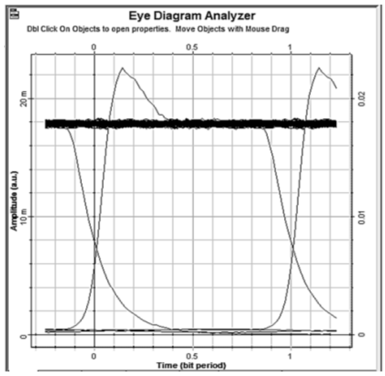

Figure .15, Eye Diagram at letter (111111) in pure oceans

3. CONCLUSION

In this paper, an underwater optical communications system was designed, simulated, and analyzed. A number of bits represented each bit of the information message to evaluate the performance and clearly know its effect. The OPTYISEYTEM system was used in the simulation and through the results obtained the following conclusions can be reached:

It allows data to be transmitted over long distances under the surface of water in a fast and efficient manner, the receiving signal is affected by the properties of water (permeability, permittivity, conductivity), and this technology relies on the use of infrared rays or lasers to send light signals through the water, which allows large amounts of data to be transferred quickly and safely, and the error rate in the data across the environment reached 2%, this technology is ideal for uses that require high speed and large bandwidth, such as marine communications and underwater scientific exploration, the use of optical wireless communications underwater opens new horizons in the field of underwater communications and communication. This may contribute to the development of industries such as natural resource exploration and ocean science research, in addition to its potential uses in marine communications and underwater entertainment, it can be said that in turbid or turbulent water, communication is lost, the higher the value of Q, the better the value of (SNR), and thus the lower the probability of errors occurring in the transmitted and received bits.

4. References

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