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Overview of Optical Wireless Networks Technology Underwater

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Abstract

In recent years, there has been a notable uptick in the exploration of underwater optical wireless communications (UOWC) as a viable alternative for efficient high-speed data transmission beneath the sea. This technology employs optical wavelengths in dedicated point-to-point connections, sharing similarities with free space optical (FSO) communications and laser satellite links. By harnessing specific wavelengths, UOWC achieves impressive data transfer rates, as demonstrated in recent research showcasing broadband communications over substantial distances. This technology holds promise in various applications such as environmental protection, seawater exploration, military operations, and emergency alarms. However, the underwater environment poses challenges due to scattering and severe absorption, making the channel a complex medium to navigate. Additionally, accurate localization presents a significant challenge, leading to improperly adjusted connections that adversely affect signal propagation quality. This work provides an overview emphasizing the significance of optical wireless communications underwater and its role in contemporary applications. It delves into the crucial factors influencing optical signals and explores the types of connections and configurations used in transmitting and receiving channels..

Keywords: UOWC, Underwater Links, underwater Attenuation, Oceanic Turbulence, Background Noise.

1. Introduction

A concise summary will highlight the key aspects of UOWC technologies to offer a foundational understanding for the special issue on Underwater Wireless Optical Communications. In contemporary times, numerous land-based devices heavily rely on wireless communications. There is a significant interest from various sectors, including the military, business, and scientific communities, in implementing wireless communication systems in underwater environments. [1-2]. Extensive research is presently focused on advancing acoustic systems due to their efficacy in long-distance underwater communication.

Ongoing studies aim to improve the efficiency of acoustic communication pathways [3–7]. However, the performance of these systems is affected by fundamental physical laws such as Doppler spreading, time-varying multi-path propagation, substantial latency, transmission losses, and limitations in bandwidth [8–13]. These restrictions prevent autonomous underwater vehicles (AUV) from using acoustic communication to transmit high definition real-time video. Since broadband underwater communications require complementary technology, real-time video transmissions, such as the teleoperation of underwater vehicles and the remote observation of underwater stations, are increasingly valuable for underwater applications [14–17]. Since they are by nature more prevalent and used in terrestrial communications, RF waves are not appropriate for usage underwater due to their significant attenuation [18]. raditional underwater acoustic communication is vulnerable to malicious attacks due to its inadequate performance characteristics, including high variability in propagation delays, substantial bit error rates, and limited bandwidth. [19]. The technology known as visible-light communication (VLC) can address these issues. The visible light spectrum (400–700 nm), which is used for illumination, is manipulated in VLC systems in order to transfer data [20–26]. Underwater optical wireless communication (UOWC) systems, which have LDs rather than LEDs as potential light sources, are comparable to VLC systems.

Both Light Emitting Diodes (LEDs) and Laser Diodes (LDs) offer distinct advantages: LDs provide larger modulation bandwidth compared to LEDs, while LEDs are more suitable for medium bit rate applications due to their higher power efficiency, lower cost, and longer lifespan. Table 1 outlines the performance attributes, encompassing advantages, constraints, and prerequisites, of the three main underwater communication methods: acoustic, radio frequency, and optical, as detailed in reference [27]. Figure 1 illustrates a typical scenario in Underwater Optical Wireless Communications (UOWC), depicting various connected platforms using light beams (such as divers, ships, submarines, and submarine sensors).

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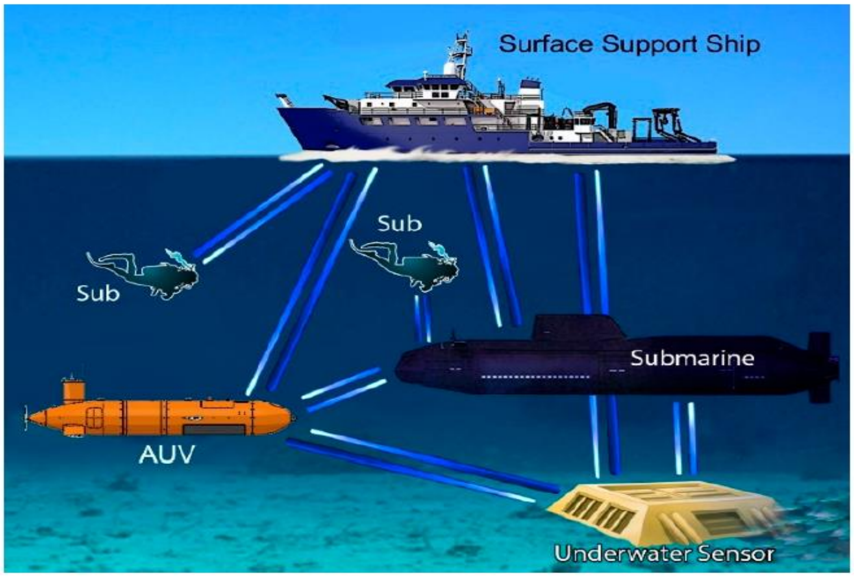

Figure 1: Typical Application Senarios of UWOC

Table 1: Compares Acoustic, Radio Frequency, and Optical Techniques

Parameters	RF	Acoustic	Optical
Attenuation	(3.50 – 5) dB/m	(0.10 – 4) dB/km	0.39dB/m (coastal) 11 dB/m (turbid)
Attenuation dependent	Frequency and Conductivity	Frequency and Distance	Distance and Type of water
Speed(m/s)	2.225 * 10^8 m/s	$1.5 * 10^3$ m/s	$2.225 * 10^8$ m/s
Data rate	(Mbps)	(Kbps)	(Gbps)
Latency	Moderate	High	Low
Range	10 meters or less	Around of km_s	10 – 100 meters
Bandwidth	MHz	kHz	10 – 170 MHz
Transmission power	mW-W	Tens of Watts	mW-W
antenna length	0.50 m	0.10 m	0.10m
Efficiency	_	100 bit /J	$3×10^4$ bits/J
Performance Parameters	permittivity and conductivity	salinity temperature, and pressure	Absorption and Scattering

2. Configurations for Underwater Links

Underwater optical link configurations are classified into three types: direct links, Non direct links, and retroreflector links [28-29].

2.1 Direct Links LOS

Figure (2) depicts a direct link LOS, which is the most elementary, unhindered, and point-to-point undersea connection between receiver and transmitter. This connection is especially well implemented in the situation of static receivers or transmitters, such as multiple sensor nodes at the ocean's bottom. When the transmitter in clear oceans transmits a narrow wave to the receiver, it works well. The likelihood of obscuration is significant, however, because of fish populations, marine life expansion, and other obstacles.

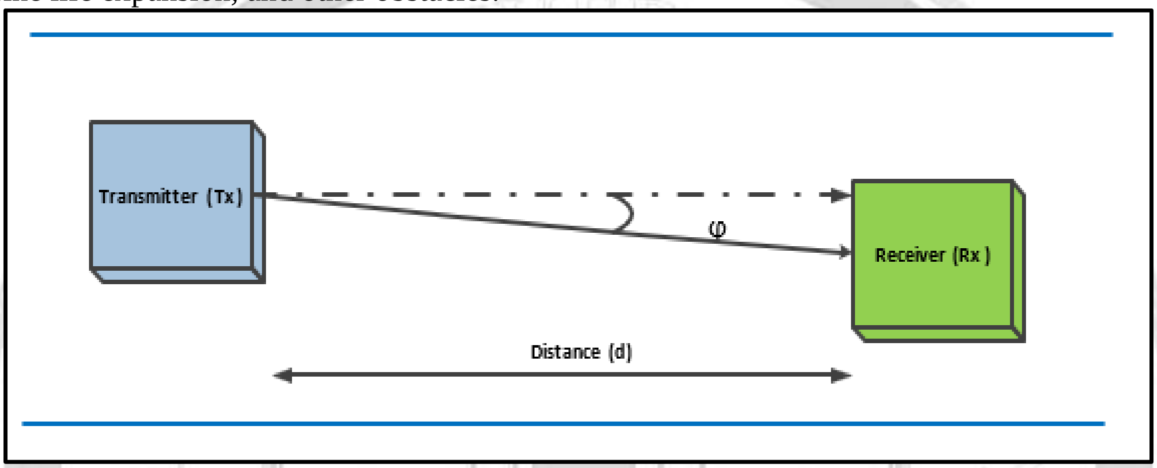

Fig.2: LOS Link Configuration [29]

Hence, establishing a Line-of-Sight (LOS) connection necessitates devising a system that prevents marine life from impeding the transmission path. Moreover, the optimal lighting used for underwater optical communication has the unintended consequence of attracting groups of fish. While fish favor yellow and green wavelengths, marine fish prefer blue and green wavelengths. As a result, erratic or flashing lights are preferred to keep fish out of the LOS area. The authority derived from P_R ($_{Los}$) is granted by [29]:

$$P_{R-los} = P_T \eta_T \eta_R L_{pr} \left(\lambda, \frac{d}{\cos\theta}\right) . \frac{A_r . \cos\emptyset}{2\pi d^2 (1 - \cos\theta_\circ)} \quad (1)$$

Where P_T is an average transmission power, η_T is the transmitters optical efficiency, Lpr is the linke range, λ is laser wavelength η_R is the receiver's optical efficiency, d represents the perpendicular space between the planes of the transmitter and receiver, θ angle formed by the reception plane and the trajectory of the transmitter and receiver, A_r area of the receiver aperture, while θ_0 is the angle of beam divergence. In situations where the angle of divergence of the laser light is extremely narrow ($\theta_0 << \pi/20$) equation (1), approximated as [29]:

$$P_{R-los} = P_T \eta_T \eta_T L_{pr} \left(\lambda, \frac{d}{\cos\emptyset}\right) . \frac{A_r . \cos\emptyset}{\pi . (d . \tan\theta_\circ)^2} \quad (2)$$

2.2 NLOS Links

Non-Los arrangement overcomes alignment limitation of LOS links at UWOC, as depicted in Figure (3). A transmitter in this design emits the light beam toward the surface of the water at an incidence angle bigger than the angle of critical incidence. To maintain proper signal reception, The receiver must keep its back to the water's surface in the direction of the light's reflection. Random water surface slopes resulting from wind or other types of turbulence pose the greatest obstacle for non-LOS connections. These unwanted occurrences are seen as a reflection in the light emitted by the transmitter, resulting in severe signal dispersion[29].

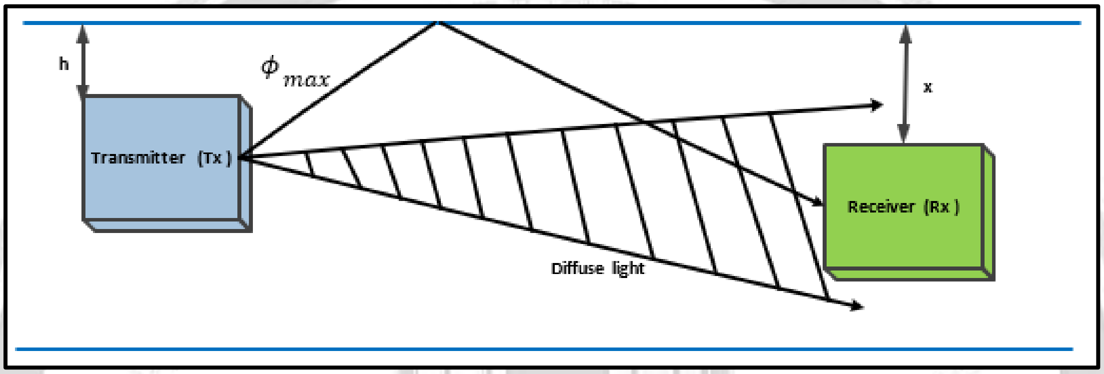

Fig.3: Configuration of a Non-LOS Link.

At a depth h, when the transmitter is positioned, it results in an illuminated ring-shaped area exhibiting equivalent power density at that particular depth z can be calculated as follows [29]:

$$A_{(ann)} = 2\pi\,[(h+z)^2(\cos\emptyset - \cos\emptyset\max)] \qquad (3)$$

The received power P_R offered by [29] :

$$P_{R(\text{non-Los})}(\emptyset) = A_r f_R(\emptyset) \qquad (4)$$

where $f_R(\phi)$ is an extra function dependent on η_T, η_R, P_T, (h + z), A_{ann}, and ϕ_t transmitting angle.

2.3 Retroreflector Links

In scenarios of limited duplex communication, retro-reflector links are employed. This is shown in Figure (4), where the receiver's power capacity is inadequate for sustaining full transceiver operations. In this setup, a small optical retro-reflector installed at the remote receiver detects the incoming beam from the source and reflects it back to the same source, whereas h refered to transmitter's depth while x refered to receiver's depth inregards to surface of the water. In this case, the received power P_R offered by [29] :

$$P_{R-Retro} = P_T\eta_T\eta_{Retro}L_{pr}\left(\lambda, \frac{d}{\cos\emptyset}\right).\frac{A_{Retro}.\cos\emptyset}{2\pi d^2(1-\cos\theta_\circ)}.\left[\frac{A_{Rero}}{\pi(d\tan\theta_{Retro})^2}\right] \qquad (5)$$

Where η_{Retro} optical efficiency of the retro-reflector, $L_{pr}$is the linke range, λ is laser wavelength, $_{Retro}$ is the divergence angle of the retroreflector, A_{Retro} is the area of the retro-reflector's aperture, and other parameters were previously defined.

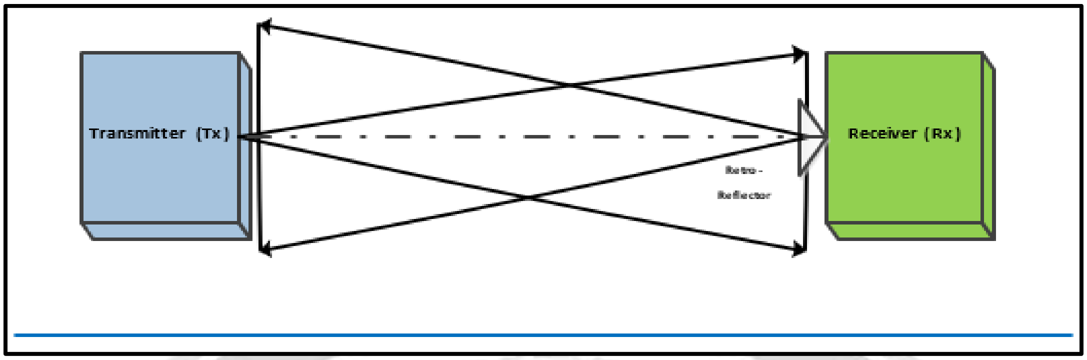

Fig.4: Configuration of Retro reflector Links

3. Factors Effecting UWOC System

Attenuation (scattering and absorption), turbulence, background noise, thermal noise , current shot noise , and dark current noise are the important facets that have an impact on UWOC systems.

3.1 Attenuation

Because of high absorption of water at optical frequencies and strong particle backscattering, typically, the range of optical signals used as wireless carriers is extremely constrained. The fact that light waves are often heavily absorbed by water is one of the major issues, and the other is that all particles in the ocean diffuse optically. However, in the (green-blue) area of the visible light, absorption is diminished. Based on water kinds for the clean water the wavelength is (400-550nm), while (350-750nm) for turbid water environments, the high-speed connection can be established using an appropriate wavelength, such as in the blue/green area. As demonstrated in Figure (5), the minimum attenuation is centered in clearwater near 460nm, for unclean waters near 540nm in coastal waters and swings to higher values [30].

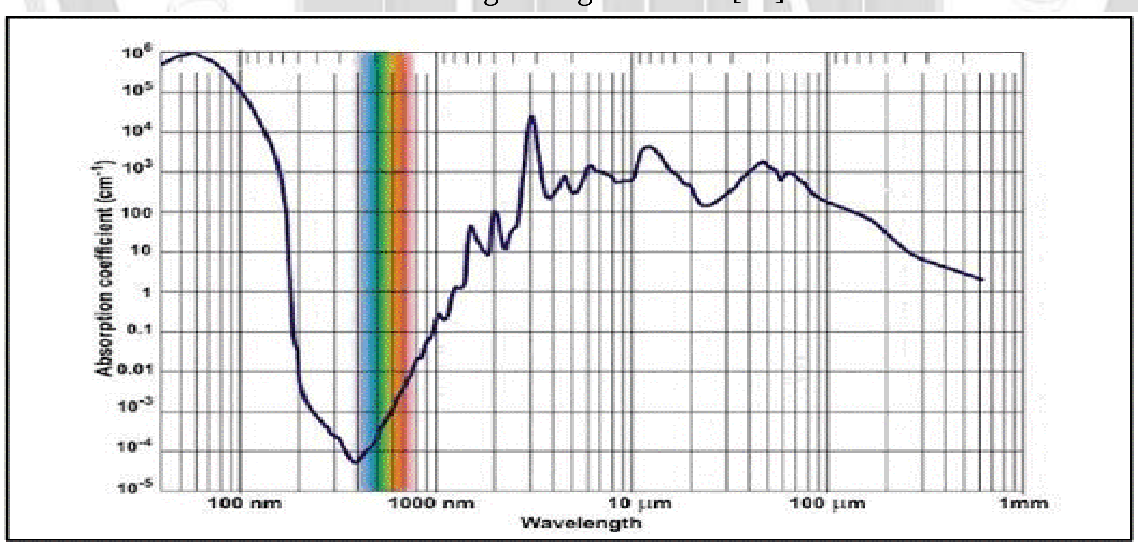

Fig.5: The Transparent Window for Light Aquatic Attenuation is Shown with Blue and Green Colors [30,31]

1. Absorption

Absorption, as measured by the spectral absorption coefficient ($\alpha(\lambda)$), is the primary mechanism responsible for the attenuation of optical signals underwater, this is the variation in the light beam due to the fact that the medium absorbs power per meter of link length. The total absorbance is a linear mixture of the absorption of clean seawater, wavelength, concentration of chlorophyll, and dissolved organically colored chemicals. The absorption factor (λ) is provided by [30] :

$$\alpha(\lambda) = acl(\lambda) + aw(\lambda) + ah(\lambda) + af(\lambda) \quad (6)$$

Where $acl(\lambda)$ is the acid chlorophyll absorption factor as a wavelength dependence, $aw(\lambda)$ is the water absorption factor in relation to wavelength (m^{-1}), $af(\lambda)$ Absorption ratio of fulvic acid and $ah(\lambda)$ is the absorption coefficient of humic acid and both depend upon wavelength [32].

2. Scattering

Amount of optical flux that is lost as a consequence of the scattering of photons is denoted by the scattering factor β(λ). Overall scattering is a convolution of water's scattering coefficient, $b_w(\lambda)$, scattering caused by minute particles, $b_{s^o}(\lambda)$ depending upon wavelength and concentration, and scattering by substantial particles, $b_{l^o}(\lambda)$ depending upon concentration and wavelength. The scattering factor β(λ) is described by [30-31] :

$$\beta(\lambda) = b_w(\lambda) + b_{s^\circ}(\lambda)Cs + b_{l^\circ}(\lambda)Cl \quad (7)$$

Where Cs represents a little particle concentration and Cl represents a big particle concentration. The route loss factor is displayed in Eq. 8 as a function of wavelength λ and distance z [30]

$$L(\lambda, z) = L^\circ e^{-c(\lambda)z} \quad (8)$$

Where L_0 is optical wave power before transmission, L (λ, z) is optical wave power after transmission, and c(λ) is the factor of extinction indicating the total attenuation caused by undersea propagation. Absorption plus scattering constitutes total attenuation. The total attenuation factor in eq. (9) It is employed in a completely scattering or absorbing medium. The scattering factor (β) or the absorption factor (α), respectively can be substituted. The cz product, commonly known as length of the attenuation, contributes to a reduction in received power using an exp factor. On this will the extinction coefficient be calculated [33]:

$$IC(\lambda) = \beta(\lambda) + \alpha(\lambda) \;\; I \quad (9)$$

Where (λ) represents the absorption factor, (λ) represents the scattering factor, and λ represents the wavelength. Table (2) provides average values for (λ), (λ), and C(λ) for the three most common forms of water. Clear ocean water has a larger concentration of dissolved particles, which impacts scattering. In coastal (mid turbulence) water, significant quantities of plankton, trash, and minerals are the primary causes of absorption and scattering. The greatest amount of dissolved substances can be found in the harbor's turbid water, which drastically limits light propagation. Table 2 displays standard values for the factors C(λ), $\alpha(\lambda)$, and $\beta(\lambda)$ in consideration of the water classification. The 3 main kinds of water, together with their extinction values, are as follows:

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Table 2: Standard extinction coefficient values (absorption and scattering)[30] .

Types of water	$\alpha(\lambda)$ (m^{-1})	$\beta(\lambda)$ (m^{-1})	$c(\lambda)$ (m^{-1})
Clearwater	0.114	0.037	0.151
Coastal Water	0.179	0.220	0.399
Turbid Water	0.366	1.829	2.195

3.2 Background Noise

Blackbody radiation and ambient light submerged in water, primarily from sunlight refracted off the water's surface, make up the background noise. One way to express the background noise power is as [34]:

$$P_{BG} = P_{BG(blackbody)} + P_{BG(Solar)} \tag{10}$$

In the equation above, the power of solar background noise, $PBG_{(Sol)}$, is given by:

$$P_{BG\ (sol)} = (\pi FOV)^2 A_R \Delta_\lambda T_F L_{(sol)} \tag{11}$$

Where Δ_λ bandwidth of an optical filter, A_R is the receiver area, FOV is the visual field, and the optical filter's transmissivity is denoted by the symbol T_F. The solar radiance, $L_{(sol)}$ W/m^2 is[34]:

$$L_{sol} = \frac{ERL_f e^{-dk}}{\pi} \tag{12}$$

where R is reflection of downwelling irradiance by water, *E* is downwelling irradiance W/m^2, L_f is the factor defining the dependence of undersea radiation on direction, K refers to the factor of diffuse attenuation, while d refers to the depth of the water (m).

3.3 Dark Current Noise

The noise that is being produced by the detector (photodiode) right now is called dark current noise. The variance of the noise of the dark current is [34]:

$$\sigma_{DC}{}^2 = 2qI_{DC}B \tag{13}$$

Where B is the bandwidth, and $I_{DC} = 12.26 \times 10^{-10}$ (Ampere).

3.4 Thermal Noise (Johnson Noise)

The variance of Johnson noise is [34]:

$$\sigma_{TH}^2 = \frac{4KT_eFB}{R_L} \tag{14}$$

Suppose that the equivalent temp T_e is 290K, that the system's noise figure is F = 4, B is the bandwidth, and that the load resistance RL = 100 Ω.

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3.5 Current Shot Noise

When the received signal is there, shot noise is present. Variance for current shot noise is [34]:

$$\sigma_{ss}^2 = 2q\Re P_S B \tag{15}$$

Where q is the charge of the electron (1.6×10^{-19}), P_s is the signal power, B is the bandwidth and $\Re$ is the responsivity.

The sum of all noise sources constitutes the total noise variance. Therefore, the variance of current noise in the detector in the absence of an optical signal can be calculated as:

$$\sigma_{0^2} = \sigma_{TH^2} + \sigma_{DC^2} + \sigma_{BG^2} \tag{16}$$

Due to the existence of shot noise the variation of current noise within the detector that is used for the detection of an optical wave is computed as follows:

$$\sigma_{1^2} = \sigma_{TH^2} + \sigma_{DC^2} + \sigma_{BG^2} + \sigma_{SS^2} \tag{17}$$

3.6 Turbulence

The fluctuations in signal strength at the receiver result from changes in the refraction coefficient within the transmission line due to variations in the underwater environment, including differences in density, temperature, and salinity. This issue, called scintillation, diminishes the effectiveness of UWOC. The constantly changing nature of the undersea environment means that there isn't an established standard model for underwater turbulence, unlike the classical model available for Free Space Optical Communication (FSO) [31].

4. Conclusion

In recent times, Underwater Optical Wireless Communication (UWOC) has garnered significant attention as a preferred method for underwater communication. It boasts higher data transfer rates over substantial distances compared to acoustic and RF techniques. This technology has found application in various critical activities such as disaster management, offshore drilling, environmental monitoring, and military operations. This paper conducts a comprehensive review of underwater wireless communications, encompassing a general description of communication networks and a detailed examination of crucial factors contributing to signal degradation. Special emphasis is placed on water types and their impact on the communication network. Furthermore, the paper explores various types of optical wireless channel links within the context of this study.

5. References

1. Gussen, C. M. G., Diniz, P. S. R., Campos, M. L. R., Martins, W. A., Costa, F. M., & Gois, J. N. (2016). A Survey of Underwater Wireless Communication Technologies. Journal of Communication and Information Systems, 31(1). https://doi.org/10.14209/jcis.2016.22

2. Ali, M., Jayakody, D.N.K., Chursin, Y.A. et al. Recent Advances and Future Directions on Underwater Wireless Communications. Arch Computat Methods Eng 27, 1379–1412 (2020). https://doi.org/10.1007/s11831-019-09354-8.

3. Haider J. Abd, Sukaina Abdullah AL-Bairmani, and Mustafa Ismael, "Improvement of the Performance of Free Space Optics Channel Based on Optimized Systems Parameters," Progress In Electromagnetics Research M, Vol. 105, 99-108, 2021.

4. Zhou, S., & Wang, Z. (2014). OFDM for Underwater Acoustic Communications. OFDM for Underwater Acoustic Communications, 9781118458860, 1-386. http://doi.org/10.1002/9781118693865

5. Gang Qiao, Zeeshan Babar, Lu Ma, Songzuo Liu, Jinqiu Wu, MIMO-OFDM underwater acoustic communication systems—A review, Physical Communication, Volume 23, 2017, Pages 56-64, ISSN 1874- 07, https://doi.org/10.1016/j.phycom.2017.02.007..

6. Bocus, J., Agrafiotis, D., & Doufexi, A. (2018). Real-time video transmission using massive MIMO in an underwater acoustic channel. In 2018 IEEE Wireless Communications and Networking Conference (WCNC 2018): Proceedings of a meeting held 15-18 April 2018, Barcelona, Spain (pp. 2069-2074). Institute of Electrical and Electronics Engineers (IEEE). https://doi.org/10.1109/WCNC.2018.8376952

7. Bocus, J., Doufexi, A., & Agrafiotis, D. (2019). Performance of OFDM-based massive MIMO OTFS systems for underwater acoustic communication. IET Communications, 14(4), 588 - 593. https://doi.org/10.1049/iet-com.2019.0376

8. Mohammed, A., Abd, H.J. , Review of underwater wireless optical communication AIP Conference Proceedings, 2023, 2804(1), 020024. https://doi.org/10.1063/5.0154238

9. H. Esmaiel and D. Jiang, "Review Article: Multicarrier Communication for Underwater Acoustic Channel," International Journal of Communications, Network and System Sciences, Vol. 6 No. 8, 2013, pp. 361-376. doi: 10.4236/ijcns.2013.68039.

10. Melodia, T.; Kulhandjian, H.; Kuo, L.C.; Demirors, E. Advances in Underwater Acoustic Networking. In Mobile Ad Hoc Networking: Cutting Edge Directions, 2nd ed.; Chapter 23; Basagni, S., Conti, M., Giordano, S., Stojmenovic, I., Eds.;Wiley: New York, NY, USA, 2013; pp. 804–852.

11. E. Demirors, G. Sklivanitis, G. E. Santagati, T. Melodia, and S. N. Batalama, "High-Rate Software-Defined Underwater Acoustic Modem with Real-Time Adaptation Capabilities," IEEE Access, vol. 6, pp. 18602–18615, 2018. DOI: 10.1109/ACCESS.2018.2814401.

12. D. Centelles, A. Soriano-Asensi, J. V. Martí, R. Marín, and P. J. Sanz, "Underwater Wireless Communications for Cooperative Robotics with UWSim-NET," Appl. Sci., vol. 9, p. 3526, 2019. DOI: 10.3390/app9173526.

13. Santos, R.; Orozco, J.; Micheletto, M.; Ochoa, S.F.; Meseguer, R.; Millan, P.; Molina, C. Real-Time Communication Support for Underwater Acoustic Sensor Networks. Sensors 2017, 17, 1629. https://doi.org/10.3390/s17071629

14. M. Doniec, A. Xu, and D. Rus, "Robust Real-Time Underwater Digital Video Streaming using Optical Communication," in Proceedings of the IEEE International Conference on Robotics and Automation (ICRA), Karlsruhe, Germany, 6–10 May 2013

15. A. Al-Halafi, H. M. Oubei, B. S. Ooi, and B. Shihada, "Real-Time Video Transmission Over Different Underwater Wireless Optical Channels Using a Directly Modulated 520 nm Laser Diode," J. Opt. Commun. Netw., vol. 9, pp. 826–832, 2017. DOI: 10.1364/JOCN.9.000826.

16. J. Ribas, D. Sura, and M. Stojanovic, "Underwater Wireless Video Transmission for Supervisory Control and Inspection Using Acoustic OFDM," in Proceedings of OCEANS 2010, Seattle, WA, USA, 20–23 September 2010.

17. S. Han, R. Chen, Y. Noh, and M. Gerla, "Real-time Video Streaming from Mobile Underwater Sensors," in Proceedings of WUWNET '14, the International Conference on Underwater Networks & Systems, Rome, Italy, 12–14 November 2014, pp. 1–8.

18. X. Che, I. Wells, G. Dickers, P. Kear, and X. Gong, "Re-evaluation of RF Electromagnetic Communication in Underwater Sensor Networks," IEEE Commun. Mag., vol. 48, pp. 143–151, 2010. DOI: 10.1109/MCOM.2010.5560598.

19. M. Quasim and H. J. Abd, "Performance Improvement of the Vertical Cavity Surface Emitting Laser Based on Active Hybrid Design and MIMO Configuration," Progress In Electromagnetics Research C, vol. 138, pp. 39–49, 2023. DOI: 10.2528/PIERC22020906.

20. M. G. Al-Hamiri and H. J. Abd, "Design and Performance Evaluation of a Hybrid LiFi Transceiver Using OSTBC-Based Spatial Multiplexing and Transmit Diversity," e-Prime - Advances in Electrical Engineering, Electronics and Energy, vol. 6, 100283, 2023. DOI: 10.1016/j.eprimes.2023.100283.

21. L. J. Johnson, F. Jasman, R. J. Green, and M. S. Leeson, "Recent Advances in Underwater Optical Wireless Communications," Underw. Technol., vol. 32, pp. 167–175, 2014. DOI: 10.3723/ut.32.167.

22. Saeed, N.; Celik, A.; Al-Na_ouri, T.Y.; Alouini, M.S. "Underwater optical wireless communications, networking, and localization: A survey." Ad Hoc Netw. 2019, 94, 101935. DOI: 10.1016/j.adhoc.2019.101935

23. Wang, J.Y.; Liu, C.; Wang, J.B.; Wu, Y.; Lin, M.; Cheng, J. "Physical-layer security for indoor visible light communications: Secrecy capacity analysis." IEEE Trans. Commun. 2018, 66, 6423–6436. DOI: 10.1109/TCOMM.2018.2823563

24. Al-Hamiri, M.G., Abd, H.J. "Designing a LiFi Transceiver based Space Time Block Coding with different pulses," in 3rd Information Technology to Enhance e-Learning and Other Application, IT-ELA 2022, 2022, pp. 110–115.

25. Al-Kinani, A.; Wang, C.X.; Zhou, L.; Zhang, W. "Optical wireless communication channel measurements and models." IEEE Commun. Surv. Tutor. 2018, 20, 1939–1962. DOI: 10.1109/COMST.2018.2838295

26. Rehman, S.U.; Ullah, S.; Chong, P.H.J.; Yongchareon, S.; Komosny, D. "Visible Light Communication: A System Perspective—Overview and Challenges." Sensors 2019, 19, 1153. DOI: 10.3390/s19051153

27. Kaushal, H.; Kaddoum, G. "Underwater OpticalWireless Communication." IEEE Access 2016, 4, 1518–1547. DOI: 10.1109/ACCESS.2016.2552538

28. Johnson, L.J.; Jasman, F.; Green, R.J.; Leeson, M.S. "Recent advances in underwater optical wireless communications." Underw. Technol. 2014, 32, 167–175. DOI: 10.3723/ut.32.167

29. Arnon, S. "Underwater optical wireless communication network." Opt. Eng. 2010, 49, 015001. DOI: 10.1117/1.3280288

30. Gussen, C. M. G.; Diniz, P. S. R.; Campos, M. L. R.; Martins, W. A.; Costa, F. M.; Gois, J. N. "A Survey of Underwater Wireless Communication Technologies." J. Commun. Inf. Syst. 2016, 31, 242–255. DOI: 10.14209/jcis.2016.22

31. Kaushal, H.; Kaddoum, G. "Underwater Optical Wireless Communication." IEEE Access 2016, 4, 1518–1547. DOI: 10.1109/ACCESS.2016.2552538.

32. Spagnolo, G. S.; Cozzella, L.; Leccese, F. "Underwater optical wireless communications: Overview." Sensors (Switzerland) 2020, 20, 2261. DOI: 10.3390/s20082261

33. Massot-Campos, M.; Oliver-Codina, G. "Optical sensors and methods for underwater 3D reconstruction." Sensors (Switzerland) 2015, 15, 31525–31557. DOI: 10.3390/s151229864

34. Jaruwatanadilok, S. "Underwater wireless optical communication channel modeling and performance evaluation using vector radiative transfer theory." IEEE J. Sel. Areas Commun. 2008, 26, 1620–1627. DOI: 10.1109/JSAC.2008.081202

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الخلاصة

في السنوات الأخيرة، كانت هناك طفرة ملحوظة في استكشاف الاتصالات اللاسلكية الضوئية تحت الماء (UOWC) كبديل عملي لنقل البيانات تحت الماء بسرعة عالية وفعالة من حيث التكلفة. من خلال استخدام الأطوال الموجية الضوئية في الاتصالات المخصصة من نقطة إلى نقطة، تشترك UOWC في أوجه التشابه مع الاتصالات الضوئية في الفضاء الحر (FSO)وروابط الليزر عبر الأقمار الصناعية. إن الاستفادة من أطوال موجية محددة تمكن UOWC من تحقيق معدلات نقل بيانات عالية. أظهرت الأبحاث الحديثة أن اتصالات النطاق العريض ممكنة عبر مسافات معقولة. يمكن أن يكون مفيدًا في تطبيقات مختلفة مثل حماية البيئة واستكشاف مياه البحر والعمليات العسكرية وأجهزة إنذار الطوارئ وما إلى ذلك. إلا أن المجال تحت الماء يمثل وسطا يصعب التعامل معه حيث تتعرض القناة للتشتت والامتصاص الشديد. بالإضافة إلى ذلك، فإن التحدي المتمثل في التعريب الدقيق يجعل الاتصالات مضبوطة بشكل غير صحيح، مما يؤثر بدوره على جودة انتشار الإشارة. تم في هذا العمل تقديم لمحة عامة عن أهمية الاتصالات اللاسلكية الضوئية تحت البحر ودورها في التطبيقات الحديثة. كما تم عرض أهم العوامل المؤثرة على الإشارة الضوئية. بالإضافة إلى ذلك، تم دراسة أنواع التوصيلات والتكوينات المستخدمة في قنوات الإرسال والاستقبال

الكلمات الدالة: الاتصالات اللاسلكية الضوئية تحت الماء (UOWC)، الوصلات تحت الماء، التوهين تحت الماء، الاضطرابات المحيطية، الضوضاء الخلفية الاتصالات اللاسلكية الضوئية تحت الماء(UOWC) ، الوصلات تحت الماء، التوهين تحت الماء، الاضطرابات المحيطية، الضوضاء الخلفية