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OCDMA Based Satellite to Underwater VLC Transmissions for Oceanic Monitoring

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Abstract: Recently, optical wireless communication has emerged as a promising alternative to radio frequency communication across various domains such as atmospheric, deep space, and underwater transmissions. Specifically, the technology of satellite-to-underwater communication holds immense potential for applications in commercial, naval, scientific, and engineering sectors owing to its attributes including high data rates, robust security, extensive reach, and cost-effectiveness. This study delves into the performance assessment of an oceanic monitoring system aimed at bridging the gap between underwater and terrestrial environments. To ensure continuous real-time monitoring and widespread coverage, the communication infrastructure is augmented by a satellite link. The evaluation focuses on a direct detection Optical Code Division Multiple Access (OCDMA) system operating within an underwater wireless optical channel (UWOC). Various performance metrics are scrutinized through analytical analyses, with simulations conducted by manipulating key parameters such as range, transmitted power, user count, and inclination angle. The investigation also accounts for different modulation techniques tailored to distinct water types classified according to the Jerlov classification system. The obtained results reveal a substantial correlation between Bit Error Rate (BER) performance and both the water type and the receiver's positioning.

Keywords: Optical Code Division Multiple Access (OCDMA), Visible Light Communication (VLC), Under Water Optical Wireless Communication (UWOC), 5g networks.

Introduction

Oceanic Light Detection and Ranging **(O-LiDAR)** represents a significant remote sensing apparatus utilized for the assessment of near-coastal water depth and the exploration of optical attributes within aquatic environments (Kandouci , 2022). The proliferation of LiDAR commercialization has spurred heightened global inquiry into the theoretical underpinnings governing the transmission properties of LiDAR in underwater settings.

Currently, ground-to-space and ground-toaircraft communications rely on microwave technology. Eventually, aircraft-to-aircraft links will be OWC. Inter-aircraft optical wireless communication systems can transmit data at speeds of several Gbps over long distances of many kilometers. A satellite-to-ground communication system has been developed utilizing OWC technology (Kumari, 2024). Even though OWC technology has many merits, it also has several disadvantages, including scintillation loss (being sensitive to temperature variations caused by the Earth’s heat rise), geometric loss, the attenuation of beam-spreading power, absorption loss (photons absorbed by water molecules or CO2), atmospheric attenuation, and scattering loss (Kumari, 2024). In addition, the ground–underwater communication system can support the development of services like deep-sea mining, high-definition video transmission, and offshore exploration through underwater wireless optical communication (UWOC). It is, therefore, possible to generate high-speed as well as long-distance OWC transmission by using satellite–ground–underwater integrated systems (Kannan, 2024). Currently, ground-to-

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Method

Jerlov Water Types

In optical oceanography, Jerlov categorized waters into oceanic and coastal types based on their chlorophyll concentration. The latter directly affects the water's particles sizes and consequently the scattering and absorption effects on any light beam propagation underwater (Kandouci , 2022). Another important parameter to take into consideration is the attenuation co-efficient c(λ) (see table 1) . In UWOC it depends on the operating transmission wavelength. It's also defined as the sum of absorption and scattering coefficient respectively represented by a(λ) and b(λ):

$$c(\lambda) = a(\lambda) + b(\lambda) \tag{1}$$

Table. 1. Ideal transmission wavelength for different water types

Jerlov water type	$a(m^{-1})$	$b(m^{-1})$	$c(m^{-1})$
Clear water	0.053	0.003	0.056
Clear ocean	0.069	0.08	0.15
Coastal ocean	0.088	0.216	0.305
Turbid harbor	0.295	1.875	2.17

In order to overcome those drawbacks, we propose to translate the benefits of Optical Code Division Multiple Acces (OCDMA, more traditionally implemented in optical fibers systems) in UWOC systems by using two dimensional wavelength hopping / time spreading (WH/TS) codes to generate and detect the O-Lidar impulsions (Kandouci , 2022)

OCDMA Codes

The choice of optical codes and their parameters involves trade-offs. Increasing the code length or number of wavelengths can improve interference management and support for more users, but this may also increase system complexity and hardware requirements. In this paper, two dimensional time spreading / wavelength hopping optical code division multiple access codes (2D - WH/TS OCDMA) are chosen for their correlation properties necessary to generate the desired Lidar pulses. Wavelength-hopping/ Time-spreading codes are generated either by using mathematical approach or by the extension of existing one dimensional codes.

The cross-correlation function in the context of 2D wavelength-hopping time-spreading (WH/TS) OCDMA codes is a key measure of how much interference is present between different users' codes. It indicates the degree of overlap between the codes of different users and is critical for evaluating the multiple-access interference (MAI) in an OCDMA system.

Autocorrelation of a WH/TS code x(t) is defined in equation 2:

$$Z_{x,x} = \sum_{m=1}^{R}\left(\sum_{n=1}^{L_T} x_{m,n}x_{m,(n+1)\ mod\ L_T}\right) \tag{2}$$

With:

N is the number of codes;

R is the number of rows;

L_T is the number of columns;

Our codes satisfies$Z_{x,x} = W$.

The cross correlation between two W/T codes x(t) and y(t) is defined as follows in equation 3

$$Z_{x,y} = \sum_{m=1}^{R} \left(\sum_{n=1}^{L_T} x_{m,n} x_{m,(n+1) mod L_T} \right) \tag{3}$$

In our case

$$Z_{x,y} = \begin{cases} 1 \; for \; (Z_{C_{i,k}, C_{i+1,k}}) \\ \quad 1 \end{cases}$$

The cross-correlation functions directly impacts the system's bit error rate (BER) and capacity. Lower cross-correlation values reduce the chance of code collision, allowing more users to share the same channel without excessive interference, which improves system scalability and reliability , thus allowing the sending of the impulsions for monitoring without any overlap.

Results and Discussion

The consists of a demultiplexer (composed of a reconfigurable selection filter) to separate the components of the three wavelengths, $\lambda_1, \lambda_3, \lambda_9$), of the spectral signature. Each component is then sent to an optical delay line and finally recombined by a multiplexer. A delay time T_D was introduced between the different wavelengths of each user's code. It can be calculated as in equation (4).

$$T_D = p \times \frac{T_b}{s} \tag{4}$$

Where p is the position of the slot ;$T_b$is the bit time and s is the number of slots

This impulsions coding is illustrated in figure 1.

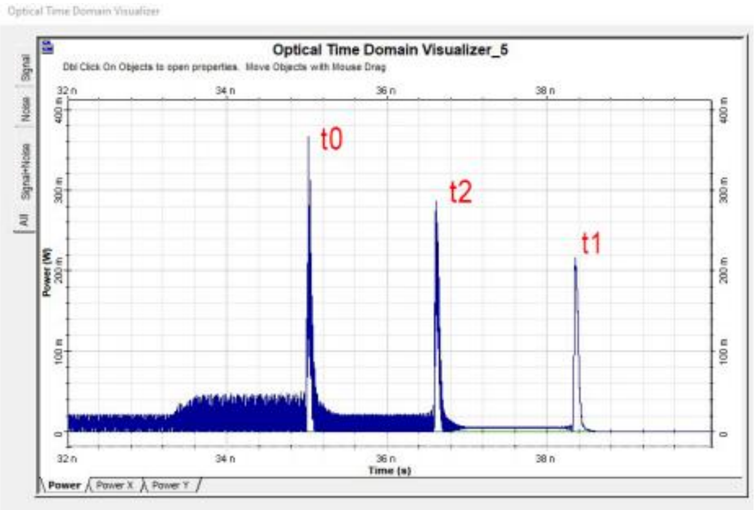


Figure 1. LiDAR impulsion's

At the receiver , each wavelength is firstly detected then delayed through delay lines. The time delay at the reception (T_R) is calculated as follow in equation (5).

$$T_R = (s - 1 - p) \times \frac{T_b}{s} \tag{5}$$

The transmission and reception delays will be the same for all codes, but in a different order and with different wavelengths to be transmitted. According to previous calculations, the three pulses should all have been received at the same instant. However, there is a slight offset due to dispersion effects. Figure 2shows the delayed wavelengths, which are then recombined at the decoder level (Mux).

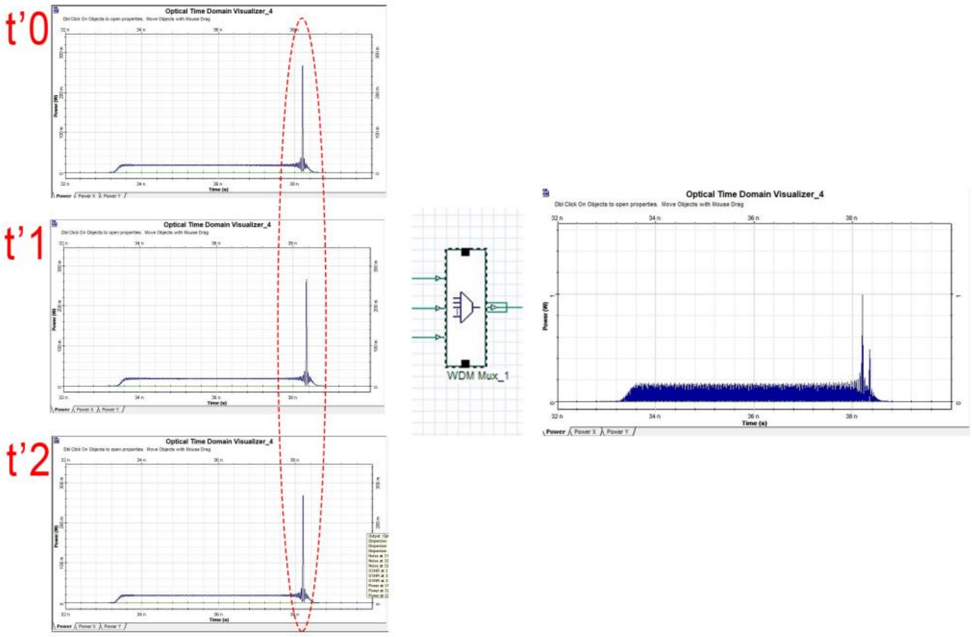
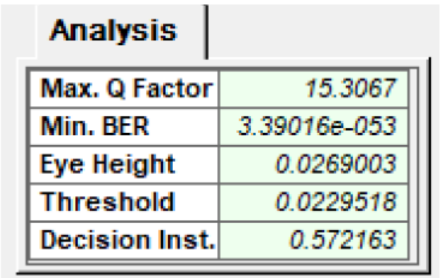


Figure 2. Impulsion's detection

The component library in the OptiSystem software uses the "BER Analyzer" block to compare the received signal with the transmitted data and then displays the expected values for various parameters (decision threshold, decision instant) and evaluation criteria (Q-factor, bit error rate (BER), eye diagram opening) to assess system performance (Figure 3).

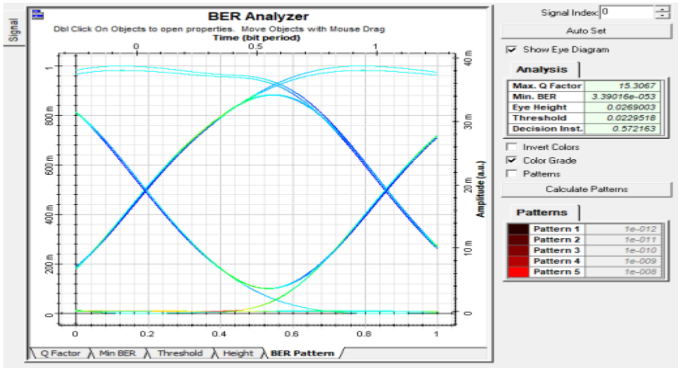


Analysis

Max. Q Factor	15.3067
Min. BER	3.39016e-053
Eye Height	0.0269003
Threshold	0.0229518
Decision Inst.	0.572163

Figure 3. Performance analysis

Figure 4 shows an eye diagram as a function of bit time. The two main characteristics of this graph are the vertical opening of the eye (which indicates the system's noise immunity) and the decision time.



Signal Index: 0

☑ Show Eye Diagram

Analysis

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Eye Height	0.0269003
Threshold	0.0229518
Decision Inst.	0.572163

☐ Invert Colors
☑ Color Grade
☐ Patterns

Patterns

Pattern 1	1e-012
Pattern 2	1e-011
Pattern 3	1e-010
Pattern 4	1e-009
Pattern 5	1e-008

Figure 4. Performance results

Conclusion

The application of O-LiDAR technology in environmental monitoring has demonstrated significant potential in enhancing the accuracy and efficiency of data collection. Its ability to provide high-resolution, three-dimensional spatial information allows for detailed analysis of various environmental parameters, from vegetation structure to topographical changes. The results of our study underscore the value of O-LiDAR in supporting sustainable environmental management practices, offering a powerful tool for researchers and policymakers to better understand and mitigate the impacts of environmental changes

Scientific Ethics Declaration

The authors declare that the scientific ethical and legal responsibility of this article published in EPSTEM Journal belongs to the authors.

Acknowledgements or Notes

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References

Kandouci, C. (2022). Performances enhancement of underwater wireless optical communications (UWOC) using pulse position modulation. *Journal of Optical Communications*, *43*(2), 289-294.

Kandouci, C. (2022). Investigation of Jervol water types properties effects on underwater optical wireless OCDMA system performances for different modulation techniques. *Optical and Quantum Electronics, 54* , 3.

Kannan, A. B. (2024). Experimental demonstration and performance analysis of free space and underwater optical wireless communication systems. *Wireless Personal Communications*, *134*(12) , 69–93.

Kumari, M., & Satyendra, K. M. (2024). High-efficiency 4 × 4 × 10 Gbps orbital angular momentum modes ıncorporated into satellite–ground–underwater optical wireless system under diverse turbulences. *Photonics*, *11*(4), 355.

Mitra, A. C. J. (2006). Lidar detection of underwater objects using a neuro-SVM-based architecture. *IEEE Transactions on Neural Networks 17*(3) , 717-731.

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