A Short Survey on Ultraviolet Communication Systems

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Abstract – The improvements made in the area of Optical Wireless Communication (OWC) has presented the new era of Ultra Violet Communication (UVC) which is used in both land and underwater arrangements. UVC has attracted extreme attention in providing more secure and reliable communication opportunities in the terrestrial environment and the same is been adapted in the underwater environment in order to increase the bit rate and efficiency of the present available systems. This short survey studies the specific uses of UVC in the terrestrial and underwater applications and identifies the future applications of UVC.

Keywords: Optical Wireless Communication, Terrestrial Communication, Underwater Communication, Ultraviolet Communication.

I. INTRODUCTION

Optical wireless communication systems (OWC), as one of the fastest growing industries in the world, has gained major importance in the field of research. Visible communication (VLC) has gained most attention as a popular OWC mechanism, yet development of VLC brought forth an important segment known as ultraviolet communication (UVC) [1]. Faster communication links were unachievable during the times where Xenon flashtubes and mercury lamps were the only UV light source available, and various advances occurred in the OWC and UVC fields within the past, with China and USA being pioneers [2].

The interaction of UV signals with atmosphere allows UVC a low-cost mode of communication and a less interception technology. The strong scattering and reflection ability of the UV signals enable them to bypass obstacles and the since the UV band has a solar-blind radiation, the system is capable to achieve higher performance through a low-transmitted power [1]. Application of UVC increased with its adaptability in the radio-silent scenarios as an alternative for wireless technologies, and thus, have become an advantage towards military grade communicational activities.

However, though UV channels show strong performance against meteorological conditions, it has strong channel attenuation which reduce the maximum achievable data rate and the rage of transmission of the signal. Thus, UVC has been characterized as requiring dense network configurations in its applications in non-line-of-sight (NLOS) optical transmission. Channel modeling through avoidance of atmospheric turbulence which can result in fluctuations of receiving power as well as scintillation attenuation effects has become a main issue and the single and multiple scattering models has been proposed on short range and middle to long range UVC respectively [3].

II. APPLICATION OF UVC

The initial studies on adaptation of UV-C spectrum to wireless communications dates back to the World War II, yet with complicated requirements being made in order to present an actual implementation, the applications have not been developed until much later. At present, UVC has been identified as applicable in both terrestrial and underwater environments.

A. Applications in the Terrestrial Environment

Terrestrial communication was mainly integrated with VLC in the past, yet the basic disadvantages that VLC showcased due to the strong influence that solar radiation had on its accuracy has created space for the development of UVC as a more suitable replacement. The current research studies on UV mainly focuses on its adaptability in the terrestrial links which assumes that both the transmitter and the receiver and locate on ground. The adaptability of FSO and UVC in military and civilian applications with lesser impact being curated through less noise generation has made its importance more higher and studies have focused on the development of more secure communication links between satellites due to the strong scattering of deep UV light in the air, especially with the strong absorption in the ozone layer [2].

Among the UVC systems that have been developed for use within terrestrial environments, mostly have been designed for short range distances and the limitations imposed by the transportation media as well as scattering effects such as Rayleigh has been identified in long-range communication channels [1].

The development in the UVC application in the terrestrial environment has been higher and performance enhancement mechanisms based on a number of techniques have been adapted, and the most studies mechanisms are presented in the table 1 below.

Table 1. Performance enhancement techniques in terrestrial UVC [1]

Technique	Advantages
Combination of MRC and ECG	Improve system BER Compensate for channel differences
Spatial diversity	Improved information rate within the system
Selective MRC	Captures mobility effect Ideal for typical transmission distances in indoor-environments
Beam reshaping	Improve intensity of received signal
Multiple input multiple output	Increase received signal power Reduce BER Reduce ISI

Present developments in the terrestrial UVC sector are focused on improving the distance and improving the quality of Tx and Rx signals. A most fundamental issue that terrestrial UVC faces is included with the noise associated in the entire transmission process [2].

B. *Applications in Underwater Environment*

Underwater communication has been mainly integrated with acoustic communication in the very beginning, and with further development underwater transmissions ranging through tens of kilometers with transmission rates of kilobits per second have been identified at the very beginning while at present it is capable to present a range of several kilometers at relatively low bit-rates. However, the limitedness of acoustic communication in presenting the required high-bandwidth has created a demand for better mechanisms with improved data capacities and RF technology emerged as a better solution [4]. With the recent developments undertaken in proposing wireless sensor networks underwater, with focus being based on unconventional factors such as soil properties. Yet, RF communications have also shown remarkable disadvantages since the higher attenuation within the underwater environments have required sacrificing of the transmission distance in the studies that were capable of maintaining higher data rates [4].

The propagation delays encountered in large transmission ranges due to the speed of sound underwater, alongside with Doppler effects and the hazards being caused to the marine environment has restricted the transmission levels and power levels [5]. The limited signal bandwidths achieved have considerable proven the systems to be much less effective and the attenuation has been shown to be higher within the water medium. Thus, the drawbacks of both acoustic and RF communication methods attracted UWC as a more suitable proposition, and the harsh environments have lesser effect.

When considering underwater FSO, it has been identified that it is capable to provide higher bandwidths with lower latency with a reduction in multipath effects [4].

III. Future Scope Of UVC

With the recent research work in the field of UVC, it is inevitably an advantageous addition towards the performance of the terrestrial communication and futuristic communication models can be expected via UVC-models. The requirements that are directly associated with the implementation of a standardized communication method. However, in the transmission and receiver-based channels still holds a number of significant issues which arises with the limited source power and the path loss as well [1]. More optimized pulse shaping is required to match the channel frequency and more improvements in beam shaping would provide considerable efficiency in energy transmission towards the receiver.

The nature of scattering needs to be considered and these improvements will provide much better opportunity to completely understand the transmission channel. With further improvements being made in the receiving end, UVC would provide an ability to extract a signal with less-noise. The optical background noise, device dark noise and the circuit thermal noises are to be considered when developing the Rx towards advanced demodulation [2].

However, the theoretical aspects of the study have been presented by various scholars yet the experimental studies are limited and the most accurate and practical models on UVC still remain unidentified [1]. Thus, the future scope of UVC needs to be more related towards experimental validation of the various models proposed and to gain comprehensive measurement analyses in the validation of the models in different environments and determining a solid model for practical use.

IV. Conclusion

When considering the future of communication, it is undeniable that further developments are essential in order to establish towards the future requirements in the social and industrial segments. The recent work in the UVC field has become an advantageous addition towards terrestrial communication but with the adaptions being made towards underwater communication, it has become an important segment in this area as well. Thus, the provision of a proper practical mechanism to further improve the transmission and receiving process in underwater transmission, it would be an important value-addition towards communicational sector.

References

[1] A. Vavoulas, H. G. Sandalidis, N. D. Chatzidiamantis, Z. Xu and G. K. Karagiannidis, "A Survey on Ultraviolet C-Band (UV-C) Communications," in IEEE Communications Surveys & Tutorials, Vol. 21, No. 3, Pp. 2111-2133, third-quarter 2019, doi: 10.1109/COMST.2019.2898946

[2] X. Ke and K. Dong, Ultraviolet Communication. In: Optical Wireless Communication. Optical Wireless Communication Theory and Technology. Springer, Singapore, 2022. https://doi.org/10.1007/978-981-19-0382-3_7

[3] L. Guo, Y. N. Guo, J. X. Wang and T. B. Wei, “Ultraviolet communication technique and its application,” in J. Semicond., Vol. 42, No.8, 2021, doi: 10.1088/1674-4926/42/8/081801.

[4] D. Kedar and S. Arnon, “Subsea ultraviolet solar-blind broadband free-space optics communication”, in Optical Engineering, Vol. 48, No. 4, April 2009.

[5] P. Wang and J. Gao, "Research on performance of marine UV communication," *2008 11th IEEE International Conference on Communication Technology*, 2008, pp. 371-374, doi: 10.1109/ICCT.2008.4716270.