Performance analysis of dual-hop underwater visible light communication system with receiver diversity

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Abstract. Visible light communication (VLC) has the ability to provide a high data rate up to Mbps in underwater environments for real-time communication systems. In underwater VLC (UWVLC), two major impairments are the turbulence-induced fading due to variation of salt and temperature of seawater and incremental path loss with distance due to absorption and scattering. We consider these two impairments and derive the closed form expressions for average symbol error probability (ASEP), asymptotic relative diversity order, and ergodic capacity for UWVLC dual-hop cooperative communication system. We consider multiple receiver branches with selection combining to combat the effect of fading. The impact of temperature on the fading parameters and system performance is highlighted. We conduct a comparative analysis of ASEP for four-pulse amplitude modulation and four-square quadrature amplitude modulation schemes and draw useful insights. We prove the accuracy of the derived analytical expression using Monte Carlo simulations. © *2021 Society of Photo-Optical Instrumentation Engineers (SPIE)* [DOI: 10.1117/1.OE.60.3.035111]

Keywords: underwater visible light communication; underwater turbulence; average symbol error rate probability; relative diversity order; ergodic capacity.

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1 Introduction

Recently, maritime activities, such as environmental monitoring, port security, oceanographic data collection, and tactical surveillance, have been expanding their scope. As a result, there is a growing demand for high-speed underwater wireless communication systems.[1,2] Acoustic underwater communication (UWC) has received attention in the last few decades because it can support a transmission range up to tens of kilometers. However, acoustic waves fail to support a high data rate.[3] Further, as the speed of the acoustic signal in water is quite low, there is a challenge of latency that needs to be dealt with. In addition, the acoustic band has a very small bandwidth, which makes it increasingly difficult to have high data rates in hundreds of Mbps.[4] Due to these limitations of acoustic communication, underwater visible light communication (UWVLC) is emerging as an envisioned alternative to acoustics communication. Optical wireless communication (OWC) has the capacity to dominate the market of underwater wireless communication due to its low latency. It has lately been applied to many underwater applications such as imaging and real-time video transmission, and the results have surely been encouraging.[1,2] The OWC supports information transmission in the wavelength range of 100 nm to 1 mm utilizing light sources such as light-emitting diodes and laser diodes.[5] The experimental results have shown that attenuation is minimum in the wavelength range of 520 to 560 nm for applications involving coastal water.[6] Looking at the current trends, the commercial market of underwater optical modems, which are currently available up to data rates of 500 Mbps, can be expected to grow at a fast rate.[5,7]

Underwater, the refractive index of the water varies with depth. This leads to abrupt changes in the average power received, thereby creating optical turbulence.[8,9] Further, the density of the water increases with depth in underwater. The density of seawater is inversely proportional to temperature and directly proportional to pressure and salinity. However, the effect of the pressure

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