Maritime Visible Light Communication with Sea Spectrum Models

Hyeongji Kim, Atul Sewaiwar and Yeon-Ho Chung

***Abstract*—-** This paper presents a Visible Light Communications (VLC) system concept in maritime environments to overcome the limitations of conventional maritime wireless communication. The proposed concept is a cost effective method of implementation using LED-based lighthouse and beacons. The transmission system presented for shore-to-sea communication considers unique properties of maritime environments where wave height, wind speed, etc. exist. Computer simulations are conducted based on the PM and JS spectrum models with various sea states for analysis. It is found that the JS model outperforms the PM model. The transmission distance of the proposed system is dependent upon the LED power and sea states. It is found to be approximately 1,000m for the sea state 6 of the JS model at a BER of 10^{-3}.

Keywords— Maritime communication, VLC, LEDs, e-Navigation, Pierson-Moskowitz model, JONSWAP model

I. Introduction

International Maritime Organization (IMO) developed e-Navigation for maritime safety and security [1]. It collects maritime data information electronically onboard and enhances berth to berth navigation and related services at sea [1]. Among those communication system projects, two exemplary systems are commonly considered: TRITON and WOP.

TRI-media Telematic Oceanographic Network (TRITON) based on IEEE 802.16 and IEEE 802.16e implemented a mesh network in Singapore for maritime communication using a ship, lighthouse and buoys as communication nodes with the objective to develop a system for high-speed and low-cost maritime communications in narrow water channels and shipping lanes close to the shore [2]. European Space Agency (ESA) also introduced Wired Ocean Project [3]. The intent of this project is to establish, on a commercial basis, cost-effective broadband IP-based communications services to ships. However, the cost is expensive with the use of VSATs.

Moreover, the current maritime wireless communications at sea mainly rely on satellite links that are relatively slow than HF, VHF and expensive Inmarsat. Like on land, sea users also need a high-speed, low-cost maritime wireless communication and special service (Mobile Telemedicine in maritime [4], Container Tracking [5], etc.). Therefore, new technology is needed to improve existing maritime communications.

In this paper, we propose a scheme to overcome the issues in maritime communication with visible light communication (VLC) termed as Maritime VLC (MVLC).

As a maritime network suffers from insufficient dedicated operation spectra, which is more likely in the future due to congested RF bands, VLC is a promising candidate with a vast spectrum, i.e. 10,000 times more than RF. Furthermore, the widespread use of visible light could provide necessary infrastructure, e.g. lighthouse and beacon. Thus, the VLC-based maritime wireless communication can be considered as an attractive technology. Maritime VLC system can support shore-to-ship, ship-to-ship communication without requiring the change of frequency channel.

The rest of this paper is organized as follows. Section II introduces the maritime VLC system together with channel model. Performance analysis and simulation results are presented in Section III. Finally, Section IV shows conclusions drawn from the investigation.

II. System Configuration

A. Concept of maritime VLC System

VLC is a communication method using LEDs, where blinking of a LED is used for communication and illumination simultaneously. LED communication offers innovative wireless technologies in terms of communication speed, flexibility, usability and security. LED's can be switched off and switched on faster than we can perceive. This on-off motion can be used to represent 0's and 1's, in other words, digital communication [6]. Unseen by the human eye, this variation is used to carry high -speed data, thereby creating wireless communication network using existing light resources in order to achieve low cost communication.

Maritime environment divides coast and offshore. We propose a VLC based maritime system that covers shore-to-sea communication services. Fig. 1 shows the proposed system in which communication coverage area can be increased at low-cost implementation. The mesh network is formed by neighbouring ships, marine beacons and buoys, and is connected to the terrestrial networks via VLC. The base station consists of power LEDs that provide coverage to a very large area, while sea transceivers (marine beacons, buoys, oil/gas platforms, sea farms) consist of an LED array and photo diodes.

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