Underwater Visible Light Communication

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Abstract- *In this paper, we investigate the performance of the proposed oceanic monitoring system that connects the oceanic life with the terrestrial life. For continuous real-time monitoring and ubiquitous coverage, the communication system is aided with a satellite link. Multiple sensor nodes (SN) are deployed at different water levels that collect sensor data and transmit it to underwater vehicles (UV) using underwater visible light communication(UVLC). The UVLC system provides higher data rates at lower latency as compared to existing radio frequency (RF) and acoustic wave alternative for underwater communication (UWC). The UWC system comprises of horizontal haul (HH) and vertical haul (VH) UVLC links modeled using turbulence induced fading.*

I. INTRODUCTION

Li-Fi is a derivative of optical wireless communications (OWC) technology, which uses light from light-emitting diodes (LEDs) as a medium to deliver network, mobile, high-speed communication in a similar manner to Wi-Fi. The Li-Fi market was projected to have a compound annual growth rate of 82% from 2013 to 2018 and to be worth over $6 billion per year by 2018. However, the market has not developed as such and Li-Fi remains with a niche market, mainly for technology evaluation. Visible light communications (VLC) works by switching the current to the LEDs off and on at a very high speed, too quick to be noticed by the human eye, thus, it does not present any flickering. Although Li-Fi LEDs would have to be kept on to transmit data, they could be dimmed to below human visibility while still emitting enough light to carry data. This is also a major bottleneck of the technology when based on the visible spectrum, as it is restricted to the illumination purpose and not ideally adjusted to a mobile communication purpose. Technologies that allows as roaming between various Li-Fi cells, also known as handover, may allow to seamless transition between Li-Fi. The light waves cannot penetrate walls which translates to a much shorter range, and a lower hacking potential, relative to plants without causing electromagnetic interference. Both Wi-Fi and Li-Fi transmit data over the electromagnetic spectrum, but whereas Wi-Fi utilizes radio waves, Li-Fi uses visible, ultraviolet, and infrared light. While the US Federal Communications Commission has warned of a potential spectrum crisis because Wi-Fi is close to full capacity, Li-Fi has almost no limitations on capacity. The visible light spectrum is 10,000 times larger than the entire radio frequency spectrum Researchers have reached data rates of over 224 Gbit/s, which was much faster than typical fast broadband in 2013. Li-Fi is expected to be ten times cheaper than Wi-Fi.[8] Short range, low reliability and high installation costs are the potential downsides. *PureLiFi* demonstrated the first commercially available Li-Fi system, the Li-1st, at the 2014 Mobile World Congress in Barcelona Bg-Fi is a Li-Fi system consisting of an application for a mobile device, and a simple consumer product, like an IoT (Internet of Things) device, with color sensor, microcontroller, and embedded software. Light from the mobile device display communicates to the color sensor on the consumer product, which converts the light into digital information. Light emitting diodes enable the consumer product to communicate synchronously with the mobile device.

II. SYSTEM MODEL

In this paper, we propose the analysis of an asymmetric satellite-UVLC system for two possible scenarios: 1) TWR based half duplex communication model, 2) Multihop relay based oceanic monitoring model. Figure 1, shows the composite functional system model for both the considered systems. The system comprises of a) SNs to collect various data of the marine ecosystems b) UVs i.e. augmented underwater SNs and communicate with the on-surface devices and c) FVs that are available on the surface of water consists of TWR based DF relay and RF transmitters to communicate directly with the satellite. Based on the turbulence strength, we have classified the UVLC link into two hauls namely horizontal haul (HH) linking terminals at the same water level and vertical haul (VH) linking terminals at different levels. The system description is given as below: 1)TWR based half duplex communication system: This system is proposed to serve the purpose of low latency communication between the submarines or divers and the outside world. The system will be working in half duplex mode using the TWR deployed on Wi-Fi. Direct line of sight is not necessary for Li-Fi to transmit a signal; light reflected off walls can achieve 70 Mbit/s. Li-Fi has the advantage of being useful in electromagnetic sensitive areas such as in aircraft cabins, hospitals and nuclear power the FVs. This is useful for transferring vital military information to the satellite and getting geographical coordinates from the satellites. The communication between the satellite and submarines is

established in two phases.In the first phase known as Mac phase both the terminals transmit their data to the relay. Further, at the relay node, the data is decoded and exclusive ORed (XOR) with each other. In the second step or the broadcast phase, the XORed data is broadcasted to both the terminals. The received data at each terminal is detected and XORed with transmitted data to retrieve back the data transmitted by the other terminal. 2) Multihop oceanic monitoring system: Figure 1, shows the deployment of SNs at different water levels in salty or freshwater bodies. The SNs gather various measurements and transmits it to the UVs because of the power limitations. The UVs collect data from the low power SNs and relay it to the FVs. The FVs then decodes the signal and re-transmits the received data from UVs to the satellite on RF carriers.

III. HARDWARE COMPONENTS

Power supply is a reference to a source of electrical power. A device or system that supplies electrical or other types of energy to an output load or group of loads is called a power supply unit or PSU. The term is most commonly applied to electrical energy supplies, less often to mechanical ones, and rarely to others. Transformers convert AC electricity from one voltage to another with little loss of power. Transformers work only with AC and this is one of the reasons why mains electricity is AC.Step-up transformers increase voltage, step-down transformers reduce voltage. Most power supplies use a step-down transformer to reduce the dangerously high mains voltage (230V in UK) to a safer low voltage. Arduino is an open-source prototyping platform based on easy-to-use hardware and software. Arduino boards are able to read inputs - light on a sensor, a finger on a button, or a Twitter message - and turn it into an output - activating a motor, turning on an LED, publishing something online.

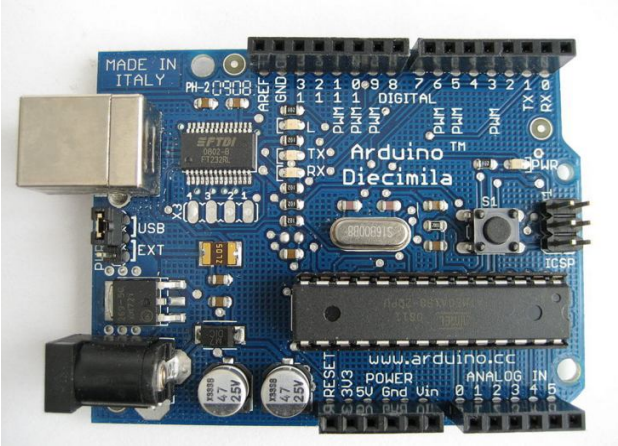

Fig 1 Aurdino module

LI-FI is transmission of data through illumination ,ie sending data through an LED light bulb that varies in intensity faster than human eye can follow

Baud rate of operation is 9600 Moderate sunlight will affect distance of reception. Trim pot on receiver board can be adjusted to increase the distance. Simple mode of working : Connect Tx of LIFI to Rx of TTL , Rx of LIFI to Tx of TTL Power supply 12v (5v regulator is on board)

Fig 2 Li-Fi module

IV. SOFTWARE UTILIZED

Embedded C is a set of language extensions for the C programming language by the C Standards Committee to address commonality issues that exist between C extensions for different embedded systems.

Embedded C programming typically requires nonstandard extensions to the C language in order to support enhanced microprocessor features such as fixed-point arithmetic, multiple distinct memory banks, and basic I/O operations. In 2008, the C Standards Committee extended the C language to address such capabilities by providing a common standard for all implementations to adhere to. It includes a number of features not available in normal C, such as fixed-point arithmetic, named address spaces and basic I/O hardware addressing. Embedded C uses most of the syntax and semantics of standard C, e.g., main() function, variable definition, datatype declaration, conditional statements (if, switch case), loops (while, for), functions, arrays and strings, structures and union, bit operations, macros, MATLAB (matrix laboratory) is a multi-paradigm numerical computing environment and proprietary programming language developed by Math Works. MATLAB allows matrix manipulations, plotting of functions and data, implementation of algorithms, creation of user interfaces, and interfacing with programs written in other languages. Although MATLAB is intended primarily for numerical computing, an optional toolbox uses the symbolic engine allowing access to symbolic computing abilities. An additional package, Simu link, adds graphical multi-domain simulation design for dynamic and embedded systems. As of 2018,

MATLAB has more than 3 million users worldwide. MATLAB users come from various backgrounds of engineering, science, and economics.

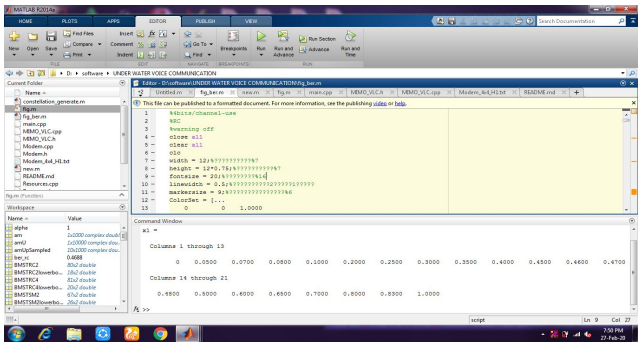

Fig 3 Matlab Coding

V. ANALYTICAL RESULTS

In this section, the analytical results of the proposed system are presented for various atmospheric and underwater scenarios. We have considered the thickness of each layer to be 10 m, thus the depth of 30 m and 40 m corresponds to three and four layers, respectively. The channel parameters for 4-cascaded layers are given as in [7] as (_j ; _j) = (4.59,2.82), (4.64,2.88), (4.70,2.96) and (4.77,3.05). The average SNR of RF link _s;fv is fixed at 30 dB. Figure 2 depicts the half duplex TWR system's outage probability versus average SNR of VH-UVLC link (_fv;uv) for varying elevation angles. The impact of elevation angle can be clearly observed as an increase in the angle leads to a better performance. This is due to the fact that the high elevation angles result in more favourable channel conditions with light shadowing. The results are iterated for varying depth and it is observed that

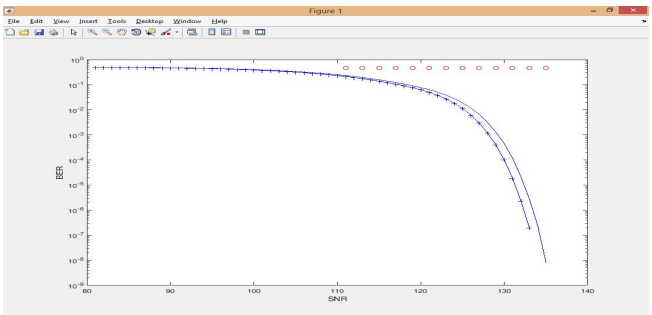

Fig 4 SNR VS BER

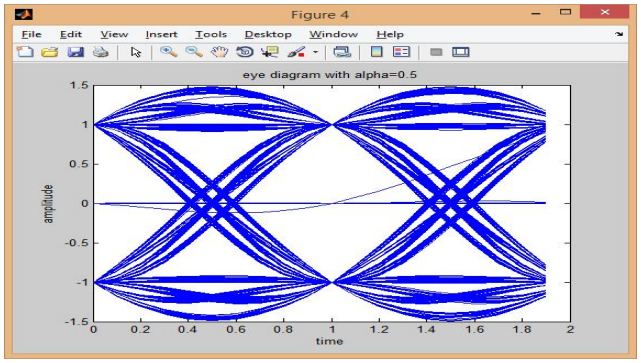

Fig 5 Eye Diagram

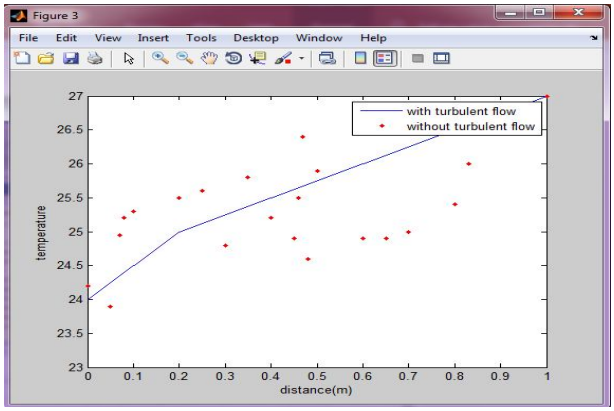

Fig 6 Temperature Vs Distance

the UVs available at lower depth are more probable of facing outage conditions. Figure 3 demonstrates the effect of oceanic depth on the underwater system performance for OOK modulation scheme. It can be observed that as the depth of deployment increases the probability of error ncreases. This is quite intuitive as increase in depth results in increase in turbulence strength owing to the multiplicative turbulence effect which results in error probability is far lesser as compared to lower elevation RF links. The low elevation angle leads to frequent heavy shadowing and thus weak satellite to FV link. This limits the performance of the system and can be improved either by increasing the transmitted power or by increasing Figure 6, demonstrates average BER versus average SNR of HH-UVLC link _sn;uv plots for triple hop VH UVLC – HH UVLC - RF system. The plot clearly demonstrates the effect of adding each link. The SNs are assumed to be deployed at a depth of 40m from the surface of water with channel parameter (_j ; _j) = (4.77,3.05) and UV available at the same depth. The average SNR _fv;uv and _s;fv are fixed at 30dB.

VI .CONCLUSION

In this paper, the novel asymmetric satellite - UVLC systemfor oceanic monitoring was proposed and its performance was analysed to prove its feasibility. The system performance was iterated for various underwater and

atmospheric conditions to study their corresponding effects. The proposed system can serve for collecting different data that can be used for detecting signs of tsunamis, monitoring water ecology, archaeological expeditions and surveying shipwrecks. The proposed system can also serve the submarines with secure link for data transfer and coordinates update. The UVLC system depends on line of sight link hence is prone to blockages by mobile aquatic animals thus future studies will include the effect of blocking on system performance. Further, the DF relay can be replaced by an energy and data buffer aided relay at the surface buoys that will make the proposed system a more greener.

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