Early Tsunami Forecasting Using Visible-Light LEDs for Sea-Level Measurement from the Seabed

Lih Chieh Png
VIRTUS, IC Design Centre of Excellence
Nanyang Technological University, School of Electrical and Electronic Engineering
Blk S2.1, South Spine, 50, Nanyang Avenue, S2.1-B2-20, Singapore 639798.
Email: lcpng@ntu.edu.sg, Tel: (65) 6592 1844, Fax: (65) 6316 4416.

Abstract—A sea-level measuring and detection system is proposed for application in the detection of seabed movements to forecast tsunamis. Target implementation objectives include flood control systems and ocean meteorology where LEDs will be installed on sea floors and river beds. Light intensity received is converted to the length of vertical displacement to reflect any rise or fall of the sea floor. Sea level and the amplitude of wave movements can also be measured using this method. The design of such a prototype is discussed.

I. INTRODUCTION

During the undersea megathrust earthquake in 2004 that hit landmasses bordering the Indian Ocean on Boxing Day, the sea floor is estimated to have risen by several metres, thus displacing 30 cubic kilometres of water and triggering devastating tsunami waves that took 230000 lives. Currently, the DART (Deep-ocean Assessment and Reporting of Tsunamis) system is used to predict tsunamis around the world [1]. The system consists of a bottom pressure recorder (BPR) and a tagged detection buoy on the surface of the ocean. Sea pressure is converted to surface height between the ocean surface and ocean floor. The BPR and the buoy are linked by acoustic communication. There are 39 such stations globally. These DART systems and the Tsunami Warning Centers (TWCs) are connected by the iridium commercial satellite which enables a two-way communication.

Acoustic communication [2] is used because RF communication works badly in thick electrical conductors like sea (or salt) water. Another way to detect sea level with respect to vertical shifts of the ocean floor is to install a high-brightness LED array farm on the seabed. Any passing vessel or docking harbour with a relative optical detector will be able to determine the sea level based on the Beer-Lambert-Bouguer Law (BLB) [3]. Besides that, these LEDs also act as an underwater lighthouse for passing ships. Position information can be sent by the LEDs to these ships and even low-flying aircrafts.

The advantage of using LEDs is that it has a long lifetime. This makes them suitable for installation in places that are difficult to reach and where maintenance are not so regular. The deepest trench in the world, located along the Mariana Trench, is about 11 km deep. The average depth of the Pacific Ocean is around 4.28 km. Thus it is not impossible to have an LED farm planted at the base of ocean floors and the light detected above sea level. The LED farm can just draw its power from any coastal wind farm. Since LEDs are energy saving and specially-designed lenses can be used, they do not require high electrical power.

II. OPERATIONAL THEORY: BEER’S LAW

Basically, the intensity of light decreases as it passes through water. The sea level can be computed by the BLB Law:

\[
\ln (I_0/I) = 0.015d
\]

where \( I \) is the intensity of light at the depth of \( d \); \( I_0 \) is the intensity of light in the atmosphere; and 0.015 is the exponential slopes of the UV and/or visible light absorption spectra of the Indian Ocean [4].

Tsunamis are also called shallow water waves since their wavelengths \( L \) are greater than the water depth \( D \). We use this principle of nature to acquire the velocity \( v \) of a tsunami and eventually determine the time it takes to reach a certain place [1]. First, by installing the LED farm on the seabed near the fault line (Fig. 1), the detector on the buoy is able to mark the change in the height of the seabed \( \delta d \) during an underwater earthquake. The equations are given in (2)-(5).

\[
\delta d = d_2 - d_1
\]
\[
L = d_1 + 2
\]
\[
D = L/20
\]
\[
v = \sqrt{g \cdot D}
\]

\( g \) is the acceleration of gravity and \( D \) is the real depth.

III. PROPOSED DESIGN OF THE Prototype

A cluster of white LEDs is installed at the base of an aquarium tank connected to a transmitter driver circuit. The LED board is vertically adjustable. A mobile water-proof receiver with high-sensitivity photodiodes is connected to an Infineon microcontroller which is linked to the PC. The microcontroller is programmed and configured according to the pathlength versus light intensity received. The tank is filled with seawater. Fig. 2 shows the diagram of the prototype.
A. Receiver Circuit

The receiver (Fig. 3) consists of a luminosity sensor which is connected to Infineon’s XMC4500 microcontroller. Programming is done on the XMC4500 to convert illuminance (lux) to depth (cm). The real-time depth readings will be reflected on the PC which is connected to the XMC4500. The receiver can be fixed or floating. A fixed receiver measures the change of height vertically, while a floating receiver imitates the DART detection buoy which is effective in measuring height as well as wave amplitude.

IV. Conclusion

The prototype is a viable and economical demonstration of the possibility of measuring sea depth by installing LEDs at the base of river beds, seabeds, or ocean floors. All measurements will be relative to the seabed such that a global tsunami alert may be sent if there is an abrupt plate shift along the trenches.

REFERENCES