Hemispherical Optical Dome for Underwater Communication

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INTRODUCTION

NASA is developing technology that could enable autonomous underwater drones, studying Earth’s oceans and those on icy moons like Jupiter’s Europa, to transmit a large volume of image and video data to a receiver at the surface via optical wireless communications. Such an optical system requires a wide field-of-view in order for a moving transmitter to be detected by a stationary receiver (Figure 1). For this purpose, we have designed, developed, and tested an optical hemispherical dome, employing multiple focusing lenses and housing an array of photodiodes at the focal plane. This design achieves a wider optical field-of-view for the underwater communication system.

A light beam/pulse propagating through aquatic media suffers from attenuation and spreading in the spatial, angular, temporal and polarization domains. The attenuation and spreading are wavelength dependent and result from absorption and multiple scattering of light by water molecules and by marine hydrosols (mineral and organic matter). Figure 2 shows blue and green wavelength are least attenuated by water.

METHODS

The dome structure was designed using PTC’s Creo CAD software and then a prototype was built with a 6-inch diameter transparent camera dome. Holes were cut in the camera dome using a 5-axis mill cut holes and were retrofitted with 2-inch diameter lenses (Figure 3).

The lens configuration has been modeled using Synopsys’ CODE V optical design software. Each lens has a focal length of 75 mm and clear aperture of 50.8 mm. The model was used to optimize the LED position in the focal plane with respect to dome at a distance of 300 mm (Figure 4).

RESULTS

Underwater optical communication follows a general line-of-sight communication, assuming a straight and unobstructed path of communication between the transmitter and receiver. The power reaching receiver is obtained from

\[ P_{R,LOS} = \frac{P_T \eta_T \eta_R L_{pp}}{(\lambda d \cos(\theta))^2} \frac{A_{Rec} \cos(\theta)}{2\pi d (1 - \cos(\theta))} \]

Where \( P_T \) is average transmitted optical power, \( \eta_T \) is the optical efficiency of the transmitter, \( \eta_R \) is the optical efficiency of the receiver, \( d \) is perpendicular distance between transmitter and receiver, \( \theta \) is the angle between the perpendicular to the receiver plane and transmitter – receiver trajectory, \( \theta_b \) is beam divergence angle, and \( A_{Rec} \) is receiver aperture area. Figure 6 shows the power recorded at the receiver (photodiode) under different scenarios. The red line shows power received by 3 photodiodes with wide field of view.

CONCLUSIONS

An optical dome for underwater optical wireless communication was designed and tested, that contains 6 lenses for the detection of light from a moving transmitter by 3 photodiodes positioned at the focal plane of the lenses. In this design, we achieved an increased power at the detector while widening the field of view. This is important since the dome allows the photodiodes to detect the light when the source is located off of the optical axis. The performance of the system could be improved by increasing the number of lenses on the dome and replacing the individual photodiodes with a planar array of photodiodes.

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REFERENCES