Study, design and realization of a communication system for untethered underwater vehicles

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This master thesis aims to design and realize a high-speed communication system for untethered underwater devices fulfilling three criteria : 1) Providing a short range, up to 50 m, untethered transmission system from the ROV or AUV to the receiver; 2) Having a data rate in the Mbps range suitable for the transmission of multimedia contents; 3) Having a limited cost in order to be more accessible than existing devices with a total BOM price under 1,000.00 EUR. After an evaluation of the technical approaches of the transmission system and the underwater environment, an optical communication system was specified. Then the design and various components of the final system were evaluated, selected, crafted and tested. The objectives were met, though additional testing to validate the maximum range of the system is required.

ABSTRACT

This master thesis was to find a way of creating an innovative, high-speed communication system for underwater devices that would be easy to develop, more accessible and less impeded by the restrictions caused by tethered systems.

In fact, an assessment of the market shows that no existing solution provides both a highly reliable transmission system for critical operations and a data rate sufficient for multimedia content transmission at an affordable cost. Therefore, developing such a comprehensive system offers new perspectives for underwater exploration.

To implement such a system, various steps were necessary, including an evaluation of the technical approaches of the transmission system in order to overcome the disadvantages often raised. This led to the choice of developping an optical communication system in this Master thesis. Though its common limitation, such as stability issues in an unstable environment, still had to be overcome thought the careful selection appropriate choice of the various components for the final design.

First, through a review of of Underwater Optical Communication Systems presenting critical considerations to take into account when designing the system for this thesis. On this basis, such a design was elaborated, and components selected for the optical emitter and receiver. For the modulation system, Differential Pulse Interval Modulation (DPIM) was selected and for the emitter light source, high powered LEDS were preferred (ED GD CSSRM3.14-AJAM-24-1-700-R33) whereas a Silicon Photomultiplier (SiPM) was chosen for the light sensors of the receiver (more specifically, the SiPM J-series 60003). This was amplified using the classical Op-Amp amplification stages. Lastly, a comparator was employed to distinguish between high and low levels based on the presence or absence of a pulse.

These elements were evaluated and relevant variables regarding their performance (amplification stages, output currents, the impact of sunlight, electrical bandwidth of the LED, etc.), use and placement on in the system were discussed and determined. A simulation was afterwards realised, both for the emitter and the receiver, before elaborating the PCB boards and crafting the UWOCS.

Thus designed, the UWOCS was tested and the results of this experiments were discussed in regards to the objectives of this thesis.

Firstly, the objective to develop a short-range, untethered transmission system between the ROV or AUV operating up to 50 meters to the receiver can be considered as mainly achieved. In fact, The test results indicate that the implemented system operates effectively over various distances. The oscilloscope displayed a consistent signal, although as the distance increased, the eye diagram began to show minor perturbations. These became more noticeable at the largest range, though remaining sufficiently insignificant to perturb the signal quality. It therefore seems that the system should be able to perform effectively at a 50m range. However, further testing taking into account the observations made, notably that the received power was likely underestimated.

The second objective sought to obtain a data rate within the Mbps range that could transmit multimedia content. By relying on the 8-DPIM modulation scheme, this aim was reached, theoretically but also, first, throughout the various tests which demonstrated clear signal transmission across different symbols, and then the FFT which proved the demarcation between the different symbols and their corresponding fundamental frequencies.

The third objective of this thesis was limit the Bill of Materials cost for the development of an UWOCS under €,1000. The cost breakdown assert that this last objective was also successfully met. Nevertheless, the significant cost of the optical filter could be further optimized in the future.

The research realized throughout this thesis presented as elaborated some limitations as previously highlighted. Nevertheless, its objectives can be considered as globally successfully me, its results can judged as promising and provides opportunities for further developments. As first expressed in our introduction, the oceans still hold many mysteries that humanity awaits to discover. The type of advances proposed by this thesis, and the subsequent development of such projects, will hopefully make it possible to facilitate communication in underwater exploration and, by the same token, our knowledge of the deep and its secrets.