Omnidirectional Surface Vehicle for Evaluating Underwater Acoustic Communication Performance in Confined Space

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ABSTRACT

This paper presents an omnidirectional surface vehicle (OSV) developed for evaluating underwater acoustic communication performance in confined water space. The OSV features centimeter-level positioning accuracy, onboard waveform probing and generation, omnidirectional maneuverability, and outstanding safety. The preliminary experimental results have successfully demonstrated the basic functionalities of this acoustic communication testbed.

KEYWORDS

Underwater acoustic communication, omnidirectional surface vehicle

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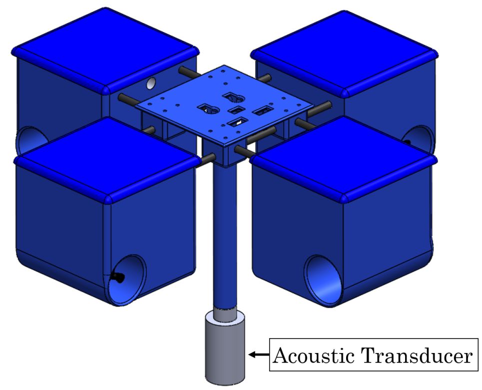

Figure 1: Omnidirectional surface vehicle that supports acoustic communication experiments in confined environments.

1 INTRODUCTION

Underwater communication is usually a mandatory requirement for autonomous underwater vehicles (AUVs) to transmit data without surfacing [8]. Among the existing communication methods, acoustic communication is a proven technology and is the only practical approach for long-range data transmission underwater [3, 7]. As miniaturization is a major technology trend in AUVs [2], there have been a few recent projects on developing, integrating, and testing acoustic communication devices for micro AUVs (μAUVs) [6, 8, 11]. In contrast to large-sized AUVs, many application scenarios of μAUVs require the robot to operate in confined environments, where there is typically more interference to acoustic communication. Moreover, μAUVs are usually more maneuverable than large-sized underwater vehicles [11], which may induce additional motion-related disturbances to the acoustic channel.

Acoustic communication incorporates sound waves to transmit data at long distance [1]. Knowing the potential disturbances of sound propagation is crucial to ensure the performance and reliability of underwater acoustic communication. There are a few recent works on evaluating the performance of acoustic communication for μAUVs. However, most existing experiments such as [6, 8], were conducted when the μAUV is stationary during transmission or receiving. Our previous work [11] evaluated the acoustic communication performance while the μAUV is either stationary or moving. However, since localization is a shared challenge among underwater robots [12], the moving transmission test only involved simple trajectories in controlled pool environment [11].

An omnidirectional surface vehicle has significantly fewer limitations on localization, and features outstanding maneuverability [10]. We extend our previous efforts on OSV development [10] towards an efficient testbed for evaluating acoustic communication performance in confined environments. The vehicle is equipped with two real-time kinematic (RTK) localization receivers for centimeter-level positioning and accurate heading measurement. The OSV is capable of logging and generating waveforms with sampling rate up to 100MSPS. Given the center frequency of most acoustic modems are relatively low (e.g., 10 kHz) [4, 9], most signals inside the modem can be probed by the OSV for analysis. With long-range WiFi connectivity, the OSV can be conveniently operated, and the probed waveforms can be viewed in real time. The symmetric over-actuated design provides adequate maneuverability to accurately follow complex trajectories designed for moving transmission tests.

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2 ACOUSTIC MODEM INTEGRATION

Fig. 2 illustrates the integration and signal probing of the acoustic modem [5]. The modem communicates with the onboard computer via serial interface. Data packets are directly sent to the modem for transmission and vice versa. Internal waveform inside the modem can be probed by the data acquisition system onboard the OSV. Signals at different circuit nodes can be logged simultaneously by utilizing multiple acquisition channels. Moreover, the onboard waveform generator allows the modem to send any arbitrarily defined waveshape.

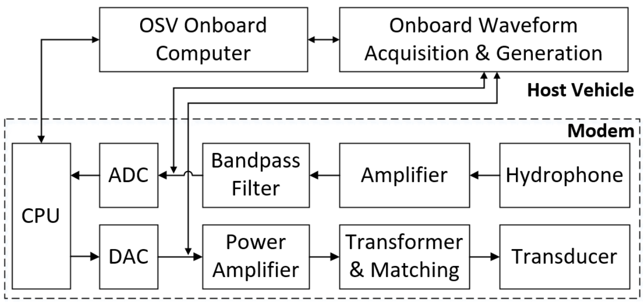

Figure 2: Block diagram of onboard waveform probing.

3 PRELIMINARY EXPERIMENTAL RESULTS

As shown in Fig. 3, a preliminary experiment was conducted to verify the basic functionalities of the OSV as an acoustic communication testbed. The OSV was hovering at around 116m from the deck in a small lake. Total of 20 messages were sent from the OSV to the basestation and vice versa. During each transmission, raw analog signals were sampled at both transmitter (TX) and receiver (RX) ends. One of the acquisitions is demonstrated in Fig. 4.

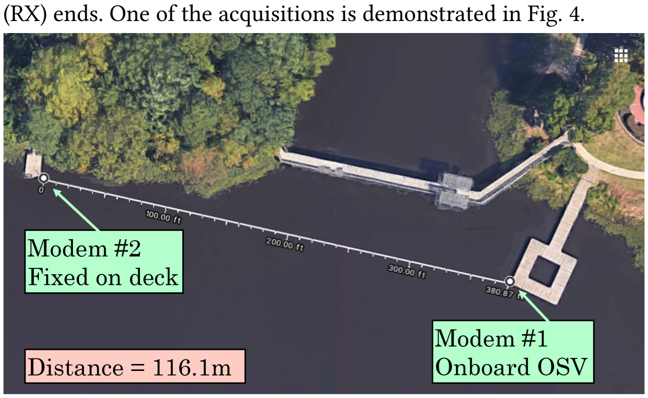

Figure 3: Experimental setup in lake environment.

4 CONCLUSION AND FUTURE WORK

This paper presents an omnidirectional surface vehicle for purpose of facilitating acoustic communication experiments in confined environments. Features including centimeter-level localization, omnidirectional maneuverability, and onboard waveform acquisition and generation are overviewed. Results of the lake test demonstrate the basic functionalities of this acoustic communication testbed.

We plan to add autonomy to the OSV to automate the experiment procedures. Additional experiments will be conducted to examine the impact of motion on acoustic communication in both pool and lake environments. Data and waveform collected from the planned experiments will be analyzed and discussed.

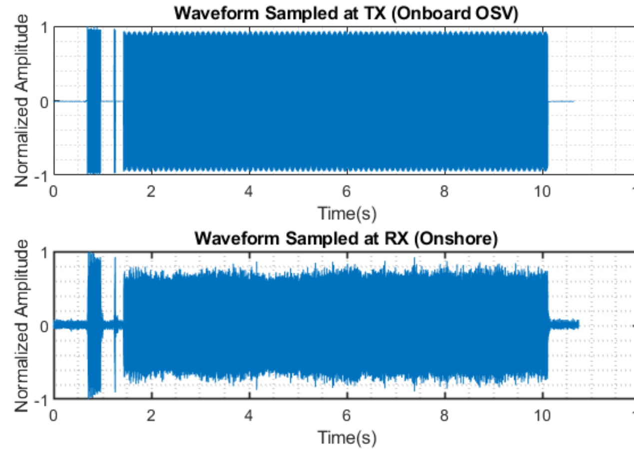

Figure 4: Probed waveform while OSV is sending message.

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REFERENCES

[1] Ian F. Akyildiz, Dario Pompili, and Tommaso Melodia. 2005. Underwater acoustic sensor networks: research challenges. *Ad Hoc Networks* 3, 3 (2005), 257 – 279.
[2] Lukas Brun. 2012. ROV/AUV Trends: Market and Technology. *Marine Technology Reporter* 5, 7 (2012), 48–51.
[3] Xianhui Che, Ian Wells, Gordon Dickers, Paul Kear, and Xiaochun Gong. 2010. Re-evaluation of RF electromagnetic communication in underwater sensor networks. *IEEE Communications Magazine* 48, 12 (December 2010), 143–151.
[4] Lee Freitag, Matthew Grund, Sandipa Singh, James Partan, Peter Koski, and Keenan Ball. 2005. The WHOI micro-modem: an acoustic communications and navigation system for multiple platforms. In *Proceedings of OCEANS 2005 MTS/IEEE*. 1086–1092 Vol. 2.
[5] Weihua Jiang, Feng Tong, and Yuehai Zhou. 2016. R&D of an Spread Spectrum Acoustic Communication Modem with Ranging Capability. In *Proceedings of the 11th ACM International Conference on Underwater Networks & Systems (WUWNet '16)*. ACM, New York, NY, USA.
[6] Benjamin Meyer, Cedric Isokeit, Erik Maehle, and Burkard Baschek. 2017. Using small swarm-capable AUVs for submesoscale eddy measurements in the Baltic Sea. In *OCEANS 2017; Anchorage*. 1–5.
[7] Jim Partan, Jim Kurose, and Brian Neil Levine. 2007. A Survey of Practical Issues in Underwater Networks. *SIGMOBILE Mob. Comput. Commun. Rev.* 11, 4 (Oct. 2007), 23–33.
[8] Christian Renner and Alexander J. Golkowski. 2016. Acoustic Modem for Micro AUVs: Design and Practical Evaluation. In *Proceedings of the 11th ACM International Conference on Underwater Networks & Systems (WUWNet '16)*. ACM, New York, NY, USA, Article 2, 8 pages.
[9] Milica Stojanovic. 2015. *Underwater Acoustic Communication*. John Wiley & Sons, Inc, 1–12.
[10] Qiuyang Tao, Kuo Huang, Chang Qin, Bo Guo, Robin Lam, and Fumin Zhang. 2018. Omnidirectional Surface Vehicle for Fish Cage Inspection. In *OCEANS 2018 MTS/IEEE Charleston*. 1–6.
[11] Qiuyang Tao, Yuehai Zhou, Feng Tong, Aijun Song, and Fumin Zhang. 2018. Evaluating acoustic communication performance of micro autonomous underwater vehicles in confined spaces. *Frontiers of Information Technology & Electronic Engineering* 19, 8 (01 Aug 2018), 1013–1023.
[12] Fumin Zhang, Giacomo Marani, Ryan N. Smith, and Hyun T. Choi. 2015. Future Trends in Marine Robotics. *IEEE Robotics Automation Magazine* 22, 1 (March 2015), 14–122.