

Acoustic communication for Maya Autonomous Underwater Vehicle - performance evaluation of acoustic modem.

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Abstract- Autonomous underwater vehicles (AUV) traverse considerable distances underwater without any intervention. Very often the operations are in coastal waters with small depth, large horizontal distances, seabed obstacles, fishing activities and surface traffic. This necessitates monitoring the AUV status and data quality through an acoustic link which needs to perform reliably under such conditions, at long range.

To address these situations partially, acoustic communication capability is planned for CSIR-NIO AUV Maya using acoustic modem communicator pair. Experiments were planned and field demonstrations of the same carried out at Dona Paula bay (5-7 m depth) and Arabian sea (15 -20 m) to gauge the performance under actual field conditions simulating two scenarios of AUV communication.

The results are presented here which allows the inference, of using these modems on Maya AUV's, even in shallow coastal waters.

Key Words: *Autonomous Underwater Vehicle, Maya, acoustic modem*

I. INTRODUCTION

Autonomous underwater vehicles are oceanographers surveying tool used from shallow to deep parts of the ocean. National Institute of Oceanography, Goa, India have developed Maya AUV [1] for coastal oceanographic applications and is shown in Figure 1.



Figure 1. Maya AUV in Arabian sea.

With the sensor combination used on Maya, these applications vary from biological,

physical to chemical oceanography domains. The features of Maya AUV are shown in Table 1.

Table 1. Maya AUV features

Endurance	6 hours @ 1m/sec	~ 21 KM
Navigations	GPS, DVL, AHRS	Way point, Path following
Communication	RF, Satellite Modem	Line of sight, Blue Water
Sensors	CTD, DO, PAR, Chlorophyll-a, camera,	Oceanography, EIA
Safety	Depth cutoff, Mission timeout Positive buoyancy	Prevents loss of Maya

Maya has been used in fresh water lakes, river and coastal waters to a maximum depth of 41 M off Candolim, Goa, India. For current and future usage it has been felt that an acoustic communication channel will be very useful to keep a track of the AUV status, possibly including underwater position and if required alter mission parameters. The data to be transmitted would normally have the complete AUV status, its current position, latest scientific sensor and other parameter data. Such data would be generally in packets ranging from a few kilobytes to tens of kilobytes depending on the mission planned.

Any AUV moving underwater with real time acoustic connection to the surface craft would require sufficiently high duplex data transmission baud rates in the range of several kilobytes per second with range capacity of over 5 to 10 kilometers. Such long ranges in sea are very difficult to achieve due to many factors, notably signal loss and spreading and has not been done so far. For normal connectivity between AUV and the surface controller a reliable communication channel is an acoustic link. This will allow exchanges of control and commands from the surface controller and data from the AUV.

For these tasks to be performed it is essential that an acoustic modem be installed with good range capability and reasonably high communication bandwidth. An elaborate literature survey indicated that EvoLogics acoustic modem [4] and EvoLogics USBL with communication capability [5] would meet the requirements. Though the primary requirement is communication, this pair was chosen keeping in mind the future requirements of underwater positioning. These

modems are shown in Figure 2a and 2b respectively.



Figure 2a. EvoLogics modem



Figure 2b. Modem with USBL unit.

To ensure that these acoustic modems can be used effectively on autonomous underwater vehicle, they need to be subjected to tests in conditions similar to actual scenario/s. Further they need to transfer some information effectively using the full bandwidth. Another important aspect is the data reliability during transmission and reception over intended distances. The problems associated with acoustic communication are very severe especially when the navigation occurs in shallow coastal waters. Here the communication channel is bounded by seabed which effects the transmission characteristics. Further the ranges are very slant and this can cause the acoustic energy to encounter temperature inversion. This introduces further noise into the acoustic signals degrading data quality. Intelligent algorithms can be embedded into the modem pairs to ensure optimum data fidelity over desired ranges. This would involve dynamic changes in transmission power, data baud rates, directivity and other factors that can be tweaked to get better performance at maximum range.

Multiple in-situ tests were planned and carried out to test the above modems for their reliability and efficacy.

II. EXPERIMENT SCENARIOS AND SETUP

The field evaluation was planned with different setups and conditions in mind. These resemble closely to actual AUV operation in shallow waters. The first location was selected inside Zuari estuary which is a closed environment on one side with shallow depth ranging from 5 to 7 meter. The other side of the estuary is open ocean with increasing depths. The second location chosen

is open water off Aguada bay. These geographical locations are shown in Figure 3a and 3b. Both are close to the institute and are logistically easy to access. This enables easy installation and deployment of the modems in the field.



Figure 3a: Zuari estuary bay, Dona Paula, Goa (Courtesy Google Maps)

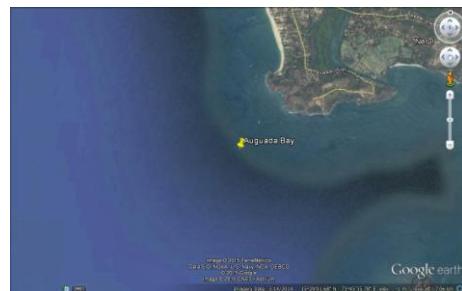


Figure 3b: Aguada open sea area. (Courtesy Google Maps)

In the first experiment in Zuari bay, the USBL/ acoustic modem was fixed at the Dona Paula jetty at a depth of 1.5M vertically resulting in horizontal communication plane. The responding modem was mounted vertically on a pole at a depth of 1.5M fixed to the side of a fibre boat and away from the propeller. A RTK GPS antenna was integrated to give high accuracy position with time. Further a Chlorophyll-a sensor was integrated with the laptop to acquire data for transmission through the acoustic modem. This was mainly done to assess the capability of data transmission of the modem over sustained times.

In the second set-up open ocean area opposite Aguada bay, Panjim, Goa, India was chosen. Two boats were used to mount the modem and USBL/modem. Acoustic modem with GPS, chlorophyll sensor and PC was installed on one boat while the modem/USBL receiver were mounted on the second boat. One boat was allowed to stand at one position while the other boat was used as rover similar to an AUV. The rover boat was used like an AUV.

III. EXPERIMENT I

The first experiment in Zuari bay, the USBL /modem was fixed on the pole mounted on the jetty. The same is shown in Figure 4.



Fig 4a. Dona Paula jetty

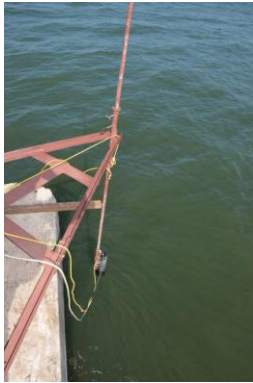


Fig. 4. USBL modem mounted at the jetty.

The location of jetty was determined using the DGPS system available. The RTK DGPS system, installed on the rover boat fed accurate position data for logging along with Chl-a data from the sensor. Water depth at the jetty was 4.5 M and the USBL modem was deployed to a depth of 1.5 M. The plane of the modem was oriented towards the Zuari bay in the direction of the river mouth. In the experiment the boat was moved away from the jetty at very slow speed in the order of 1 to 1.5 m/s similar to the speeds achievable by Maya AUV. Chlorophyll-a data was acquired, merged with the DGPS position data. This string was being transmitted to the USBL modem at the jetty. This received the data along with the range and bearing information which was continuously received was logged on a local laptop for analysis.

IV. EXPERIMENT II

The second experiment was aimed at checking the modem capability in the open ocean, at depths from 15 to 20 M, opposite Aguada fort, Goa. The area is shown in Figure 3b. These depths were selected more due to logistic reasons. Two boats were used for installing with one boat hosting the USBL modem for navigation and communication while the other boat was fitted with the communicating modem. Two trials were undertaken. In the first trial the USBL boat was stopped at a location and drifting and the other boat was moved away into the deeper water. In the second trial both boats were moved relative to each other to check for the response in terms of data communication, similar to from AUV to the mother

vessel. Both the modems were configured to send 1 byte arbitrary with ACK mode. This method allows the determination of range and bearing of the remote modem.

V. RESULTS

In **experiment I** tracking of the mobile/remote modem was undertaken. The data continuously transmitted was logged and displayed using the SiNAPS software from EvoLogics. XYZ coordinate system with antenna at the centre of the local reference frame was used with coordinates given in meters. Every position information received from the USBL was merged and compared with the raw RTK DGPS position. The position data from acoustic modem was unfiltered. This comparison allows to determine the accuracy of the USBL system in comparison to the DGPS positions. The data obtained and compared is shown in Figure 5.

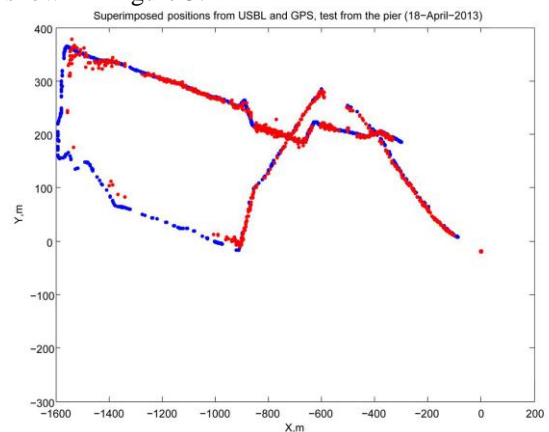


Figure 5: Superimposed boat (red) and RTK DGPS (blue) positions

Additionally payload data, that is chlorophyll data, string was sent to the modem. This in turn send the combined string to the target USBL modem by using the instant messaging technique embedded in the modem firmware. This allowed to receive the payload data as well as navigation data. The data received was plotted and is shown in Figure 6.

It is seen that when range is less than 1300 m, the angular error was typically under 0.12° . Sometimes it was as high as 0.39° . The range error was mostly under 0.1% of the total range even when the range was more that 1300 and to a maximum detected distance of 1650 M. But the angular error in the higher range was 0.22° and sometimes 0.67° .

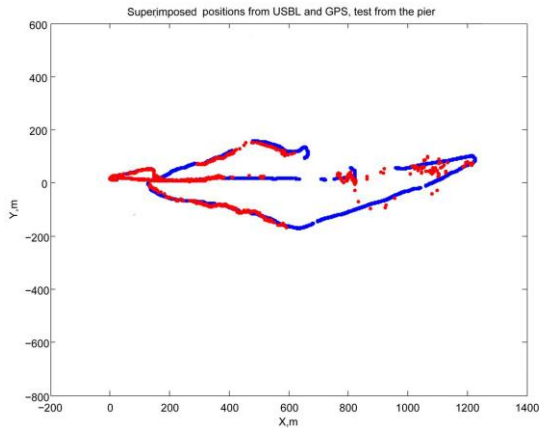


Figure 6. Position matching during payload data transmission.

In the second setup the position accuracies were same but the transmission rates for , communication + positioning data, were varying as a result of the water mass characteristics. This is a very useful capability of the modem to deliver data even at extreme detectable ranges.

In **experiment II**, where in the payload chlorophyll data was transmitted between two moving trawlers a maximum horizontal range of about 2100 meter was obtained. This was despite the abrupt sound velocity profile resulting in additional reflecting boundary and multiple bottom scattering of the acoustic signal.

Payload data and navigation was plotted together to verify the position accuracy. As there was no AHRS, the angular error was of the order of 3.8° . With a built in AHRS or with external AHRS data the angular accuracy can be improved considerably. The result of these experiment is shown in Figure 7. It shows the positioning results obtained when integrated with payload data.

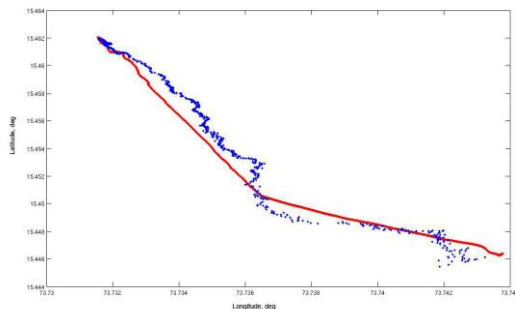


Figure 7. Position matching with payload data transmission in experiment II in open sea. (RTK GPS red and USBL position blue) (Without AHRS)

When the modem was lowered to depth more than 10 meter the communication was received to a maximum of 800 M. This is but to be

expected due to the sound velocity profile during this season off the coast of Goa.

Further the data rate over the ranges was analysed. It was estimated that below 1100 meters, the update rate was upto 0.9 Hz, but when range increased beyond these progressively fell to 0.2Hz at 2100M. In intermediate ranges it improved a bit but can be attributed to prevailing sound velocity structure. [6]

VI. CONCLUSION

With the multiple experimental setup and data acquisition, it was found that in very shallow coastal waters, Zuari Bay, these modems have very good angular accuracy and range accuracy, and data update rates. In open shallow waters such as off Aguada the range improves and the data update rate is quite good. However the angular accuracy was inferior but this can be easily tied to the non-availability of a quality AHRS data. This implies that for Maya AUV these modems are very suitable with good quality AHRS installed onboard the AUV.

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