3-D Forward Look and Forward Scan Sonar Systems

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LONG-TERM-GOALS

The long term goals this project is to develop high resolution, forward looking sonar systems that can be used in AOSN class AUV's for navigation, obstacle avoidance, and target location, identification and classification. To enhance the classification of targets, one of the forward looking sonar systems being developed generates 3-D images of the insonified targets.

OBJECTIVES

The objectives as defined over the two years of the project had the overall aim to transition the sonar systems to AOSN AUV deployment. These objectives can be summarized as follows:

(a) Develop the technology required to integrate the Forward Scan (FS) and 3-D Forward Look (FL) sonar systems in the general operation of an OE class UUV.
(b) Develop smaller processing and data acquisition units with low power consumption to allow the deployment of the sonars on a UUV of the Ocean Explorer class.
(c) Transition the existing processing software to faster processors to achieve near real time processing of the FS data and generate real time images.
(d) Develop the analysis and processing required to extract structural acoustic characteristics of the target from the scattering signal. This will be performed on a simple structure such as a spherical shell.

APPROACH

To address the main objectives of this project, the approach followed has two main tasks. The fundamental task deals with the continuation tests of the operation of the two sonar systems using the available sonar transducer hardware and data acquisition and processing components. The second task in the approach deals with the development of new data acquisition and data processing hardware to deploy the sonar systems on an AOSN class AUV.

The tasks to be performed were thus as follows, all of these tasks were under the responsibility of Joe Cuschieri and Lester LeBlanc.
(a) Complete shakedown tests for the FS sonar in the FAU test tank.
(b) Mount the FS on a bottom-mounted frame and check at sea operations.
(c) Mount the FS system on a towed platform and obtain dynamic images of the sea floor.

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(d) Complete tank tests on the 3-D FL sonar.
(e) Mount 3-D FL on a stationary bottom mounted frame and check at sea operations.
(f) Develop a data acquisition board with low power consumption and sufficiently compact to fit in an OE class AUV.
(g) Transition the processing software to a more current data processing hardware.
(h) Develop numerical models for the structural acoustic scattering from simple spherical targets, in the frequency range of operation of the sonars in this project.

WORK COMPLETED

Tank tests have been completed for both the FS sonar and the 3-D FL sonar. Stationary at sea tests have been completed for the FS, while the stationary at sea tests for the 3-D FL sonar are scheduled in the next few days.

The tow body tests for the FS sonar have been completed and images processed using the SKYBOLT processing hardware.

The numerical modeling of the structural acoustics scattering from a spherical shell using the FS sonar (Most critical feature is the operating frequency) have been completed and a M.S. Thesis has been completed.

The design of the new data acquisition system is nearly completed and a two-channel prototype, using evaluation boards is completed. The final design is based on a PCI bus interface to make the board useful to many other projects. The layout of the complete board is nearly finished and the PC board should go to fabrication before the end of the month of October.

The data processing algorithms have been transitioned from the SKYBOLT's to an 18 SHARC PCI board. As a result of this transition, up to 3 frames per second of the FS sonar data can be processed. For the 3-D FL sonar, with this set-up, a full 3-D image can be processed every 40 seconds. On the PC PCI bus, there is room for a second PCI board with 18 SHARC processors. Once implemented with the two SHARC processor boards, real time (data processed at the same rate as it is being received) images can be processed for the FS sonar, and for the 3-D FL sonar, an image can be generated every 20 seconds.

RESULTS

The FS sonar hardware has been in use over the last two years of work. The emphasis in the last two years was in developing the hardware for performing sea trials. For most of the year the sea trials had to be performed using a surface ship, since the data acquisition, processing and display hardware are at present too bulky to deploy on the AUV. The tests performed can be classified into two categories. In one instance the FS sonar system was mounted on a stationary frame resting in about 6 meters of water and data collected using the surface ship which contained the acquisition, processing and display hardware. This approach provides for a very stable platform to mount the FS sonar system and perform an overall check of the system. The tests were performed in an area where there is an old shipwreck. A typical result of these measurements is shown in figure 1. From the sonar image one can clearly see the hull of the wreck resting on the sandy bottom and some steel piling in front of the sonar.

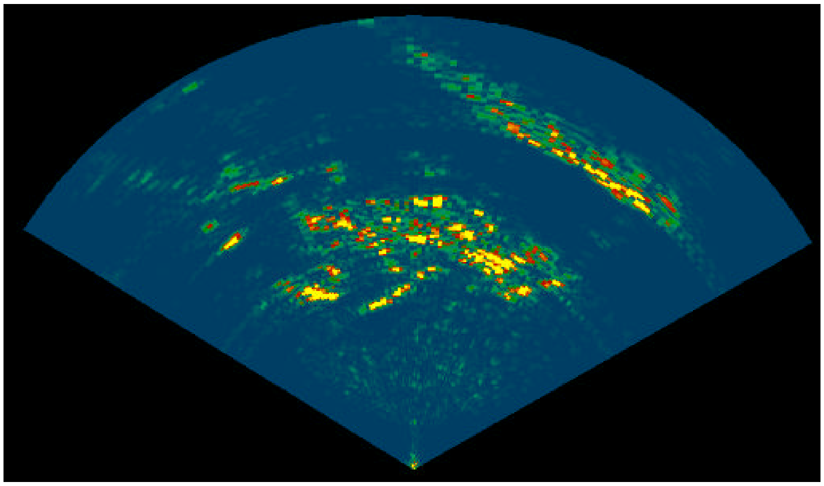
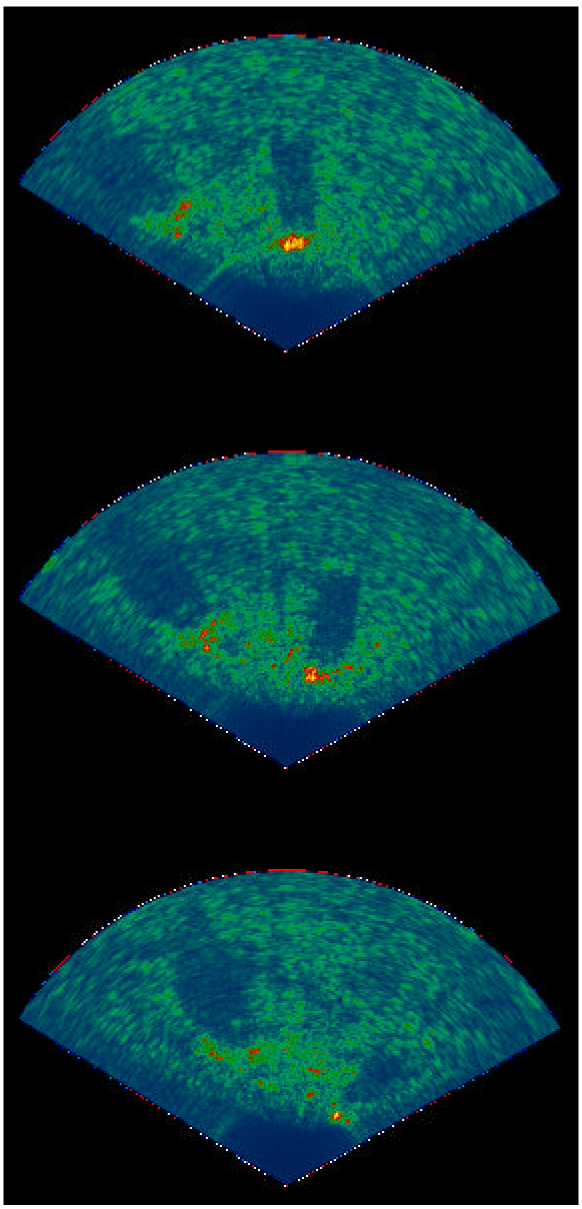


Figure 1. FS sonar image deployed using bottom mounted stationary platform.



The second type of measurements had the FS sonar towed on a sled. In this case as well, the acquisition, processing and display hardware were located on the surface ship. Some results from these tow sea trails are shown in figure 2 as a sequence of three typical images. A movie of this data is available on the Ocean Engineering FAU web site.

The 3-D FL sonar system as received from the vendor needed extensive modifications to the projector hardware. The projector electronics had some stability problems within the EEPROMS that stored the XILINX program for the generation of the pseudo random signal. The data in the EEPROMS were getting corrupted. This was attributed to unstable clock signals on the motherboard that holds the individual microprocessor modules that drive each element of the projector. The redesign of these motherboards has been completed and the system is back in the test tank and the results of the test tank are good. The system is scheduled to go to sea trails within the next few days. The same approach will be used as was used for the FS sonar, namely that the sonar will be mounted on a frame in some 20 meters of water to ensure stability of the sonar, will be used. Figure 3 shows two typical profiles of the FAU test tank, where the bottom and far wall of the tank can be clearly seen.

Figure 2. Sequence of three FS images when mounted on a tow vehicle

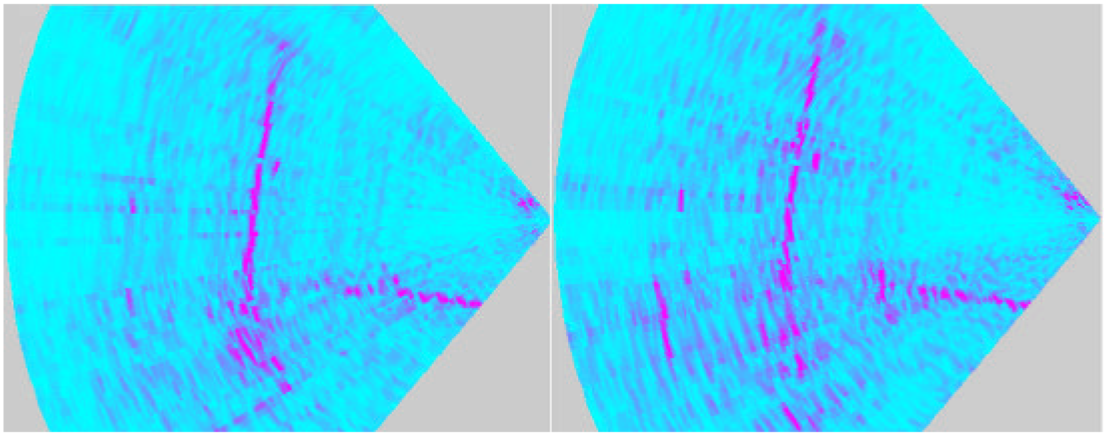


Figure 3. Two typical profiles of the test tank generated by the 3-D FL sonar.

Good progress is being made on the design and fabrication of the new data acquisition board. The basic design of the new system consists of a Pentium based motherboard with a PCI bus, which will have 4 PCI cards each with 16 data acquisition channels. The A/D's selected for the design are Delta Sigma units, which have an upper cut-off frequency of approximately 500 KHz. The Delta Sigma A/D's contain digital FIR anti-aliasing filters that have a very sharp cut off at the high frequency end which eliminates the need for external anti-aliasing filters and any differential phase errors associated with analogue components. A pair of A/D's connect to, and are controlled by a DSP processor (TI C54) that performs the band filtering and decimation on the digitized data. The narrow band sonar data, at a maximum has only a 20% bandwidth. Thus, to minimize the data volume rates that need to be transferred to the data processing unit, the data rates across the bus from the data acquisition to the data processing can be decimated by up to five times. The purpose of the DSP's is to perform the digital filtering and decimation and thus reduce the data transfer bandwidth required through the PCI bus to the processing board. The data from the eight DSP's are then placed on a local bus and a programmable logic device (PLD) takes care of routing the data from all DSP's (8 total per board) over to the PCI interface. The PCI interface was selected since this will give maximum flexibility in the design. Four of these cards will be utilized to achieve the required 64 data acquisition channels. The four cards will reside in a five PCI slot Pentium motherboard. All the programming to control the cards is being developed in house. Figure 4 shows a photograph of the prototype two channels, build using evaluation boards for the DSP and the A/D chips.

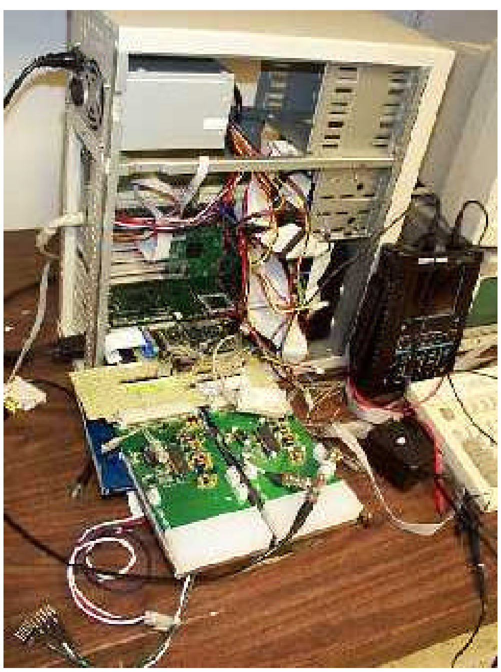


Figure 4. 2 channel prototype of data acquisition system.

For the processing, a single data processing board that resides on the PCI Pentium motherboard, has been selected. It is an ALEX Computer Systems Inc. board that has 18 SHARC processors. Transferring the processing algorithms was rather straight forward, however, tailoring the processing software to squeeze as much out of the processing hardware so as to push the frame rate up as much as possible was not as trivial. This is because of the way that the SHARC processors handle the data I/O. A methodology has been identified that will allow processing of one frame of the FS sonar data every 280ms. With this approach, three frames per second for the FS sonar are possible and with some further improvements it is conceivable to get the target four frames per second (processing time per frame to be less than 250ms).

With the data acquisition system soon to be completed, and the processing transitioned to the new processing hardware, the design of an AUV payload to hold the FS sonar has been started, and is scheduled for completion by the end of this year. Figure (5) shows the payload for the FS sonar together with the aft portion of the AUV.

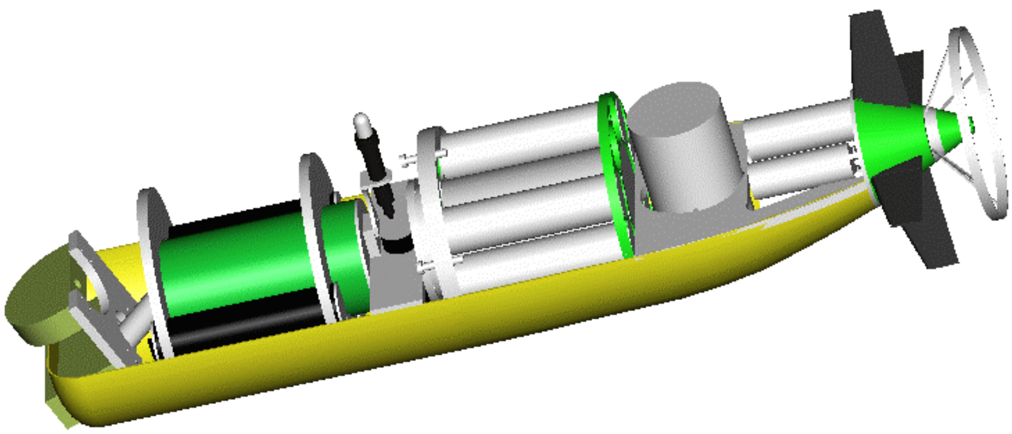


Figure 5. FS sonar payload and OE class AUV

IMPACT/APPLICATIONS

This project should have multiple impacts on future ocean science and system applications.

The PCI base-band data acquisition board with the high phase accuracy between channels will have a significant impact on other sonar development work. This data acquisition board is unique and any band-limited sonar, such as the ACOMS, would benefit from the availability of this board. This board can significantly improve most ongoing and future sonar systems with its low power consumption (less than 20 watts per board of 16 data acquisition channels), basebanding capabilities and high phase accuracy within the channels of a single board and across multiple boards.

Both the FS and 3-D FL sonars are unique and can provide high-resolution images for target locating, classification and identification. The 3-D FL sonar further provides 3-D renditions of submerged targets that can improve target classification and reduce false alarm rate.

The integration of structural acoustics information with the imaging data can further decrease the likelihood of false identification. In this project it has been demonstrated that even at the highest frequency of operation of 250 KHz, there are structural acoustics characteristics that can be used to identify targets and improve target classification.

TRANSITIONS

At present, the results of the work in this project are not being utilized in other work. However, as soon as the FS sonar AUV payload is completed at the end of this year, at sea experiments will be conducted in conjunction with other ONR funded AOSN projects, (mainly collaboration with Dr. S. Smith of FAU). Additionally, the data acquisition board will become an integral part of the ONR funded ACOMS system (Dr. LeBlanc - FAU). Finally, requests have already been received for the use of the data acquisition board in other ONR funded projects.

RELATED PROJECTS

Related projects are the projects in AOSN AUV development program currently under way at FAU under the direction of Dr. S. Smith.

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Web Sites:
http://jmc.oe.fau.edu/~joe/sonar.html/ - Sample FS and 3-D FL sonar images.
http://oe.fau.edu/www.oe.fau.edu/~acoustics/ - Overview of sonar systems.