Chirp Sonar Software for Development for Multiple Chirp Processing, Sediment Classification and Data Quality Control

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Contract Number N00014-01-C-0203
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LONG TERM GOALS

The long term research objective is to develop a cost effective technique for remotely predicting sediment properties using normal incidence acoustics.

OBJECTIVES

1. To develop software that will provide Florida Atlantic University's chirp sonar with enhanced sediment classification capability including simultaneous generation of 1) high resolution normal incidence reflection data for sediment classification, and 2) low frequency, high energy normal incidence reflection data for deep geological imaging.

2. In addition, software will be added to predict sediment velocity and to automatically calibrate the sonar. This software will be used by the FAU chirp sonar during the mine burial prediction, geologic clutter and ASIAEX experiments sponsored by ONR.

APPROACH

Software operating in FAU's chirp sonar system is being modified to provide the following capabilities:

1. Alternating transmission of different FM pulse sets to provide two simultaneous data sets, a low frequency data set providing imagery with deep penetration and a wideband data set useful for sediment classification

2. Measurement of the compressional wave velocity of the top sediment layer

3. Automated calculation of matched filters during sonar calibration

Transmitting multiple pulse sets provides the chirp sonar with the capability of generating reflection profiles in different frequency bands so that a low frequency, high energy acoustic record with deep subsurface penetration can be acquired simultaneously with a wideband, low energy acoustic record, a requirement for sediment property prediction. For example, a 4 msec long FM pulse with a bandwidth of 1-40 kHz is transmitted during one transmission event followed by a 40 msec long FM pulse with a band of 1-4kHz which is transmitted during the next transmission event, thereby generating a deep penetration, low resolution image of the top 100 meters of sediment for determining geologic structure

and a high resolution wideband image pulse for detailed imaging of the top 5 meters of the seabed and sediment classification. The 40 msec pulse has 10 times the energy of the 4 msec pulse. Each transmission event may require driving up to 3 transducers simultaneously with a set of 3 transmission pulses since three transducers may be required to cover the full band of a given transmission event. Each transmission event will require a unique matched filter for each receiver channel. The software will calculate matched filters for at least 2 receiver channels for each pulse set. This will provide the sonar ability of simultaneously using different receiving array size or using two line arrays with a horizontal offset for acoustic velocity measurements.

The compressional wave velocity of the top sediment layer can be measured using the travel time differences for the normal incidence echo and the oblique incidence echos measured using three arrays mounted across the vehicle with along track spacing of 2 meters. The travel time differences along with simultaneous measurements of vehicle pitch and roll will be used to calculate water speed and sediment sound speed for the top layer. A history of reflector travel times will be used to measure seabed and reflector slopes which are needed by the velocity prediction algorithm.

Due to the complexity of using multiple pulse sets, hydrophone arrays and projectors, an automated calibration procedure is needed to calculate the pilot signal for each projector and the matched filter associated with each hydrophone array/ pulse set combination. During the calibration procedure, the sonar measures the system characteristic function by transmitting FM pulses at the air water interface. The pulses are formed by acoustically summed the outputs of the bandlimited projectors each driven with an FM pulse that corresponds to the band of the projector. The matched filter of each sonar channel is adjusted so that the frequency spectrum of the interface reflection is white.

Dr. Schock supervises the research program including graduate and undergraduate students and at sea experiments. Jim Wulf is the lead electrical engineer who designs, fabricates and tests sonar modifications and attends at sea experiments.

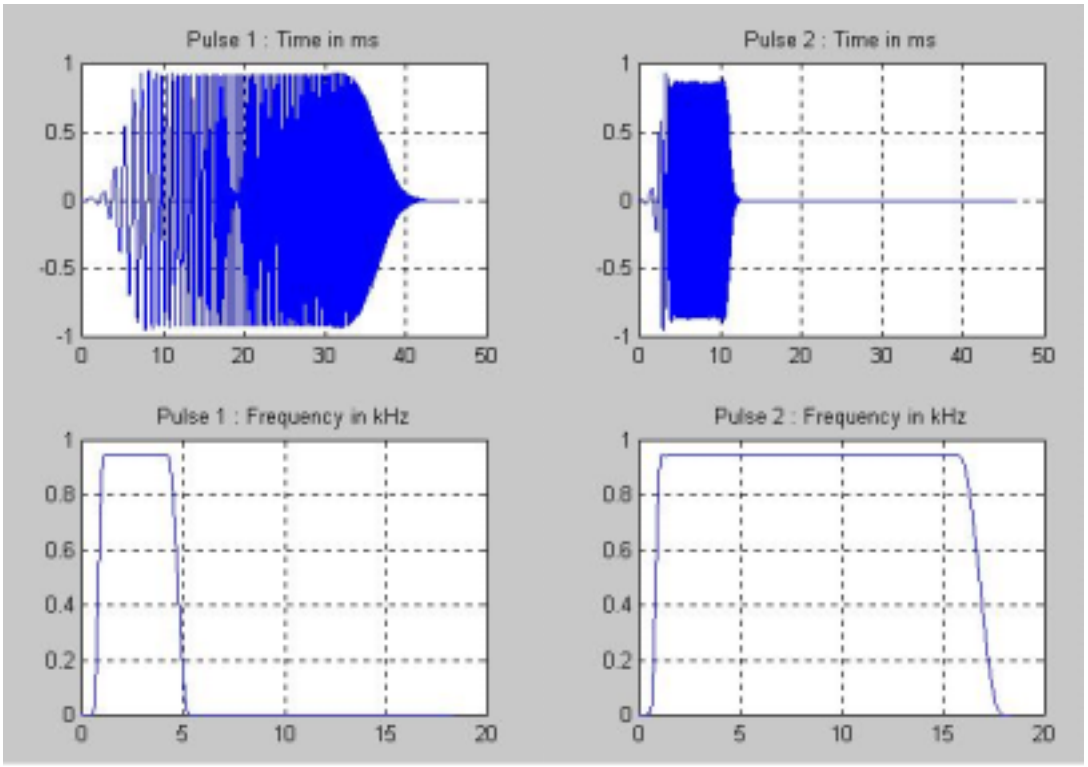
WORK COMPLETED

The chirp sonar modifications enabling multiple pulse transmissions and automated system calibration were completed and tested during the August to September 2001 Geoclutter experiment off New Jersey. During that experiment 40 msec 1.5-4 kHz FM and 10 msec 1.5-15 kHz FM pulses were sequentially transmitted to generate 2 simultaneous data sets. The 40 msec pulse was used to map buried rivers channels formed during the low stands associated with last two ice ages. The subsurface penetration in the sandy sediments was about 30 meters. The 10 msec provided a detailed image of the top 5 to 10 meters of the seabed and a wideband data set for sediment property prediction.

Hardware modifications of the sonar vehicle for measuring acoustic velocity were completed and tested. Software was modified to allow collection of reflection data from 3 line hydrophone arrays in addition to the main planar hydrophone array. During the Geoclutter experiment 3 channels of acoustic data were simultaneously collected on the 3 line arrays that had an along track spacing of 2 meters. The reflection data was recorded with vehicle motion data while the vehicle was towed about 10 meters above the seabed. The data is being used by Florida Atlantic University to refine algorithms for measuring acoustic sediment velocity in real time.

RESULTS

The most significant result for the past year was the addition of the multiple pulse set capability to the chirp sonar. During the New Jersey Geoclutter experiment the alternating FM pulses shown in Figure 1 were used to simultaneously collect two data sets, one for geologic imaging and one for sediment property prediction. The vertical resolution of the 40 msec 1.5-4 kHz pulse was about 30 cm while the resolution of the 10 msec 1.5-15 kHz pulse was approximately 5 cm.



Example of a dual pulse sonar chirp. Sonar alternates between a low frequency long pulse (Pulse 1) and a wide bandwith short pulse (Pulse 2).

Figure 1. Time (msec) and frequency (kHz) domains of FM pulses sequentially transmitted during Geoclutter experiment off New Jersey.
[The spectrum of the 40 msec pulse is flat over the band of 1.5 to 4 kHz. The spectrum of the 10 msec pulse is flat over the band of 1.5 to 15 kHz]

IMPACT/APPLICATIONS

The software being developed under this contract will allow remote prediction of acoustic sediment velocity with the chirp sonar and will allow simultaneous collection of bandband data for sediment property prediction and low frequency data for deeper geologic imaging.

TRANSITIONS

The software developed under this contract is being used by Florida Atlantic University to support chirp sonar and sediment property prediction research.

RELATED PROJECTS

"Remote Sediment Property Estimation From Chirp Data Collected During Geoclutter Experiment," ONR G&G Grant to Florida Atlantic University. The Geoclutter Experiment provided the means of testing multiple pulse set software and collecting data sets for developing remote sediment velocity estimation procedures.