NPAL Acoustic Coherence and Broadband Full Field Processing

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LONG TERM GOALS

The long term goals are i) to measure and model the horizontal and vertical coherence of the array data from the North Pacific Acoustic Laboratory (NPAL) and ii) to specify stochastic models for representing these data foe inclusion in broadband passive sonar processing algorithms.

OBJECTIVES

Noise fields in most sonar models are characterized nonparametrically wherein the noise coherence matrix for an array of sensors is estimated across frequency with no constraints imposed upon it by the propagation physics. Arrays are now becoming so large that is difficult to estimate this coherence matrix reliably because of the constraints of nonstationarity. [1] In many environments shipping is a dominant component of the noise field and it does not take much source-receiver motion to introduce variability and nonstationarity in the noise field. The motion induced variability is much larger than that caused by natural processes such as surface or internal waves. The ambient field is simply not stationary long enough to be well characterized nonparametrically. An approach to mitigating this problem is to substitute *a priori* models for some components of the noise field such as the ones generated by strong, directional sources from shipping. Moreover, the effects of motion are induced across the band which can provide additional constraints if one can incorporate them in a robust way. The fundamental problem is the stochastic nature of the propagation introduces variablity, so signals from a directional source cannot be simply characterized by running a deterministic propagation code. My objective is determine robust models for directional sources using using data from the NPAL arrays and to evaluate their utility for sonar array processing algorithms.

APPROACH

The NPAL array was deployed in July 1998 off Pt. Sur, CA. It has five vertical arrays, four with an aperture of 650 m and one of 1300 m. The positions of the sensors are determined by an AEL (acoustic element location) system. The internal recording is set to capture signals from the ATOC source in Kauai from transmissions over a 20 minute interval which could occur every 4 hours. Since the source transmits only episodically because of constraints imposed by marine mammal issues, most of the recordings are of ambient noise. The arrays are located near one of the main shipping channels

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off the California coast and the preliminary data analysis from “pop up” capsules indicate that the data is rich with discrete sources characterized by spectra with strong tonals.

Our approach is to i) scan the 20 minute recordings to assess the overall ambient noise level; ii) isolate the discretes in those recordings with high ambient noise levels; iii) remove the motion effects of the VLA’s to compensate for receiver doppler spreading; iv) determine the rank of spatial covariance of these components across the individual VLA’s and the full set of VLA’s if the precision of the AEL permits. Plane wave and modal beamforming in the vertical is also done to analyze the vertical structure of the signals from each discrete.

WORK COMPLETED

The NPAL arrays were recovered this summer. The various data components i) array recordings, ii) engineering data and iii) AEL times are now being downloaded. Currently, we are working jointly with SIO, UW and WHOI to work up the AEL tracking data so compensate for receiver doppler and use them for covariance estimates and high resolution beamforming. The AEL for a single array will probably be relatively easy; however, obtaining 1/10 wavelength resolution (2 m at the 75 Hz center frequency of the ATOC source) across an aperture of 3600 m will be very challenging.

Until now we used data from the “pop up” capsules. These data suggest a highly variable noise field which is rich in both shipping and natural noise sources. We have determined sonograms and done preliminary beamforming based upon a nominally vertical array for all the “pop up” recordings. They data are generally excellent although there are intermittent drop outs whose cause remains uncertain.

We have also completed work on “stochastic modeling” of signals based using the RAM PE code to propagate signals through an ensemble of oceans with Garrett-Munk perturbations. These simulations support our concept of a stochastic model for noise sources in order to provide more robust sonar array processing algorithms, especially for nulling. The concept here differs from the approaches of Tappert and Dozier [2,3] who were concerned with modal coupling or Colosi [4] who considered the time spread statistics. We focus upon the covariance of the signal at a VLA as the source receiver range increases in order to span the signal space. The work completed to date indicates a “red” spectrum for the eigenvalues and a propagating structure for the eigenvectors.

RESULTS

The data from the “pop up” capsules has already revealed some interesting results regarding the ambient field. Figure 1 indicates a sonogram on five of the channels from the 1300 m VLA. (The sensors are positioned from bottom to top in the figure.) One can observe two low frequency events in the early part of the recordings. These are characteristic of the T phase of a small earthquake. In addition, one can observe several tonals in all the sonograms indicative of shipping.

The vertical components contributing to this field suggested by beamforming across 5 Hz bands. (This smears the discretes since this 5 Hz bandwidth is much larger any tonal component.) The low band centered from 15 - 20 Hz is dominated by the earthquake events and is centered at low grazing angles suggesting it coupled into the sound channel at long range. The high band centered from 50 – 55 Hz has power concentrated at high angles and relatively little at low grazing angles. This is a nice illustration of the “noise notch.”

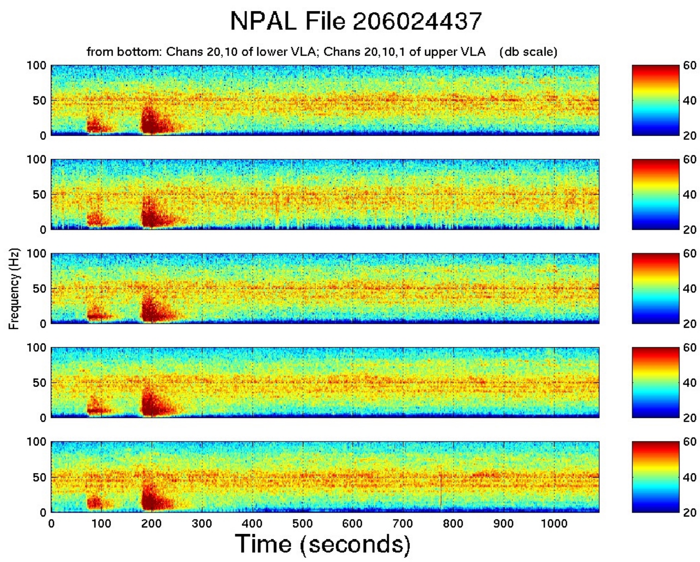

Figure 1: Sonograms from five VLA hydrophones indicating earthquake events and shipping discretes

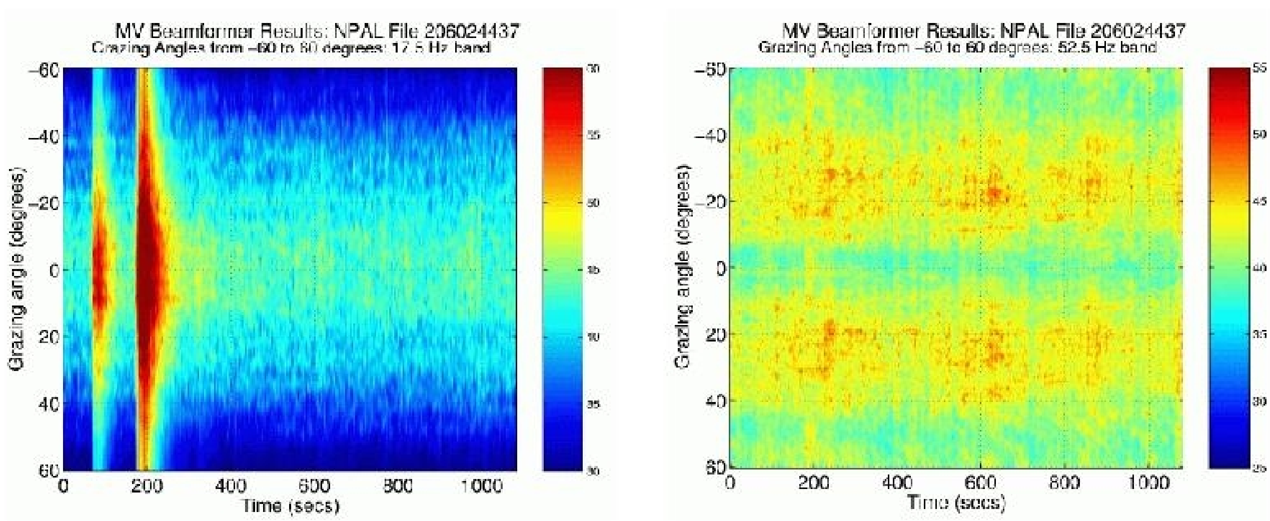

Figure 2: Beamformer output from the 1300 VLA: left: 15 – 20 Hz band indicating earthquake T phase: right: 50 – 55 Hz band with noise notch at high grazing angles.

IMPACT/APPLICATIONS

The impact of more robust signal models based upon recorded data and supported by models is one of the most important issues in improving the performance of large aperture arrays for both passive and active sonar. The rank of covariances for an ambient field and its coupling to the non-stationarity of the environment dominates much of the design of adaptive algorithms now being used for submarine sonars. More efficient characterizations which exploits the constraints of the propagation medium should improve the performance of these sonars.

RELATED PROJECTS

1) Acoustic Observatory Working Group: The effort was chartered by ONR in 1998 to examine the concept of an "acoustic observatory." The results of our initial effort were briefed to ONR – DARPA – OPNAV/N87 in December 1998. After a hiatus of several months ONR commissioned a second phase wherein we are to focus on littoral environments and make recommendations regarding the i) the design and location of an observatory, ii) assess candidate array processing methods and their potential gain, iii) establish a first order estimate of the costs. The effort is run by ONR Code 32 with John Zittel (OPNAV/N84) and Arthur Baggeroer as cochairs.
2) Santa Barbara Channel Experiment (SBCX): We have participated in the DARPA sponsored Santa Barbara Channel Experiment since its execution in April 1998. This experiment has tested MFP beyond all previous ones and identified many of the issues which need to be addressed in any operational use of MFP. We designed many of the transmitted waveforms and assisted in the field program. Now, we are processing the data in conjunction with SAIC (Peter Mikhalevsky), Orincon (Harry Cox) and MIT Lincoln Laboratory (Lisa Zurk). We are next looking beyond to determine how *a priori* information such as the position of discrete shipping sources of noise might be used in adaptive processing algorithms. Our recent work on stochastic MFP suggests one approach especially for robust nulling. The program is run by CAPT John Polcari, TTO DARPA.
3) Review of the State of the Acoustic Telemetry and Constraining Adaption Dimensions for Acoustic Telemetry Systems: This is an ONR project which recently summarized the state of the acoustic telemetry (in press: *Journal of Oceanic Engineering,* January 2000) and to improve the performance of adaptive systems by minimizing the number of degrees of freedom, such as taps, by exploiting constraints imposed by the propagation. The grant is administered by Dr. Tom Curtin, ONR Code 322.
4) Submarine Superiority Technical Advisory Group (SSTAG): This panel is commissioned by OPNAV/N87 to assess the capability of sonars and their performance compared to other systems. It also review the APB (Advanced Processor Build)-NN experiments and results. Several working groups involved with various signal processing group issues operate under the SSTAG. The PI went to sea last year on the SSN Augusta in order to obtain a better operational understanding of the performance of the passive sonars developed under the APB program. The SSTAG is run by Jim Griffin, OPNAV/N87.
5) Geoacoustic Clutter: This is a nascent ONR effort whose focus is to better understand the role of buried geologic features and how they contribute to clutter in active sonar systems. The program is run by ONR Code 32, Drs. Jeff Simmens and Joe Kravitz.

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