NPAL Acoustic Noise Field Coherence and Broadband Full Field Processing

Arthur B. Baggeroer
Massachusetts Institute of Technology
Cambridge, MA 02139
Phone: 617 253 4336 Fax: 617 253 2350 Email: abb@boreas.mit.edu

Henrik Schmidt
Massachusetts Institute of Technology
Cambridge, MA 02139
Phone: 617 253 5727 Fax: 617 253 2350 Email: henrik@keel.mit.edu

Edward K. Scheer
Woods Hole Oceanographic Institution
Woods Hole, MA 02543
Phone: 508 289 2823 Fax: 508 457 2194 Email: escheer@whoi.edu

Award Number: N00014-98-1-0274
http://acoustics.mit.edu

LONG TERM GOALS

The long term objective is to understand the characteristics of ambient noise to provide better models i) the distribution of their source mechanisms and ii) to provide better models to support advanced sonar array processing algorithms.

OBJECTIVES

The objectives are i) to characterize the ambient noise field coherence for the data recorded on the North Pacific Acoustic Laboratory (NPAL) and ii) to apply broadband, full field processing to characterize the sources in the local environment. Coherence measurements based upon field data are fundamental to understanding how the various sources of the ambient noise superimpose and lead to both the observed spectral covariances and to the performance of advanced array processing algorithms such as matched field processing.. The data from the NPAL vertical line arrays (VLA's) are broadband and have an accurate array element positioning system, so we examining the potential for broadband, full field processing.

APPROACH

Our approach this year has focused upon two issues: i) examining the heterogeneity of the statistics of the NPAL data set and ii) source localization using broadband methods. The statistics are done for each NPAL transmission where the mean square noise level for the full band (10 – 100 Hz), and the bands (10 – 20, 20 – 40 and 40 –80 Hz) are calculated. The presumes a stationarity over the 20 minutes of the transmission which we know from earlier analyses often is not a good assumption primarily due to passing ships. In addition, we examine the gaussianity of the data for each

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE
30 SEP 2002

2. REPORT TYPE

3. DATES COVERED
00-00-2002 to 00-00-2002

4. TITLE AND SUBTITLE
NPAL Acoustic Noise Field Coherence and Broadband Full Field Processing

5a. CONTRACT NUMBER

5b. GRANT NUMBER

5c. PROGRAM ELEMENT NUMBER

6. AUTHOR(S)

5d. PROJECT NUMBER

5e. TASK NUMBER

5f. WORK UNIT NUMBER

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
Massachusetts Institute of Technology,,Cambridge,,MA,02139

8. PERFORMING ORGANIZATION REPORT NUMBER

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)

10. SPONSOR/MONITOR'S ACRONYM(S)

11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution unlimited

13. SUPPLEMENTARY NOTES

14. ABSTRACT
The long term objective is to understand the characteristics of ambient noise to provide better models i) the distribution of their source mechanisms and ii) to provide better models to support advanced sonar array processing algorithms.

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT	b. ABSTRACT	c. THIS PAGE			
unclassified	**unclassified**	**unclassified**	**Same as Report (SAR)**	**6**	

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std Z39-18

transmission by calculating the skewness and kurtosis. These are very simple tests on only the first order densities and their impact is often mitigated by Central Limit Theorem considerations when processing the data; nevertheless, the do provide some insight about the usual gaussian assumption for the data when computing performance metrics.

The second issue concerns source localization. The NPAL arrays are highly aliased. With a horizontal separation of 900 m among the VLA's, the aliasing angle is roughly
2 degrees at 50 Hz. Narrowband horizontal beamforming in a region filled with discrete shipping sources, which the NPAL site is, is practically impossible. We have developed an approach that is a two step, broadband method for source localization. First the source azimuth is computed by fitting the broadband travel times to a short vertical segment of the arrays. This yields a good bearing estimate as well as a modest estimate of the range using wavefront curvature. We have found that coherent narrowband processing among the VLA's to be very sensitive. The second step for range estimation creates a model for the crosscorrelation delays among the ray paths and matches them as a function of range. The ranging capability seems to be comparable to the matched field approach previously reported.

WORK COMPLETED

The noise levels for the entire NPAL data set *versus* year day are illustrated in Figure 1. There are four bands plotted: 10 – 20, 20 – 40, 40 – 100 and the full band 10 – 100 Hz.

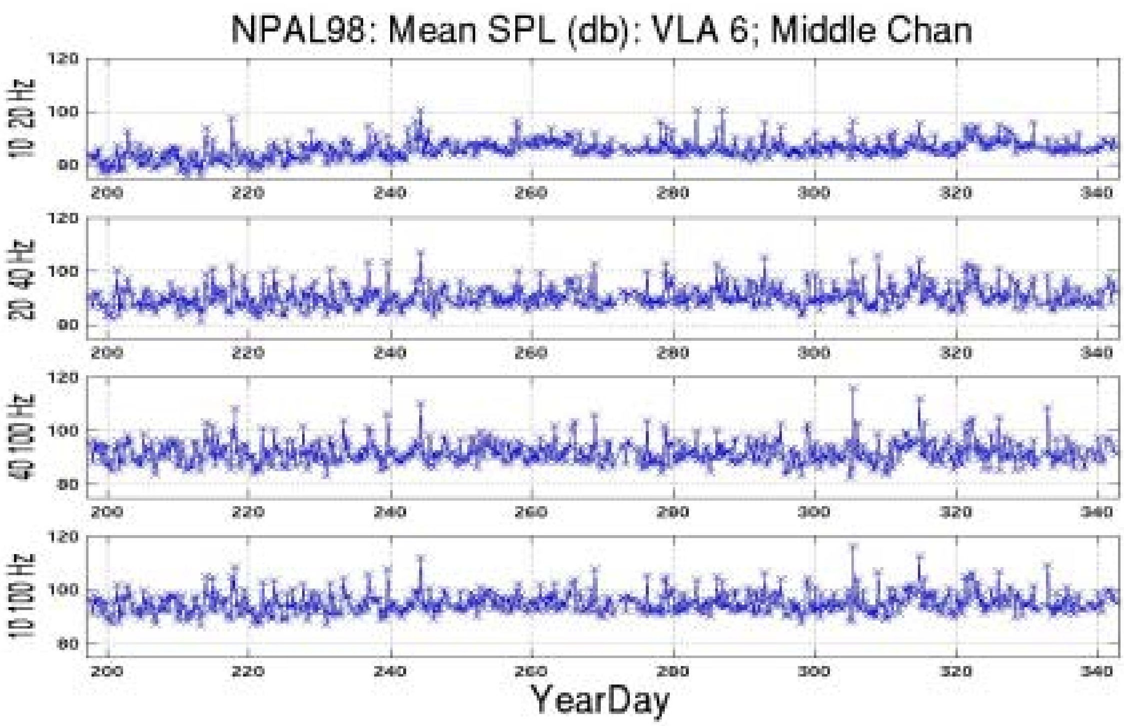

Figure 1: Spectral power in bands 10-20, 20-40, 40-80 and 10-100 Hz versus year day on a midwater (700 m) hydrophone. Note approximately 5 dB increase from 200 (early July) to 270 – 345 (Sept to Dec) in low bands as well as levels over 110 dB on the full band (10-100 Hz).

The spectral levels are approximately 5 dB lower than those predicted levels for the NPAL site using Navy models; moreover, there are numerous transmissions with levels in excess of 20 dB larger, probably the consequence of a nearby passing ship. Another observation is the consistent increase of 5 dB starting from yearday 220 (early July) to yeardays 270-345 (Sept to Dec) in the low spectral bands.

Many models for ambient ocean noise invoke a gaussian assumption for the probability distributions, especially for performance analysis where this is the only tractable one for calculating receiver operating characteristics (ROC's). We have calculated the skewness and kurtosis for the first order statistics of the entire NPAL data set. The skewness is not remarkable as it is usually very close to zero as it would be for a gaussian distribution. The kurtosis has, however, a very large range and differs significantly from the value of 3, or approximately 10 dB when expressed as 20log[ ]. Figure 2a indicates the kurtosis of all the transmissions

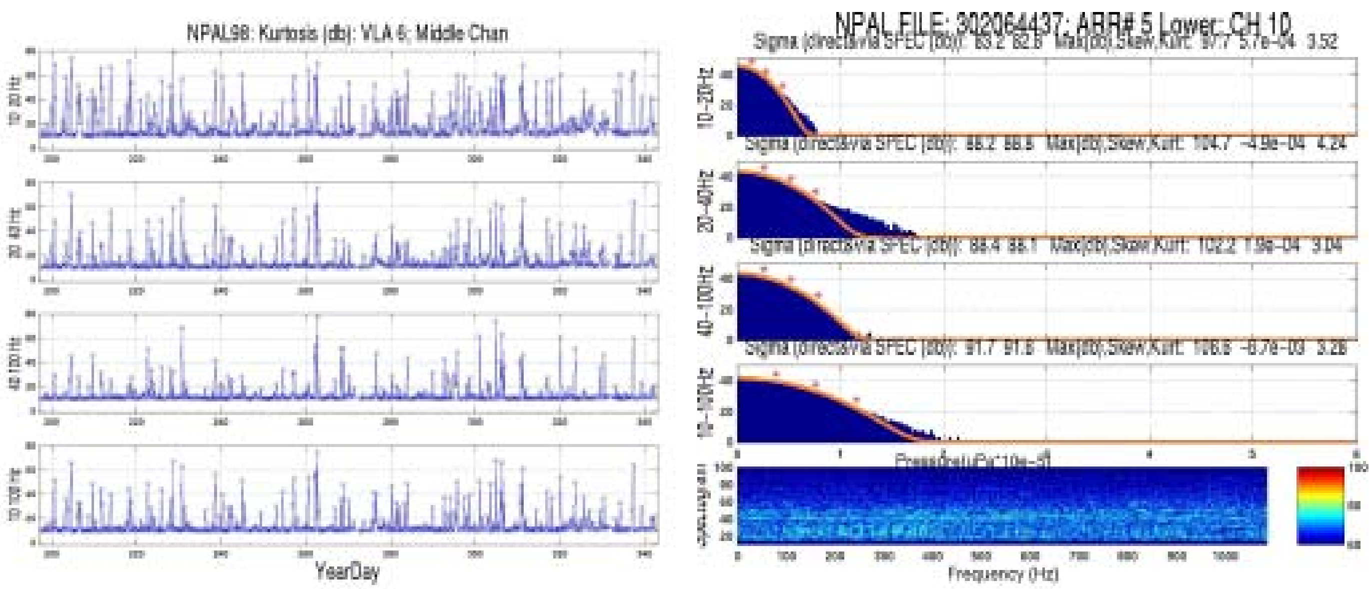

Figure 2: (a) Left – broadband kurtosis of the entire NPAL transmissions (20log[ ]). Note the events where the kurtosis exceeds 40 dB suggesting levels well beyond 3 standard deviations. (b) Right – band (10-20, 20 –40, 40 – 100 and broadband) kurtosis for a transmission w/ whale calls compared to a gaussian orange curve (orange pts are 1, 2 and 3 standard deviations. Spectrogram for the transmission is at the bottom.

There are many transmissions where the kurtosis exceeds 40 dB suggesting levels well in excess of three standard deviations. Some of these seem to be due to irregularities in the data recording; however, many can be associated with strong local shipping. Figure 2b breaks the data up into spectral bands. The second band (20 – 40 Hz) has a significant extent beyond a gaussian fit to the same standard deviation. One can notice in the lofargram at the bottom that this band has frequent episodic events most likely identified as whale vocalizations. The statistics are useful for identifying features of ambient noise and possibly their use as a classification tool. Their use as a detection metric is probably limited in the typical low SNR conditions for ASW.

Because of the difficulties of registering the VLA's together for narrowband array processing, we have examined methods using broadband cross correlation. Here, we obtain an azimuth to a source by simply fitting time delays to the broadband correlograms as normally done for a bearing estimate. Next, we attempt to match the vertical structure by constructing a ray path model for the cross correlations. This is illustrated in Figure 5.

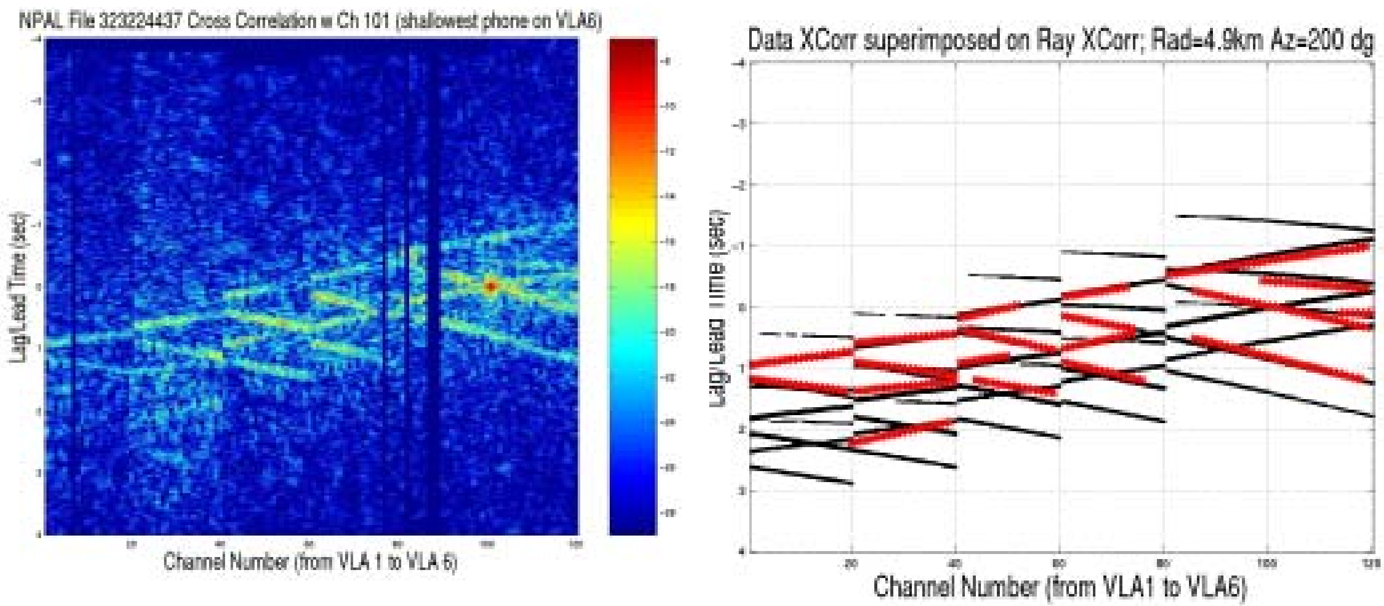

Figure 3: a (Left) Broadband cross correlations of VLA data using the center phone of the large VLA as the reference. (Note the coherence extends for the full aperture of the NPAL array.) Comparison to a ray model for a surface source at 4.9 km (black) with the dominant cross correlations (red)

In its simplest form this is D/E (direction/elevation) ranging when using a single vertical sensor. This simply extends the techniques to use all the elements in the NPAL array. The difficulty found in using the technique robustly is to calculate the signal levels mainly due to uncertainties in the geoacoustics.

IMPACT/APPLICATIONS

The long term impact of this for the Navy involves the performance of VLA's. Spectral structure and time domain coherence have long been specified. In addition, the coherence with towed arrays has also been extensively studied. Here we are making a detailed analysis of all the ambient signal components propagating across the NPAL arrays with the goal of understanding how each can be processed to improve sonar performance. Since there are a number of VLA systems being considered by the Navy,
These results will be useful in analyzing each of these systems.

TRANSITIONS

None

RELATED PROJECTS

This analysis of the ambient noise is related to the Acoustic Observatory Testbed Array now planned for deployment by ONR. In addition, several of the analysis methods have been used for the grant "Stochastic Matched Field Processing and Array Processing in Snapshot Limited Environments," sponsored by ONR Code 321US and the ONR DRI on Uncertainty. In addition, the PI serves on the Submarine Superiority Technical Advisory Group for N77 and ASTO – PEO Undersea Warfare and the Fixed Surveillance Technical Advisory Committee for SPAWAR.

PUBLICATIONS

Wage, K.E. , Baggeroer, A.B. and Preisig, J., Broadband modal coherence measurements for long range propagation," to apprear *J. of the Acoustical Soc. Of America,* December 2002.