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1. SPACE/TIME TRACKING OF NARROW-BAND PASSIVE SOURCE

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Joint Services Electronics Program (Contract DAAB07-75-C-1346)

Arthur B. Baggeroer, Louis S. Metzger, José M. F. Moura

Passive tracking systems, with active radar or sonar signals not used, are applicable to a variety of fields, such as oceanography, meteorology, passive sonar, and navigation. This research is directed toward understanding the fundamental limitations on the performance of these systems that exploit the curvature of a wave front across an array in conjunction with constraints on the source motion in order to estimate its position and velocity.

José M. F. Moura has completed doctoral thesis research in which he examined the situation of a narrow-band signal with linear constraints on the source motion.[1] He

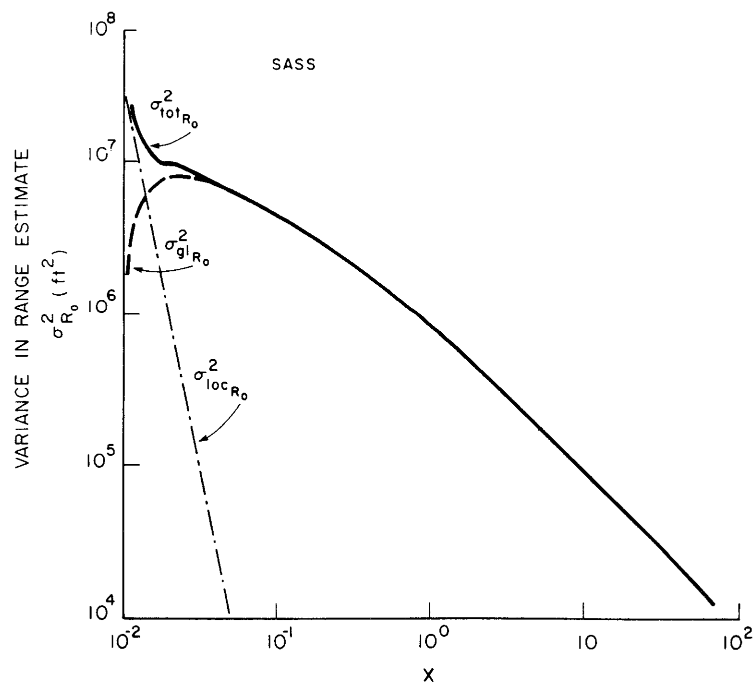

Fig. XIV-1. Total range mean-square error vs X. ($X = .5\ L/R_O$, where L = array length, R_O = target range.)

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identified two important considerations in the analysis of these systems. First, the global observability in the absence of noise in these systems is determined by the higher order phase modulations induced by the array geometry and source motion. Second, for a given signal-to-noise ratio, the local estimation accuracy as specified by Cramer-Rao bounds and the global anomalies as determined by the signal ambiguity need to be examined. Both are strong functions of the geometry and exhibit individual critical points. Figure XIV-1 illustrates typical behavior.

Sources usually radiate signals with some modulation and the transmission medium induces its own fluctuations. In any event, the signals are not pure sinusoids. Louis S. Metzger investigated the problems of tracking the bearing and estimating the signal of a moving source with finite bandwidth.[2] Using these representatives, he devised representations for the signals which reflected the space/time structure of the signal and estimator structures.

2. DETECTION AND ESTIMATION THEORY METHODS

Joint Services Electronics Program (Contract DAAB07-75-C-1346)

Arthur B. Baggeroer, Leroy C. Pusey, Thomas Marzetta,
Kenneth B. Theriault

A generalization of procedures in spectral analysis and wave propagation by using optimal filtering concepts has been described in a doctoral thesis by Leroy C. Pusey.[3] He has specified necessary and sufficient conditions for going between an observed continuous-time response and a reflection coefficient profile, or equivalently between a covariance function and h(t,0), the impulse response of the optimal filter. This has generalized the concept of covariance extension. Some results are indicated in Fig. XIV-2.

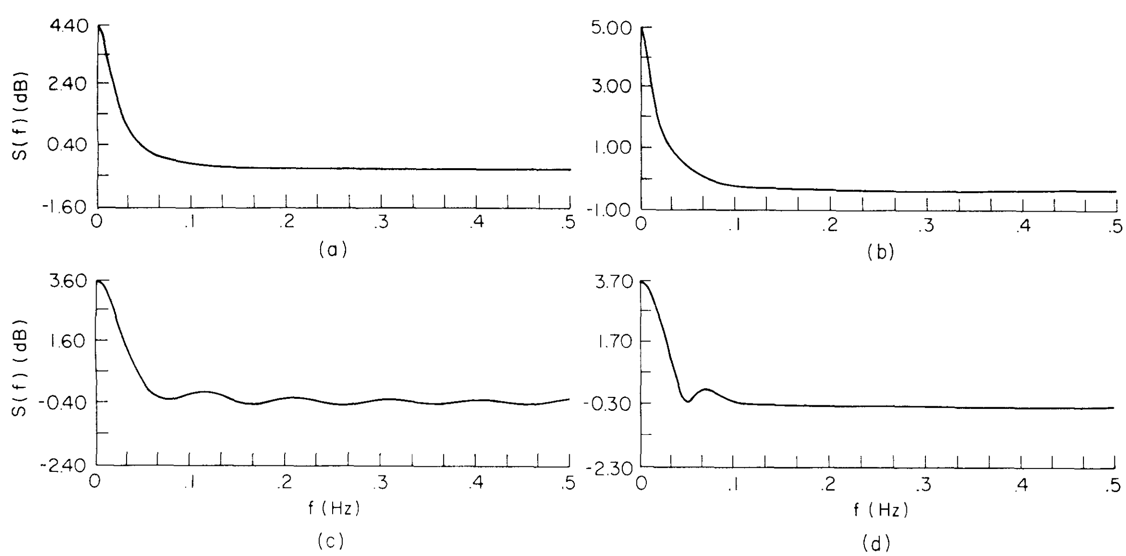

Fig. XIV-2. Estimated spectra for a first-order process: (a) True extension. (b) Exponential extension ($\lambda = .1$). (c) Autoregressive (AR) extension. (d) Damped sinusoid extension ($\lambda = .1$, $f_o = .05$).

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In related work, Thomas Marzetta is attempting to generalize Pusey's results to two-dimensional processes, and Kenneth B. Theriault is formulating the problem of reflection-coefficient estimation in the presence of noise and finite bandwidth excitation. Their results will be reported in forthcoming theses.

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3. MULTICHANNEL SEISMIC DATA ACQUISITION AND PROCESSING

Woods Hole Oceanographic Institution Purchase Order 4554

Arthur B. Baggeroer, J. Bruce Gallemore, Richard B. Kline,
Steven J. Leverette, Kenneth B. Theriault

In a cruise aboard the R/V Atlantis II on Georges Bank, a six-channel, 1-km, seismic array was successfully tested during July and August, 1975. Aside from some navigation hazards and routine failures of electronic components, we encountered no problems in the array deployment and the data acquisition. Onboard processing, including deconvolution, and velocity analysis with common shot-point stacking were implemented. The throughput rate, however, continues to be a difficulty because of the extensive interpretation that is needed in the velocity analysis of the seismic modeling. Figure XIV-3 is a section of a processed multichannel record indicating reflections observed in up to 3.8 seconds of two-way travel time.

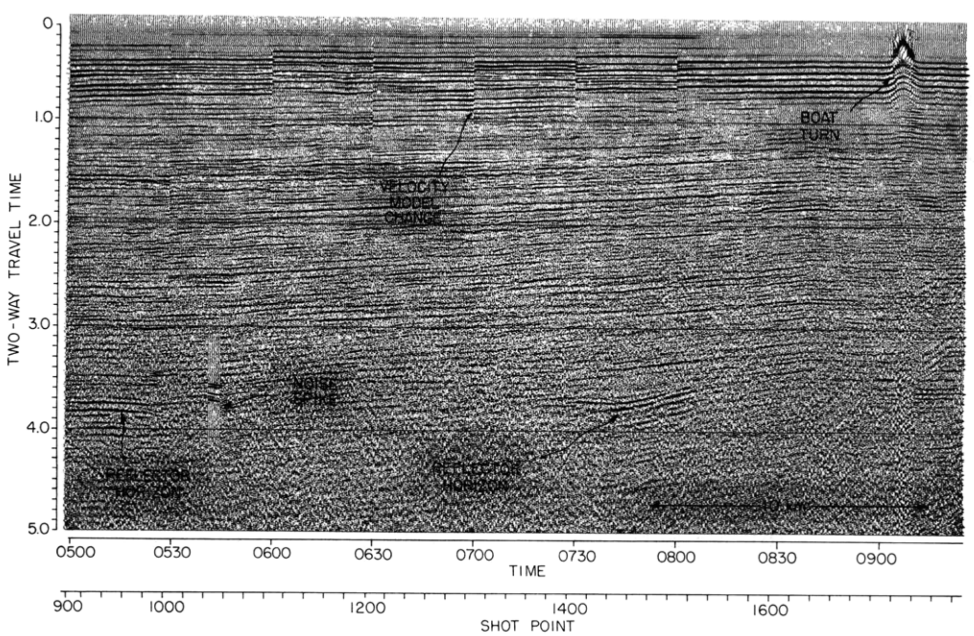
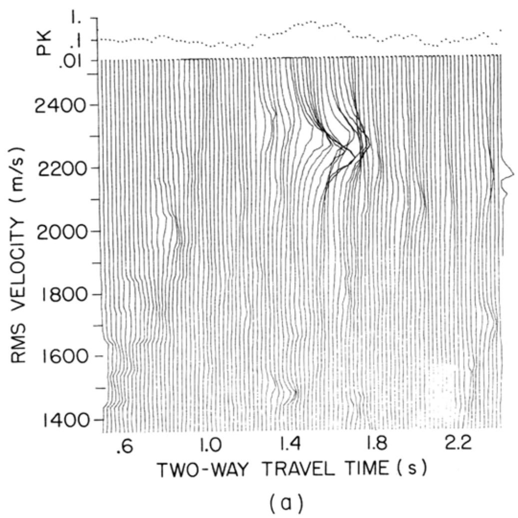


Fig. XIV-3. Seismic profile on Georges Bank.

Velocity analysis is an important step in seismic data processing in which we attempt to devise a model of the seismic section which is parametrized by the travel time to a reflector and the velocity to it. We attempt to estimate these parameters by the time delays observed across a multichannel array. Experiments involving the application of high-resolution spectral analysis procedures, e.g., the maximum-likelihood method, have been conducted this year. Figure XIV-4a illustrates the results of applying these procedures to synthetic seismograms, while Fig. XIV-4b indicates results using real



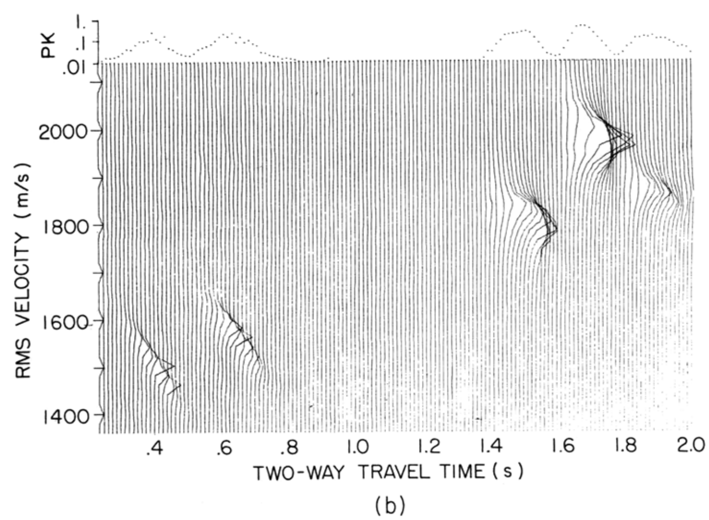


Fig. XIV-4. Maximum-likelihood method velocity spectra estimates.
(a) Georges Bank data (16 Hz).
(b) Synthetic multichannel data (broadband 16-36 Hz).

data from reflections observed in Georges Bank. These results were presented at the 1975 Society of Exploration Geophysicists Conference.[4] Steven J. Leverette is pursuing this topic in his thesis research.

In other work on seismic data processing, J. Bruce Gallemore is comparing the performance of tapped delay-line and homomorphic filters for removing deep water multiples.[5, 6] Richard B. Kline is analyzing the theoretical resolution capabilities of a seismic array for velocity analysis.

4. DESIGN OF A SEISMIC SIGNAL SOURCE USING PARAMETRIC SONAR

Arthur B. Baggeroer, Steven W. Zavadil

Seismic source signals are typically nonideal impulses. Moreover, they cannot be effectively modulated in order to take advantage of available signal-processing techniques. In a design project for the Department of Ocean Engineering, Steven W. Zavadil is using parametric sonar techniques to design a modulated seismic source. The parametric models have been designed in conjunction with the U. S. Navy Underwater Systems Center.

References

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4. A. B. Baggeroer and S. J. Leverette, "Estimation of Velocity/Depth Spectra Using the Maximum-Likelihood Method," Society of Exploration Geophysicists 45th Annual Meeting, Denver, Colorado, October 12-16, 1975.

5. A. B. Baggeroer, "Trapped Delay Line Models for the Dereverberation of Deep Water Multiples," IEEE Trans., Vol. GE-12, No. 2, pp. 33-54, April 1974.

6. P. Buhl, P. Stoffa, and G. Bryan, "The Application of Homomorphic Deconvolution to Shallow Water Marine Seismology – Models," Geophys. 39, 401-416 (1974); "The Application of Homomorphic Deconvolution to Shallow Water Marine Seismology – Real Data," Geophys. 39, 416-426 (1974).