D4

source can be represented in terms of normal modes with different Doppler-shifted frequencies and, hence, different changes of modal eigenvalues. Using these Doppler's shifts, matched-mode processing schemes for estimating the frequency, velocity, depth, and range information of a time-harmonic point source moving uniformly in stratified oceanic waveguides has been presented [H. Y. Chen and I. T. Lu, J. Acoust. Soc. Am. Suppl. 1 **87**, S153 (1990)]. The processing schemes over time domain is especially promising because only one receiver is required. Here, an iterative algorithm to reduce the monitoring time is used [A. Papoulis, IEEE Trans. Circuits Sys. **25**, 735–742 (1975)], which is essential in practical applications. The central problem here is to determine the frequency spectrum $F(\omega)$ of measured data $f(t)$ only known in *finite* time interval. Due to finite Doppler shift, $f(t)$ is a *band-limited* function that is analytic in the entire t axis. Therefore the unknown part of $f(t)$ can be determined by some forms of extrapolation. Since the received $f(t)$ is only known in finite time interval, its frequency spectrum $\hat{F}(\omega)$ will not be band-limited. Those spectral constituents outside the frequency band of $F(\omega)$ are not supposed to exist. Performing inverse transform of the truncated $\hat{F}$, some of the unknown portions of $f(t)$ were extrapolated. Combining these unknown portions with the known portions of $f(t)$, new "received" data defined over the *entire* time domain were obtained. The above procedure can be iterated until the solution converges. The method involves only discrete Fourier series and makes use the $N \log N$ economy of the FFT. Numerical calculations show very promising results.

2UW8. Self-surveying techniques for matched-field processing. Jean-Marie Tran and W. S. Hodgkiss (Marine Phys. Lab., Scripps Inst. of Oceanography, San Diego, CA 95152-6400)

The classic problem of matched-field processing is the detection and localization of (unknown) sources assuming a known oceanic environment and a calibrated vertical line array of known shape. If a broadcasting source is deployed at a known location, the array shape can be determined through assumptions on the environment, or the environmental characteristics (such as the sound-speed profile) can be determined if the array shape is known. These two problems are investigated in the framework of matched-field processing. First, the array shape calibration is discussed and a simple procedure, using a correlation measure and a standard multidimensional optimization algorithm, is proposed. This procedure is used on simulated data (where convergence is observed) and on real data collected at sea in September 1987 with a 900-m-long array with 120 sensors. The experimental results are found consistent with those obtained through previous analysis. Then, the problem of calibrating the oceanic environment is studied using a normal mode formulation. Bucker's self-cohering approach to correct for tame environmental mismatch in the matched-field processor output [H. Bucker, 4th MFP Workshop, 6–8 Sept. 1989, Victoria, Canada], provides a convenient measure of the environmental mismatch for a range-independent medium. An approach to tomography, using a vertical line array that samples well the normal modes, is proposed. The preliminary simulation results show that the Bucker correction factors provide a smooth measure of sound-speed mismatch and that the inversion for the sound-speed profile should be possible through optimization. [Work supported by ONR.]

2UW9. Reduction of matched-field sidelobes by subtraction of cross-spectral matrix elements associated with strong signals. Homer P. Bucker (Naval Ocean Systems Ctr., Code 541, San Diego, CA 92152)

Matched-field processing can be used to locate a sound source in the ocean by finding the best correlation between the signals received by a set of hydrophones and expected signals that would be received if the sound source were at a particular location. When standard (Bartlett) correlations are used, the sidelobes of a strong source may obscure the main response of a weaker source. A simple palliative for this problem is to calculate the elements of the cross-spectral matrix associated with the strongest signal and subtract these from the observed cross-spectral matrix. This process can be repeated for the next strongest signal, etc. This method has been suggested before for use with conventional plane-wave beamforming [H. P. Bucker, J. Acoust. Soc. Am. **62**, 1222–1225 (1977)]. In this report, the sidelobe reduction is quantified as function of mismatch in the environmental parameters and the proposed subtraction method is compared to high-resolution adaptive matched-field algorithms.

2UW10. A new method for range and depth source localization in shallow water. Sérgio M. Jesus (NATO SACLANT Undersea Res. Ctr., La Spezia, Italy)

Range and depth source localization in shallow water amounts to the estimation of the normal mode structure of the acoustic field. As "seen" by a vertical array, and from a modeling point of view, the normal mode structure appears as a set of nonplane coherent waves closely spaced in angle. The technique presented in this paper uses the eigen decomposition of the data cross-correlation matrix in order to resolve this set of nonplane waves and to estimate the subspace spanned by the normal modes that are significantly excited by the source(s): the mode subspace. The projection of the replica pressure vector onto the mode subspace for all possible range/depth source locations gives the final ambiguity surface. Results obtained on realistic environments show that its performance is always greater or equal to that of the generalized MLM processor [A. B. Baggeroer, W. A. Kuperman, and H. Schmidt, J. Acoust. Soc. Am. **83**, 571–587 (1988)]. Good performance results have been obtained on short time records; this suggests the method may be applicable to localizing moving sources and/or sources emitting transient signals. Preliminary results obtained on real data will be discussed and compared with those obtained by the conventional and MLM processors.

2UW11. Performance bounds on the passive localization of a moving source for ocean acoustics. Hee Chun Song and Arthur B. Baggeroer (MIT, Rm. 5-007, Dept. of Ocean Eng., Cambridge, MA 02139)

Matched-field processing (MFP) for locating a point acoustic source in the ocean using a vertical array is extended to treat a moving source problem. The extension involves both temporally nonstationary and spatially inhomogeneous structure of the sound field generated by a time-harmonic point source moving uniformly in a stratified oceanic waveguide. Using normal mode description of the sound field, the focus was on the effect of source motion on MFP. An optimum receiver based on maximum likelihood method is developed in the presence of spatially and temporally white noise. The generalized ambiguity function (GAF) was used to analyze problems of accuracy, ambiguity, and resolution. The principal result is the demonstration that a moving source problem can be treated as a stationary source problem if the source travel distance (uncompensated speed × time window) is less than half the wavelength of trapped modes. Also, a closed-form expression for the optimum potential resolution is derived based on the Cramer–Rao bound. The lower bound provides physical insight of how each mode contributes to the localization process, and can be easily evaluated for a wide range of source positions in any sound channel using sound channel eigenfunctions, eigenvalues, and the number of modes involved. Simulations of GAF and the bounds for Arctic environment illustrate the coupling of ocean environment to the localization performance.

San Diego, CA,