D3

signal contains information about both source position and source motion. To take full advantage of the information in the time sequence, MFP in the time domain (TDMFP) was implemented. TDMFP is equivalent to obtaining the narrow-band gain and MFP gain in one step through the use of a Fourier transform modified by the propagation. Simulated results confirm the improved localization and array gain of TDMFP compared to FDMFP for a moving source.

9:20

**G2. A stable data adaptive method for matched-field array processing in acoustic waveguides.** C. L. Byrne, R. I. Brent (Department of Mathematics, University of Lowell, Lowell, MA 01854), C. Feuillade (SYNTEK, Inc., 2101 E. Jefferson Street, Rockville, MD 20852), and D. R. DelBalzo (Naval Ocean Research and Development Activity, Stennis Space Center, MS 39529-5004)

The presence of a "modal noise" component leads to estimator instability when Capon's maximum likelihood (ML) method is applied to the processing of data from a vertical array in an acoustic waveguide. The physics of the waveguide forces signal vectors and noise vectors alike to be projected onto the span of the "mode" vectors, when the number of sensors ($N$) exceeds the number of propagating modes ($M$). The instability occurs whenever the (single snapshot) $N \times 1$ data vectors have the form $\mathbf{x} = U\mathbf{s} + U\gamma +$ white noise, where the matrix $U$ is $N \times M$ (sampling the normal modes at the hydrophone locations and independent of the actual acoustic disturbances present), and $\mathbf{s}$ and $\gamma$ correspond to signal and ambient noise sources, respectively. This condition arises in normal-mode and local normal-mode propagation. The dominant eigenvectors of $R^{-1}$ (where $R$ is the cross-spectral matrix) are sensitive to slight inaccuracies in the calculation of $R^{-1}$ in ways that affect the performance of the ML estimator. Following transformation of the $N \times N$ matrix $R$ to the $M \times M$ modal space cross-spectral matrix $T$, Capon's method is applied to $T$ to obtain the "reduced maximum likelihood" (RML) estimator. This procedure, which is a development of the sector focused stability technique of Steele and Byrne [Proceed. ISSPA 87, 24–28 August 1987, Brisbane, Australia, pp. 408–412], largely eliminates instabilities due to inaccurate inversion of $R$. Simulations are presented for a shallow-water environment to provide comparison between the ML and the RML estimators. These indicate that the degree of instability depends upon the level of noise (both correlated noise and white noise) and that a significant improvement in performance can be expected by use of the RML estimator in both cases.

9:35

**G3. A symmetry renormalization method for matched-mode sidelobe reduction.** George B. Smith and George M. Frichter, IV (Naval Ocean Research and Development Activity, Stennis Space Center, MS 39529-5004)

Current matched-field research at NORDA is centered on techniques that attempt to match measured and predicted modal amplitudes for improved detection and localization of acoustic sources in shallow-water waveguides. Ambiguity functions generated by these modal estimators display a sidelobe structure that is symmetric about the true source peak. This symmetry represents additional information about the signal location, which can be used to further enhance detection. Here, a simple correlation algorithm is presented which enhances the signal peak and suppresses sidelobes by renormalizing each point of the ambiguity function in accordance with the symmetry around that point. Since a renormalized ambiguity function retains the range symmetry of the original, the technique can (within limits) be applied iteratively. Computer simulations of a shallow-water Pekeris waveguide are used to demonstrate the effectiveness of renormalization when applied to both narrow-band and frequency-averaged mode matching.

9:50

**G4. Source localization: Matched field versus matched mode. Synthetic and real data performance analysis.** Sergio M. Jesus and Rachel M. Hamson (SACLANT Undersea Research Centre, I-19026 La Spezia, Italy)

The present study compares the matched field and the matched mode techniques for passively localizing a narrow-band point source in a shallow-water, range-independent environment. The matched mode technique is fully characterized in terms of sidelobe ambiguity performance and robustness against both system and environment parameter variation and mismatch. Comparative results are also shown for real data detection of a cw source immerged at different depths in a 120-m depth channel using a 62-m aperture vertical array. The results of this study indicate that the matched mode method is much less sensitive to the environmental conditions than the matched field method, and in particular, the result is less degraded by the effects of partial water column sampling (short array). Results obtained on real data showed good agreement with the corresponding tests from simulated data. However, a large sidelobe coverage was found for some situations leading to detection losses. Major causes of performance degradation are the uncertainty on the array sensor position due to array motion and correlated noise due, mainly, to surface-generated noise.

10:05

**G5. Broadband acoustic-field simulations from standard ray theory.** Stanley M. Flatté, John Colosi, Timothy F. Duda, Galina Rovner, and Jan Martin (Physics Department, University of California, Santa Cruz, CA 95064)

The complete wave field over a small region around 1000 km from a pulsed source is reconstructed in two ways. First, all the rays from the source to a vertical array of receivers at 1000 km are found, along with their travel times, number of caustics, arrival angles, and intensities. The pattern of wave fronts in a space at a given time is then reconstructed on a closely spaced grid surrounding 1000 km by treating these rays in an appropriate way. Second, the parabolic equation method is used at multiple frequencies to synthesize a pulse. The two fields are compared. Finally, the effect of internal waves is simulated by use of the first method, introducing random fluctuations on the travel times and arrival angles of each ray. [Work supported by ONR, Code 1125OA.]

10:20

**G6. Acoustic wave front distortions at long ranges from internal waves.** Timothy F. Duda and Stanley M. Flatté (Physics Department, University of California, Santa Cruz, CA 95064)

In the absence of small-scale variations on sound speed in the ocean, a pulsed source delivers a series of smooth wave fronts onto a vertical array at long range from the source (multiray propagation). Small-scale variations such as internal waves induce distortions on the wave fronts with transverse correlation function determined by the phase-structure function, which is itself calculable by integrating appropriate functions along the trajectory of an undistorted ray. Expressions for the phase-structure function at small separations have been previously given in the form of arrival-angle spreads due to internal waves, but these expressions are only for vertical receiver separations up to about 100 m. Evaluations of the phase-structure function for separations up to several kilometers are presented, and particular realizations of wave front distortions that result from these internal-wave effects are shown. [Work supported by ONR, Code 1125OA.]





Syracuse, NY