ANNUAL LETTER REPORT FOR FY92

I. ADMINISTRATIVE INFORMATION

Title: Higher-Order Spectral Processing and Wavelet Based Cumulant Processing
Contract: N00014-91-J-1719 and N00014-91-J-4138
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II. TECHNICAL OBJECTIVES AND ISSUES

The objective of this program is to combine higher order spectral processing and wavelet processing to improve the detection and classification of certain types of signals that arise in sonar full spectrum processing and in condition based maintenance. We are focusing initially on two types of signals: coherently related narrowband tonals, and metallic transients. Coherent sets of narrowband tonals arise frequently from various types of rotating machinery. We are trying to exploit the coherent relationship between these tonals, as well as their proportional bandwidth properties, to improve the detection of these sets of tonals in noise and to provide additional information that can be used for condition based maintenance algorithms. Higher order spectral processing is used to exploit the coherence, and wavelet processing is used to exploit the proportional bandwidth properties.

In addition to the tonal sets, we are also focusing on metallic transients. In sonar full spectrum processing a critical issue is the separation of target generated transients from naturally occurring transients. Based on physical considerations we have developed a model for *metallic* transients that resulted in a time-scale model for the transients. We are seeking to exploit the time-scale features of wavelet processing along with previously demonstrated gains in transient processing using higher order spectra to develop processing that preferentially detects metallic transients. This processing can also be used in condition based maintenance algorithms since metallic transients can also be an indicator of machinery wear or failure.

III. TECHNICAL APPROACH

This work has both theoretical and experimental aspects. The theoretical work is taking two approaches. One is to develop wavelet based higher order spectral processing directly as the cumulant of wavelet transforms, analogously to Fourier based higher order

spectral processing. The other is a more fundamental approach that seeks the appropriate definition for "spectrum" and "higher order spectrum" for time-scale processes. In both cases we seek the statistical properties of estimators of these transforms to develop analytically the expected detection performance against signals and noise of interest. In addition we are developing simple physical models of mechanical systems that take into account the phase coherences, proportional bandwidth, and time-scale features of the various signals of interest. Based on these models we are conducting simulations and simple experiments to provide us with data to test against the models and evaluate the signal processing algorithms we develop. We also have access to data from full scale marine systems that can be used to evaluate algorithms under more realistic conditions.

IV. SUMMARY OF ACCOMPLISHMENTS

We have developed a modified Morlet wavelet that can be matched to the bandwidths of a set of proportional bandwidth narrowband tonals, and are evaluating its detection performance compared to conventional power spectrum processing. In addition, we have developed a time-scale model for metallic transients and developed a matched wavelet for metallic transients. We are currently evaluating the second order cumulant for the matched wavelets. Experimental metallic transient data and bearing vibration data have been obtained for use in evaluating these processing methods. We have also made some progress on pursuing more fundamental issues of the proper definition of "spectrum" for time-scale processes.

V. SIGNIFICANCE

If successful, this approach of combining higher order spectral and wavelet processing methods should result in detection improvements over conventional sonar processing for the types of full spectrum signals being considered here. In addition, these processing methods should provide additional useful information about mechanical systems that can be used to provide more accurate diagnostics for condition based maintenance. Transition paths have been identified for the full spectrum aspects of the work to 6.2 and 6.3 programs.

VI. PLANNED EFFORTS

Future efforts will be directed toward the evaluation of the processing methods already developed using simulated data and data obtained from laboratory experiments and

full scale systems. These evaluations will seek to determine the benefits of using these approaches in terms of detection performance and improved diagnostic capability.

VII. PRESENTATIONS AND PUBLICATIONS

Hinich, Melvin J. and Gary R. Wilson, "Time Delay Estimation Using the Cross-Bispectrum," IEEE Trans. Sig. Proc., **40**, Jan. 1992, pp 106-113.

Baugh, Kevin W. and Keith R. Hardwicke, "On the Detection of Transient Signals Using Spectral Correlation," accepted for publication in the IEEE Circuits, Systems, and Signal Processing.

Hardwicke, Keith R., Wilson, Gary R., and Baugh, Kevin W., "Characterization of Spectral Correlation Detector Statistics Useful in Transient Detection," accepted for publication in the IEEE Circuits, Systems, and Signal Processing.

Wilson, Gary R., Hardwicke, Keith R., and Trochta, Robert T., "Coherent Harmonic Detection Using Nonstationary Higher Order Spectra," Proceedings of the 1992 IEEE International Conference on Acoustics, Speech, and Signal Processing, March 23-26, 1992, San Francisco, CA.

Wilson, Gary R., et al, "Applications of Wavelet Based Higher Order Spectral Processing to Machinery Diagnostics," presented at the International Conference on Higher-Order Statistical Signal Processing with Application to Nonlinear, Non-Gaussian, and Nonstationary Signals and Systems (HOSSPA 92), Gold Coast, Queensland, Australia, 20-21 August 1992.

VIII. PARTICIPANTS

Dr. Gary R. Wilson, Research Scientist

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