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12a. DISTRIBUTION / AVAILABILITY STATEMENT

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12 b. DISTRIBUTION CODE

13. ABSTRACT *(Maximum 200 words)*

We are developing a new framework, called Programmable Canonical Correlation Analysis (PCCA), for the design of blind adaptive spatial filtering algorithms that attempt to separate one or more signals of interest from co-channel interference and noise. Unlike many alternatives, PCCA does not require knowledge of the calibration data for the array, directions of arrival, training signals, or spatial autocorrelation matrices of the noise or interference. A novel aspect of PCCA is the ease with which new algorithms, targeted at capturing all signals from particular classes of interest, can be developed within this framework. The performance of the new method is being investigated analytically and by computer simulations to quantify its capabilities of signal separation, multipath mitigation, and interference rejection. Preliminary results suggest that the new method can converge very quickly to yield estimates that are comparable to those obtained by the MMSE method that uses perfectly known training signals.

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PROGRAMMABLE BLIND-ADAPTIVE MULTIVARIATE FILTERING

William A. Gardner

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U. S. Army Research Office

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1. *SCIENTIFIC PROGRESS & ACCOMPLISHMENTS*

This research focused on adaptive spatial filtering, which is a means for combining signal waveforms measured at distinct points in space (e.g., by an array of antennas) in such a way that signals of interest are enhanced and separated from each other (e.g., for demodulation by a conventional radio receiver) and interfering signals are rejected. Adaptive spatial filters can be used to improve the quality or quantity of service in wireless communications systems in either hostile or cooperative environments (e.g., battlefield communications or civilian cellular radio), and can significantly improve capabilities in signals intelligence, surveillance, reconnaissance, and information warfare applications where multiple signals are active in the same spectral band.

Two emphases distinguish this research:

1. novel methods for blind adaptation which adapt the adjustable parameters in the spatial filter without access to the known training signals or array calibration information required by conventional non-blind adaptive methods; focus within this effort is provided by Programmable Canonical Correlation Analysis (PCCA), a new framework developed by the primary scientific personnel (Gardner, Schell, and Kahn) on the this project, which simplifies the development of new methods and unifies several important existing ones.

2. novel spatial filtering structures that use not only spatial redundancy (the fact that each signal is observed at multiple locations in space) but also spectral redundancy (the fact that most man-made communications signals contain information that appears in more than one spectral band); focus within this effort is provided by the theory of cyclostationarity and spectral correlation, which was developed primarily by the PI.

Within the first area of emphasis in this project, we have developed new blind adaptation methods within the PCCA framework and evaluated their performance in different scenarios for the purpose of extending the applicability of the PCCA framework to a wider range of problems and improving the convergence rate.

Also within the first area of emphasis, we have developed a generalization of conventional canonical correlation analysis (CCA) (developed in the multi-variate statistics field) called GCCA that extends CCA to more than two data sets. In addition to being an original theoretical contribution to multi-variate statistics, GCCA provides means of further extending our

PCCA framework for blind adaptive spatial filtering. GCCA has the capability of providing an even greater degree of control over the nature of the blind adaptation process for the purpose of being applicable to a wider range of problems than PCCA and of adapting more quickly to separate signals of interest and reject unknown interference. It enables the use of both training signals and multiple-property restoral, and provides for specifying the importance of each type of training. (Papers for publication are currently in preparation.)

Within the second area of emphasis in this project, we have developed the multi-sensor generalization of the single-sensor FRESH filter. Both basic theoretical research and computer simulations show that the multi-sensor FRESH filter can separate a number of spectral overlapping signals that exceeds the number of sensors. No other linear spatial filtering structure is known to be capable of this feat. It has been shown that this unique capability obtains from the filter's simultaneous exploitation of the spatial and spectral redundancies that characterize particular types of man-made communications signals. Among the signal types being investigated in the context of this research is the Gaussian MSK signal used in the GSM world standard (Global Systems for Mobile communications) for wireless cellular communication systems. For this signal we have shown that an array of M sensors can separate up to 2M of these GSM signals. (Papers for publication are currently in preparation.)

2. *TECHNOLOGY TRANSFER*

The PI was awarded, as a subcontractor to an SBIR proposal from industry (Mission Research Corporation), a DARPA SBIR contract (DAAH01-96-C-R265) for application of our adaptive spatio-temporal filtering algorithms to smart antenna technology for cellular telephone.

3. *SCIENTIFIC PERSONNEL WHO PARTICIPATED IN THIS PROJECT*

* William A. Gardner (PI)
* Stephan V. Schell (Post-doctoral researcher)
* Mark F. Kahn (industry supported Ph.D. student, graduated 1998)
* Jeffrey L. Schenck (Ph.D. student)
* Matthew Mow (industry supported Ph.D. student, graduated 1998)
* Thomas E. Shrimpton (Ph.D. student)
* Kurt E. Sundstrom (M.S. student)
* Doreen Meyer (Technical support staff)

4. *LIST OF MANUSCRIPTS SUBMITTED & PUBLISHED*

* M. F. Kahn and W. A. Gardner, "A Time-Channelized Programmable Canonical Correlation Analyzer". *Proc. 29th Annual Asilomar Conf. on Signals, Systems, and Computers*, Oct. 30-Nov. 1, 1995, pp. 346-350.

* M. F.Kahn, W. A. Gardner, and M. A. Mow, "Programmable Canonical Correlation Analyzers with Recursion and Feedback". *Proc. 29th Annual Asilomar Conf. on Signals, Systems, and Computers*, Oct. 30-Nov. 1, 1995, pp. 351-356.

* S. V. Schell, "A Separability Theorem for 2M Conjugate-Symmetric Signals Impinging upon an M-Element Sensor Array". *IEEE Transactions on Signal Processing*, SP 45(3):789-792, March 1997.

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* R. B. Ertel and S. V. Schell, "Comparative Study of Adaptive Antenna Arrays in CDMA Communication Systems". *Proc. Virginia Tech's Sixth Symposium on Wireless Personal Communications*, June 5-7, 1996, pp. 10.1-10.10.

* S. V. Schell, "Corollaries, for Cyclostationary Signals, to Whittle's Theorem on the Cramer-Rao Bound". Submitted to *Signal Processing*, July 1998.

* M. Mow, "Periodically-time-variant spatio-temporal filtering for improvement of GSM". Ph.D. dissertation, Dept. of Electrical and Computer Engineering, Univ. of California, Davis, 1998.

* M. F. Kahn, Generalized Canonical Correlation Analysis with Application to Blind Adaptive Signal Processing". Ph.D. dissertation, Dept. of Electrical and Computer Engineering, Univ. of California, Davis, 1998.

5. *INVENTIONS*

None.