

# Signal Analysis Research by University of New Orleans Department of Physics Faculty, Students, and Graduates

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***Abstract** – Signal analysis research has been active in the Department of Physics at the University of New Orleans since 1969. Signal analysis courses have been taught in the Department since 1973. An overview of the research and contributions by faculty, students, and graduates is given in this article. The research areas described include deconvolution; noise reduction; seismic data inversion; detection of weak signals in noise; symmetries, and sampling and aliasing properties of higher order correlations and spectra; analysis of airborne electromagnetic data; modal analysis of tether dynamics; vector map data compression with wavelets; and ocean acoustic measurements, data analysis, and modeling. References are given to published work in each area. A complete list of theses and dissertations supervised is also given as well as a list of courses offered.*

**Keywords:** Deconvolution; noise reduction; seismic data inversion; detection; higher order correlations and spectra; sampling and aliasing; airborne electromagnetic data analysis; satellite tether dynamics; wavelet data compression; underwater acoustic measurements, data analysis, and modeling.

## 1 Introduction

The purpose of this article is to give an overview of the signal analysis research by faculty, students, and graduates of the University of New Orleans (UNO) Department of Physics. This research has an extensive history, beginning in the mid-1960s when one of the authors (GEI) applied noise removal and deconvolution techniques to ion-atom collision data while a graduate student at the University of Florida. The research is discussed in his dissertation (Ioup, 1968) and in a journal article (Ioup and Thomas, 1967). The first UNO master's thesis in this area, on the convergence of iterative deconvolution, was completed in 1973. Since then, 35 master's theses and four Ph.D. dissertations have been written, directed by George and/or Juliette Ioup. See Appendix A. Related theses

and dissertations directed by other Department of Physics faculty are not included in this overview. Currently there are 19 students in the Ph.D. Program in Engineering and Applied Science who are working in the area of signal analysis with the authors. Beginning in 1973, the first signal analysis course was taught. There are now five Fourier-based courses and two wavelet-based courses available. See Appendix B.

This summary consists of a description of the research areas and the UNO contributions made to each by the authors and their students. The research has generally been in physics and applied physics with crossover into electrical engineering, applied mathematics and statistics, applied computer science, and geophysics.

## 2 Research Areas and Contributions

### 2.1 Deconvolution

The convolution integral or sum is the input/output relation for a linear shift-invariant system. Deconvolution is the process of solving for the input given the output and, in the case of ordinary deconvolution, given the system response function. The convolution model describes many physical experiments and instruments. Therefore deconvolution is an important numerical process for recovering the input. It is a very difficult problem, however, due to its sensitivity to noise and consequent ill-condition and due to the information lost in the convolution process. A stable iterative technique was developed by van Cittert in 1931 [1] and its convergence established by Bracewell and Roberts in 1954 [2]. We have worked on this problem since 1964. The techniques have been applied to several types of experimental data. The convergence condition was initially given in the Fourier transform domain [2]. We have shown corresponding necessary conditions in the function domain. We have investigated the effects of physically motivated constraints and Gibbs oscillations on solutions. We have developed two new always-

convergent iterative techniques which are not limited as the original method is to convergent system response functions. We have extended our iterative methods to the processing of two-dimensional images. Our group has pioneered optimization by simulation as a method to determine the optimum iteration number for iterative deconvolution. We have shown the accuracy of the deconvolution by comparing the deconvolved results from a defocused mass spectrometer to a high resolution result from the same instrument. We have investigated and developed noise reduction techniques (see next section) to improve the problem condition, i.e., decrease the noise sensitivity, for deconvolution. We have investigated autocorrelation estimation and spectral estimation using constrained iterative spectral deconvolution. We are now performing research into blind deconvolution, in which neither the input nor the system response are known. The Master's theses with contributions to this area are by Keaton, Hu, Drackett, Chundururu, Ni, Alexander, Kamminga, Amini, Murphy, Ramaswamy, Powe, Mark Whitehorn, Yoerger, Zeringue, Field, Bivens, and Hill, and the Doctoral Dissertation is by Larue. See Appendix A.

Metropolis Monte Carlo Deconvolution Technique Compared to Iterative Methods for Noisy Data, Amini, Abolfazl M., Ioup, George E., and Ioup, Juliette W., Proc. SPIE Vol. 4380, p. 552-563, Signal Processing, Sensor Fusion, and Target Recognition X, Ivan Kadar; Ed. (2001).

Improved Sensitivity for Lidar Based Chemical and Biological Standoff Detection, George E. Ioup, Juliette W. Ioup, and George M. Wood, STC Technical Report (2000).

Deconvolution II (book) eds. Enders Robinson and Osman Osman, Society of Exploration Geophysicists Reprint Series, ed. Dan Ebrum, 1996, reprinted the following two invited papers:

Iterative Deconvolution, G.E. Ioup and J.W. Ioup, Geophysics 48, pp. 1287-1290 (1983), book pages 295-298 (1996); and

Autocorrelation Estimation Using Constrained Iterative Spectral Deconvolution, Murali Ramaswamy and George E. Ioup, Geophysics 54, 381-391 (1989), book pages 299-309 (1996).

Shift Variant Linear System Modeling for Multispectral Scanners, Abolfazl M. Amini, George E. Ioup, and Juliette W. Ioup, Proceedings of the SPIE International Symposium on Aerospace/Defense Sensing & Control and Dual-Use Photonics, SPIE, Vol. 2484, 372-382 (1995).

Constrained Iterative Spectral Deconvolution for Analysis of Closely Spaced Modal Peaks in the Fourier Transform of Tethered Satellite Dynamics Data, Abolfazl M. Amini, George E. Ioup, and Juliette W. Ioup, Proceedings of the Fourth International Conference on Tethers in Space, 1461-1474 (1995).

Optimizing Iterative Noise Removal and Deconvolution by Simulation, James H. Leclere, Abolfazl M. Amini, George E. Ioup, Juliette W. Ioup, Optical Society of America 1995 Technical Digest Series 11, 58-60 (1995).

Enhanced Data from Analytical Instrumentation by Deconvolution of Periodically Sampled Signals, George E. Ioup, Juliette W. Ioup, Abolfazl Amini, Grayson H. Rayborn, Dong Wang, and George M. Wood, paper presented at the 4th International Conference on Computational Methods and Experimental Measurements (CMEM 89) of the Computational Mechanics Institute, 23-26 May 1989, Capri, Italy, and published in Computers and Experiments in Stress Analysis, G. M. Carlomagno and C. A. Brebbia, eds., Springer-Verlag, Berlin, hardbound, p. 449-463 (1989).

Autocorrelation Estimation Using Constrained Iterative Spectral Deconvolution, Murali Ramaswamy and George E. Ioup, Geophysics 54, 381-391 (1989).

Improved Deconvolution for Low Signal-to-Noise Ratio Seismic Data, Abolfazl M. Amini, George E. Ioup, Juliette W. Ioup, and Reginald Powe, paper presented at the Seventeenth International Symposium on Applied Identification, Modelling, and Simulation, of the International Association of Science and Technology for Development, November 1987, New Orleans, LA and published in the Proceedings, p. 116-118 (1987).

Shallow Marine Sediment Characterization Using a Frequency-Spatial Wavenumber Discrimination Technique, M. F. Werby, G. J. Tango, G. E. Ioup, and M. Ramaswamy, paper presented at the Society of Exploration Geophysicists 1986 Annual Meeting, November 1986, Houston, TX, and published in the Proceedings, 406-409 (1986).

A Comparison of Convergent Iterative Deconvolution Methods with the Least Squares Technique for Synthetic Seismic Data, Reginald Powe, George E. Ioup and Juliette W. Ioup, paper presented at the Society of Exploration Geophysicists 1985 Annual Meeting, October 1985, Washington, D.C., and published in the Proceedings, 556-558 (1985).

Iterative and Function -Continuation Fourier Deconvolution Methods for Enhancing Mass Spectrometer Resolution, Juliette W. Ioup, George E. Ioup, Grayson H. Rayborn Jr., George M. Wood Jr., and Billy T. Upchurch, Int. J. Mass Spectrom. and Ion Processes 55, 93-109 (1983/1984).

Iterative deconvolution, George E. Ioup and Juliette W. Ioup, Geophysics 48, 1287-1290 (1983).

An Introduction to Deconvolution, Ioup, George E., The Louisiana Physics Teacher, Vol. 7, 15-18 (1982).

Data Enhancement and Analysis through Mathematical Deconvolution of Signals from Scientific Measuring Instruments, George M. Wood, Grayson H. Rayborn, Juliette W. Ioup, George E. Ioup, Billy T.

Upchurch, and Samuel J. Howard, paper presented before the International Congress on Instrumentation in Aerospace Simulation Facilities, September-October 1981, Dayton, OH, and published in '81 Record, 25-37 (1981).

Deconvolution of Mass Spectrometer Data, Juliette W. Ioup, George M. Wood, Jr., Billy T. Upchurch, George E. Ioup, and Grayson H. Rayborn, Jr., paper presented to the 28th Annual Conference of Mass Spectrometry and Allied Topics, May 1980, New York, NY, and published in the Proceedings, 682-83 (1980).

Convergence of the van Cittert Iterative Method of Deconvolution, Hill, N. R. and G. E. Ioup, J. Opt. Soc. Am. 66, 487-89 (1976).

Analysis of Low Energy Atomic and Molecular Collisions: Semi-Classical Elastic Scattering Calculations and Deconvolution of Data, George E. Ioup, Ph.D. Dissertation, University of Florida (1968).

Smoothing and Unfolding the Data of Beam Collision Experiments, G. E. Ioup and B. S. Thomas, J. Chem. Phys. 46, 3959-61 (1967).

## 2.2 Noise Reduction

We have investigated Morrison's iterative method of noise removal and its convergence. We have applied the method to several data types. Because these noise removal iterations converge for only system response functions similar to those for iterative deconvolution, we have developed an always-convergent iterative noise removal iteration. Optimization by simulation was first applied to determine the optimum use of Morrison's noise removal, both for noise removal alone and to minimize the noise resulting after a subsequent deconvolution. We have also applied other noise reduction techniques including wavelets. See also references in Section 2.1. The Master's theses with contributions to this area are by El-Saba, Amini, Leclere, Mark Whitehorn, Wright, and Yoerger.

Noise Removal and Compression Using a Wavelet Transform, Juliette W. Ioup and George E. Ioup, Society of Exploration Geophysicists Proceedings, 1076-1079 (1998).

Low Pass Filtering of AEM Fields by MIM Impulse Functions, Clyde J. Bergeron, Jr., Ninke Yi, Juliette W. Ioup, and George E. Ioup, Marine Tech. Soc. J., 30, 14-19 (1996-97).

Low Pass Filtering of AEM Fields by MIM Impulse Functions, Clyde J. Bergeron, Jr., Ninke Yi, Juliette W. Ioup, and George E. Ioup, Proceedings of the ERIM Third Thematic Conference on Remote Sensing for Marine and Coastal Environments Vol. II, 675-685 (1995).

Phase Coherency Filtering of Reflection Seismic Data, John D. McGlynn and George E. Ioup, Geophysics 50, 1505-1509 (1985).

## 2.3 Seismic Data Inversion

We have expanded upon a plane wave seismic inversion technique developed by Sarwar. We have shown how to reconstruct the impedance log from the Fourier components of the seismogram and the effects of bandlimiting and noise on the inversion procedure. We have also examined the effects of multiples and resolution on the inversion. The Master's thesis with contributions to this area is by Amini.

A Fourier Approach to Stable Inversion of Bandlimited and Noisy Seismograms, A. K. M. Sarwar, J. W. Ioup, and G. E. Ioup, paper presented at the Mathematical Geophysics Fifth International Seminar of Model Optimization in Exploration Geophysics, Berlin, February 1987, and published in Model Optimization in Exploration Geophysics Vol. 2, A. Vogel, Ed., Friedr. Vieweg & Sohn, Wiesbaden, hardbound, 311-322 (June 1988).

Effects of Multiples and Resolution on Fourier Inversion, George E. Ioup, Juliette W. Ioup, and A. K. M. Sarwar, paper presented before the Society of Exploration Geophysicists, October 1987, New Orleans, LA and published in the Proceedings, 444-446 (1987).

Inversion of Synthetic Seismograms from Fourier Components, Juliette W. Ioup, A. K. M. Sarwar, and George E. Ioup, paper presented at the Society of Exploration Geophysicists Annual Meeting, November 1986, Houston, TX and published in the Proceedings, 270-273 (1986).

A Fourier Approach to Stable Inversion of Bandlimited and Noisy Seismograms, A.K.M. Sarwar, J. W. Ioup, and G. E. Ioup, invited paper presented at the Regional Conference on Petroleum Exploration in Complex Areas, Urumqi, People's Republic of China, August 1986, and to be published in the Proceedings (in Chinese).

Reconstruction of the Acoustic Impedance Log from the Fourier Components of the Seismogram Using One-Dimensional Inverse Theory, A.K.M. Sarwar, Juliette W. Ioup, and George E. Ioup, paper presented at the Society of Exploration Geophysicists 1985 Annual Meeting, October 1985, Washington, D.C., and published in the Proceedings, 325-327 (1985).

## 2.4 Detection of Weak Signals in Noise

Although this is a problem that pervades many areas from medical imaging to seismic data analysis to communication theory, we have concentrated on underwater acoustic transients (energy signals), a problem of interest to the Navy, which has provided support. We have applied ordinary and higher order

correlation detectors (bicorrelation and tricorrelation) to received signals and functionals of received signals. We have evaluated the performance of these detectors using large scale computer simulations. We have examined the effects of bandlimiting and prefiltering on the detection. We have developed theoretical formulas to predict the performance of these detectors for active and passive detection and compared the predictions to simulation results. The Master's theses with contributions to this area are by Gardner, Mire, and Pflug, and the Doctoral Dissertation is by Dean.

Maximum Performance Gains for Higher Order Correlations Detectors, L. A. Pflug, G. E. Ioup, and J. W. Ioup, submitted to *Jour. Acoust. Soc. Am.*

The Performance of Single and Multiple Channel Moment Detectors for Unknown Transient Signals in Ambient Shipping Noise, L.A. Pflug, G.E. Ioup, and J.W. Ioup, *IEEE Jour. of Oceanic Eng.*, in press.

Functional Inputs to Threshold Correlation Detectors for Oscillatory Transient Signals, L.A. Pflug, G.E. Ioup, and J.W. Ioup, *IEEE Jour. of Oceanic Engineering*, Vol. 24, 67-80 (1999).

Known Source Detection Predictions for Higher Order Correlators, L. A. Pflug, G. E. Ioup, and J. W. Ioup, *J. Acoust. Soc. Am.* 103, 2469-2477 (1998).

The Effects of Ambient Shipping Noise on the Performance of Single and Multiple Channel Moment Detectors for Unknown Transient Signals, L. A. Pflug, G. E. Ioup, and J. W. Ioup, *NRL/FR/7173--97-9678 Technical Report* (1998).

Higher Order Moment Detection of Transients in Measured Shallow-Water Noise, Lisa A. Pflug, George E. Ioup, and Juliette W. Ioup, *Proceedings of the IEEE Signal Processing Workshop on Higher Order Statistics*, 405-409 (1997).

Performance Prediction Formulas for Higher Order Correlation Detection of Energy Signals, L.A. Pflug, G.E. Ioup, and J.W. Ioup, *IEEE Signal Processing/ATHOS Workshop on Higher-Order Statistics*, 152-156 (1995).

Prediction of SNR Gain for Passive Higher Order Correlation Detection of Energy Transients, Lisa A. Pflug, George E. Ioup, Juliette W. Ioup, and Robert L. Field, *Jour. Acoust. Soc. Am.* 98, 248-260 (1995).

Prefiltering for Improved Correlation Detection of Bandlimited Transient Signals, Lisa A. Pflug, George E. Ioup, Juliette W. Ioup, Robert L. Field, *Jour. Acoust. Soc. Am.* 95, 1459-1473 (1994).

Transient Signal Detection and Time Delay Estimation Using Higher Order Correlations and Spectra, L.A. Pflug, R. L. Field, G. E. Ioup, and J. W. Ioup, *Naval Research Laboratory Memorandum Report*, *NRL/MR/7173-93-7038* (1993).

Time Delay Estimation for Deterministic Transients Using Second and Higher Order Correlations, Lisa A. Pflug, George E. Ioup, Juliette W. Ioup, Robert L. Field, and James H. Leclere, *Jour. Acoust. Soc. Am.*

94, 1385-1399 (1993).

Prefiltering for Higher Order Advantage, George E. Ioup, Lisa A. Pflug, Juliette W. Ioup, and Robert L. Field, paper presented at the *IEEE Signal Processing Workshop on Higher-Order Statistics*, 7-9 June 1993, South Lake Tahoe, CA, and published in the *Proceedings*, 309-313 (1993).

Detection of Oscillatory and Impulsive Transients Using Higher Order Correlations and Spectra, Lisa A. Pflug, George E. Ioup, Juliette W. Ioup, Kenneth H. Barnes, Robert L. Field, and Grayson H. Rayborn, *Jour. Acoust. Soc. Am.* 91, 2763-2776 (1992).

Higher Order Correlations for the Detection of Deterministic Transients, George E. Ioup, Lisa A. Pflug, Juliette W. Ioup, Kenneth H. Barnes, Robert L. Field, James H. Leclere, and Grayson H. Rayborn, *Jour. of Underwater Acoustics* 40, 925-940 (1990).

Higher Order Correlations and Spectra and Detection and Time Delay Estimation for Deterministic Transients, Lisa A. Pflug, George E. Ioup, Juliette W. Ioup, Kenneth H. Barnes, Robert L. Field, James H. Leclere, and Grayson H. Rayborn, paper presented at the *Second NOARL/NRL/ONR Acoustic Transients Workshop*, Washington, D.C., 1-2 Nov 1990, and published in the *Proceedings*, *NOARL Publication No. PR 91:073:200*, p. 127-169 (1990).

Evaluation of Bicorrelations for Transient Detection, George E. Ioup, Juliette W. Ioup, Kenneth H. Barnes, Robert L. Field, James H. Leclere, and Grayson H. Rayborn, paper presented at the *ONR/NSF/IEEE Workshop on Higher-Order Spectral Analysis*, Vail, CO, 28-30 June 1989, and published in the *Proceedings*, p. 46-51 (1989).

Higher Order Correlations for Transient Detection, George E. Ioup, Juliette W. Ioup, Robert L. Field, and James H. Leclere, paper presented at the *ONR Acoustic Transient Workshop*, 13-17 Feb 1989, Naval Ocean Research and Development Activity, Stennis Space Center, and published in the *Proceedings* (*NRL Publication No. 152-5100*), p. 628-660 (1989).

Application of Acoustic Signal Processing Techniques for Improved Underwater Source Detection and Localization, George E. Ioup, Juliette W. Ioup, and Grayson H. Rayborn, *U.S. Navy Contract N00014-87-K-6002* (1988).

## **2.5 Symmetries, and Sampling and Aliasing Properties of Higher Order Correlations and Spectra**

We have deduced the symmetries of the trispectrum and have determined the sampling requirements for the bicorrelation, the tricorrelation, and any  $n$ th order correlation, and the resulting aliasing when these sampling requirements are not met. In spite of some disagreement in the literature, we feel that our results describe sampling requirements for both deterministic

energy signals and random power signals. The Master's theses with contributions to this area are by Rodrigue and Pflug.

A Review of Sampling Requirements and Aliasing for Higher Order Correlations, G.E. Ioup, L.A. Pflug, and J.W. Ioup, submitted to IEEE Trans. on Signal Processing.

Sampling Requirements for n-th Order Correlations, Lisa A. Pflug, George E. Ioup, and Juliette W. Ioup, Jour. Acoust. Soc. Am. 95, 2762-2765 (1994).

Sampling Requirements and Aliasing for Higher Order Correlations, Lisa A. Pflug, George E. Ioup, and Juliette W. Ioup, Jour. Acoust. Soc. Am. 94, 2159-2172 (1993).

Properties of Higher-Order Correlations and Spectra for Bandlimited, Deterministic Transients, Lisa A. Pflug, George E. Ioup, Juliette W. Ioup, and Robert L. Field, Jour. Acoust. Soc. Am. 91, 975-988 (1992).

## 2.6 Analysis of Airborne Electromagnetic Data

Research is in the analysis and signal processing for data gathered by airborne electromagnetic remote sensing. We have done inversions and examined the effects of noise removal and deconvolution. Using a modified image method developed by Bergeron we have inverted measured field data to determine layer thicknesses and conductivities. The Master's thesis with contributions to this area is by Drackett and the Doctoral Dissertation is by Bryan.

Case History: MIM and Nonlinear Least Squares Inversions of AEM Data in Barataria Basin, Louisiana, Melissa Whitten Bryan, Kenneth W. Holladay, Clyde J. Bergeron, Jr., Juliette W. Ioup, and George E. Ioup, Geophysics 68, 1126-1131 (2003).

Multilayer MIM inversion of AEM data: Theory and field example, Clyde J. Bergeron, Jr., Juliette W. Ioup, Yan Wu, George E. Ioup, and Kenneth W. Holladay, Geophysics 66, 125-136 (2001).

A new vertical continuation procedure for airborne electromagnetic field data from the modified image method, Clyde J. Bergeron, Jr., John Brusstar, Ningke Yi, Yan Wu, and Juliette W. Ioup, Geophysics 64, 1364-1368 (1999).

Comparison of Inversion Results from AEM Data to Field Measurements in Barataria Bay, Louisiana, Clyde J. Bergeron, Jr., Juliette W. Ioup, Yan Wu, George E. Ioup, Kenneth W. Holladay, Greg Hymel, Wayne H. Hudnall, L. Cecil Dharmasri, Ramona Pelletier, and Larry Rouse, Society of Exploration Geophysicists Proceedings, 2024-2027 (1998).

Delineation of Coastal Near-Surface Geology Using Airborne Electromagnetic Profiling, K.W. Holladay, C.J. Bergeron, J.W. Ioup, G.E. Ioup, Y. Wu, J.R. Brusstar, G. Hymel, A. Massasati, W.H. Hudnall, L.C. Dharmasri, R.E. Pelletier, and L.J. Rouse, Proc. 5<sup>th</sup> Intl.

Conf. on Remote Sensing for Marine and Coastal Environments, I pp. 451-458 (1998).

Layer Thickness and Conductivities from Inversion of AEM Data from Barataria Basin, Louisiana, Juliette W. Ioup, Clyde Bergeron, George E. Ioup, Yan Wu, John Brusstar, Kenneth W. Holladay, Proceedings of the American Society of Photogrammetry and Remote Sensing, 92-99 (1998).

Correlation of Inversion Results of AEM Data with Ground Measurements in Barataria Bay, Louisiana, Clyde J. Bergeron, Jr., Juliette W. Ioup, Yan Wu, George E. Ioup, Kenneth W. Holladay, Wayne H. Hudnall, L. Cecil Dharmasri, Ramona T. Pelletier, Proceedings of the AEM 98, International Conference on Airborne Electromagnetics, pages 2.p2 1-16 (1998).

Processes and Fate of Sediments and Carbon in Barataria Bay, Louisiana, R. L. Miller, M. Giardino, B.A. McKee, J.F. Cruise, G. Booth, R. Rovasek, D. Muirhead, W. Cibula, K. Holladay, R.E. Pelletier, W. Hudnall, C. J. Bergeron, J. Ioup, G. Ioup, and G. Love, Proceedings of the ERIM Third Thematic Conference on Remote Sensing for Marine and Coastal Environments Vol. I, 233-244 (1995).

Convolution Modeling for 1-D Inversion of 2-D AEM Sea Ice Data, Clyde J. Bergeron, Jr., Juliette W. Ioup, George E. Ioup, Long B. Trinh, Abolfazl M. Amini, and Austin Kovacs, paper presented at the Society of Exploration Geophysicists 1992 Annual Meeting, 25-29 Oct 92, and published in the Proceedings, 466-469 (1992).

The Upward and Downward Continuation of Airborne Electromagnetic Data, Clyde J. Bergeron, Jr., Terrence L. Morris, and Juliette W. Ioup, paper presented before the Society of Exploration Geophysicists, 23-27 Sep 1990, San Francisco. Paper published in Proceedings, p. 696-699.

Interpretation of Airborne Electromagnetic Data Using the Modified Image Method, Juliette W. Ioup, Clyde J. Bergeron, Jr., and Gus A. Michel, II, presented to the U.S.G.S. workshop on Developments and Applications of Modern Airborne Electromagnetic Surveys, Denver, CO, 7-9 Oct 1987, and published in Developments and Applications of Modern Airborne Electromagnetic Surveys, U. S. Geological Survey Bulletin 1925, p.75-79 (1990).

Theory of the Modified Image Method for Airborne Electromagnetic Data, Clyde J. Bergeron, Jr., Juliette W. Ioup, and Gus A. Michel, II, presented to the U.S.G.S. Workshop on Developments and Applications of Modern Airborne Electromagnetic Surveys, Denver, CO, 7-9 Oct 1987, and published in Developments and Applications of Modern Airborne Electromagnetic Surveys, U. S. Geological Survey Bulletin 1925, p.65-74 (1990).

Interpretation of Airborne Electromagnetic Data Using the Modified Image Method, Clyde J. Bergeron, Juliette W. Ioup, and Gus A. Michel, Geophysics 54,

1023-1030 (1989).

Modified Image Method for Inversion of Synthetic AEM Data, Clyde J. Bergeron, Jr., Juliette W. Ioup, and Gus A. Michel, II, Proceedings of the Louisiana Academy of Sciences 51, 48-59 (1988).

Lateral Resolution of the Modified Image Method for Sea-Ice Thickness, Clyde J. Bergeron, Jr., Juliette W. Ioup, and Gus A. Michel, II, paper presented before the Society of Exploration Geophysicists, 12-16 Oct 1987, New Orleans. Paper published in Proceedings, p. 55-58 (1987).

Application of MIM to Inversion of Synthetic AEM Bathymetric Data, Clyde J. Bergeron, Jr., Juliette W. Ioup, and Gus A. Michel, II, Geophysics 52, 794-801 (1987); abstract published in Geophysical Prospecting 35, 935-936 (1987).

Application of MIM to Inversion of Synthetic AEM Bathymetric Data, Clyde J. Bergeron, Jr., Juliette W. Ioup, and Gus A. Michel, II, paper presented before the Society of Exploration Geophysicists, 2-6 Nov 1986, Houston, TX. Paper published in Proceedings, 49-52 (1986), and abstract published in Geophysics 52, 382 (1987).

## 2.7 Modal Analysis of Tether Dynamics

We have applied spectral estimation techniques to determine the presence of and almost real-time analysis of the details of skiprope type oscillations and other dynamic modes in the tether used for tethered satellites in space, from the dynamics measurements made aboard the satellite. This knowledge is important for understanding the motion of the tether and in some situations for canceling the skiprope oscillations to retrieve the satellite.

Transform Domain Based Observation and Prediction of Tether Skiprope Oscillations for the TSS-1 Flight Experiment, Stephen M. Rodrigue, Abolfazl M. Amini, George E. Ioup, Juliette W. Ioup, Stan N. Carroll, D. Keith Mowery, Don D. Tomlin, Proceedings of the Fourth International Conference on Tethers in Space, 455-468 (1995).

Three-Dimensional Modal Development with Time and Tether Length as a Dynamics Diagnostic Tool for SEDS, Juliette W. Ioup, George E. Ioup, Stephen M. Rodrigue, and George M. Wood, Proceedings of the Fourth International Conference on Tethers in Space, 721-730 (1995).

Constrained Iterative Spectral Deconvolution for Analysis of Closely Spaced Modal Peaks in the Fourier Transform of Tethered Satellite Dynamics Data, Abolfazl M. Amini, George E. Ioup, and Juliette W. Ioup, Proceedings of the Fourth International Conference on Tethers in Space, 1461-1474 (1995).

Transform Domain Skiprope Observer, Steve M. Rodrigue, Abolfazl M. Amini, George E. Ioup, and Juliette W. Ioup, NASA Contract Number NAS8-

38841, 146 pages (June, 1994).

Detection of Skiprope Effects for the Tethered Satellite, Steve M. Rodrigue, Abolfazl M. Amini, Juliette W. Ioup, George E. Ioup, Stan Carroll, and Grayson H. Rayborn, paper presented at the Louisiana Aerospace Forum, University of New Orleans, 29-31 Jan 1992, and published in the Proceedings, pages 145-162 (1992).

## 2.8 Vector Map Data Compression with Wavelets

Storage and transmission of vector-map data can be improved if the data can be compressed, but the compression must not delete any critical information. For example, the speed of transmission of vector-map data from a ground transmitter station to a receiver in the cockpit of an aircraft can be increased if a compressed version of the data is available. Wavelets and wavelet transforms can be used for vector-map data compression. The choice of wavelet, the level of decomposition, the method of thresholding, the height of the threshold, relative CPU times and file sizes, and reconstructed map appearance have been investigated and quantitative error measures obtained. Compressions of 35 to 50 percent were obtained with small root-mean-square errors for wavelet packet decompositions. The Master's theses with contributions to this area are by Gendron and Hu.

Vector Map Data Compression with Wavelets, Juliette W. Ioup, Marlin L. Gendron, and Maura C. Lohrenz, Journal of Navigation 53, 437-449 (2000).

Wavelet Multi-scale Edge Detection for Extraction of Geographic Features to Improve Vector Map Databases, Marlin Gendron and Juliette W. Ioup, Journal of Navigation 53, 79-92 (2000).

Vector Map Data Compression with Wavelets, Juliette W. Ioup, Marlin L. Gendron, and Maura C. Lohrenz, Proceedings CD of the Symposium on Vector Moving Map Display, Alexandria, VA (1999).

Wavelet Multi-scale Edge Detection for Extraction of Geographic Features to Improve Vector Map Databases, Marlin Gendron and Juliette W. Ioup, Proceedings CD of the Symposium on Vector Moving Map Display, Alexandria, VA (1999).

## 2.9 Ocean Acoustic Measurements, Data Analysis, and Modeling

After previous modeling in underwater acoustics, we joined the University of Southern Mississippi and the Naval Research Laboratory-Stennis to form the Littoral Acoustic Demonstration Center (LADC) in 2001. LADC also works closely with the Naval Oceanographic Office at Stennis. Extensive underwater acoustic measurements were made in the

Gulf of Mexico in the summers of 2001, 2002, and 2003 and in the Mediterranean in the summers of 2002 and 2003, using bottom-moored hydrophones. We are currently heavily involved in data analysis. The Master's theses with contributions to this area are by Barron, Frichter, Paz, Lawrence, and Fusillo, and the Doctoral Dissertation is by Sidorovskaia.

Stationarity and Gaussianity of Shallow-Water Ambient Noise Dominated by Local Shipping, L. A. Pflug, G. E. Ioup, P. Jackson, and J. W. Ioup, submitted to J. Acoust. Soc. Am.

Measurements of Ambient Noise and Sperm Whale Vocalizations in the Northern Gulf of Mexico Using Near Bottom Hydrophones, Joal Newcomb, Robert Fisher, Robert Field, Grayson Rayborn, Stan Kuczaj, George Ioup, Juliette Ioup, Altan Turgut, presented at MTS/IEEE OCEANS2002, 29-31 Oct 2002, Biloxi, MS, and published in the Proceedings, 1365-1371 (2002).

Acoustic Pulse Propagation Studies in the Gulf of Mexico, Jerald W. Caruthers, Vladimir Kamenkovich, Natalia Sidorovskaia, Ilya Udovydchenkov, and George Ioup, presented at MTS/IEEE OCEANS2002, 29-31 Oct 2002, Biloxi, MS, and published in the Proceedings, 1434-1437 (2002).

Nonorthogonality of Measured Normal Modes in a Shallow Water Waveguide, Grayson H. Rayborn, Juliette W. Ioup, and George E. Ioup, book chapter in Acoustic Interaction with Submerged Elastic Structures, Vol. 3, Chapter 7, 215-238, Dr. Arde Guran, ed., World Scientific Publishing Company Pte. Ltd., (invited) (2002).

Modeling and Measuring the Acoustic Environment of the Gulf of Mexico, Joal Newcomb, Robert Fisher, Altan Turgut, Robert Field, George Ioup, Juliette Ioup, Grayson Rayborn, Stan Kuczaj, Jerald Caruthers, Ralph Goodman, and Natalia Sidorovskaia, presented at the Information Transfer Meeting of the Minerals Management Service, 8-10 Jan 2002, and published in the Proceedings, 509-521 (2002).

"Performance of sinusoidally deformed hydrophone arrays," Deanna M. Caveny, Donald R. Del Balzo, James H. Leclere, and George E. Ioup, Jour. Acoust. Soc. Am., 105, 2203-2209 (1999).

Variability in Higher Order Statistics of Measured Shallow-Water Shipping Noise, Lisa A. Pflug, George E. Ioup, Juliette W. Ioup, and Pamela Jackson, Proceedings of the IEEE Signal Processing Workshop on Higher Order Statistics, 400-404 (1997).

Moment Analysis of Ambient Noise Dominated by Local Shipping, Lisa A Pflug, Pam M. Jackson, Juliette W. Ioup, and George E. Ioup, Proceedings of the 8th IEEE Signal Processing Workshop on Statistical Signal and Array Processing, 271-74 (1996).

"A Brief Introduction to BEAMSTATPAK with Sample Calculations of Array Performance on Multiple Line Spectra," J. H. Leclere, D. R. Del Balzo, H. A.

Chandler, R. R. Slater, and G. E. Ioup, Naval Oceanographic and Atmospheric Research Laboratory Technical Note 49, 58 pages (May 1991).

"Density-Sound Velocity Relationships for Two Marine Surface Sediment Classes," Grayson H. Rayborn, Juliette W. Ioup, and George E. Ioup, Jour. Acoust. Soc. Am. 87, 2248-2251 (1990).

"Shallow Water and Under Ice Acoustic Propagation Report on Computer Models," Juliette W. Ioup, George M. Frichter, and George E. Ioup, NAVO Contract N62306-86-M-2200, 20 pages (Jan 1987).

Locating and Determining the Orientation of Underwater Research Equipment: Acoustic range and Range Rate Data, Gary A. Ransford and Juliette W. Ioup, IEEE Journal of Oceanic Engineering OE-12, 524-534 (1987)

"Northwest Atlantic REX Inverted Echo Sounder Location: Acoustic Doppler Data," Gary A. Ransford, Juliette W. Ioup, and Jim L. Mitchell, Marine Geodesy 10 (3/4), 185-203 (1986)

"Northwest Atlantic REX Inverted Echo Sounder Location: Acoustic Range Data," Gary A. Ransford, Juliette W. Ioup, and Jim L. Mitchell, Marine Geodesy 10 (2), 169-193 (1986)

## 2.10 Other Research

In addition to the above research areas, we have examined combining windows to improve spectral estimates, derivative filters using the discrete Fourier transform, the use of laser spectroscopy to analyze crude oil samples, finite element modeling around a borehole for well logging, and several other research topics. The Master's theses with contributions to this area are by Higgins, Broadhead, Kreamer, Smith, and Kathleen Whitehorn, and the Doctoral Dissertation is by Dean.

"On-site Analysis of Crude Oil Using Laser Spectroscopy," Melissa Gail Whitten, Ashok Puri, and George E. Ioup, Society of Exploration Geophysicists Proceedings, 1331-1334 (1996).

"Remote Sensing of Hydrocarbons Using a Portable Fluorimeter," Anthony M. Haag, Ashok Puri, and George E. Ioup, paper presented at the Society of Exploration Geophysicists 1994 Annual Meeting, 23-28 Oct 94, and published in the Proceedings, 580-583 (1994).

"Finite Element Method for EWR Tool in a Borehole Intersected by Bed Boundaries," Yajun Wu, Ashok Puri, and George E. Ioup, paper presented at the Society of Exploration Geophysicists 1993 Annual Meeting, 26-30 Sep 93, and published in the Proceedings, 385-388 (1993).

"Approximating the Finite Square Well with an Infinite Well: Energies and Eigenfunctions," Barry I. Barker, Grayson H. Rayborn, Juliette W. Ioup, and

George E. Ioup, Amer. Jour. of Physics 59, 1038-1042 (1991).

"Effect of Continuously Varying  $\rho$  in a Quadrupole Mass Spectrometer," Juliette W. Ioup, George M. Wood, and Mostofa Mosharrafa, paper presented before the 28th Annual Conference on Mass Spectrometry and Allied Topics, New York, May 1980. Paper published in Proceedings, 111-112 (1980).

"Derivatives of the Classical Deflection Function," G. E. Ioup and B. S. Thomas, J. Chem. Phys. 50, 5009-15 (1969).

### 3 Conclusions

Signal analysis research in the University of New Orleans Department of Physics has spanned diverse topics and been performed by many students and graduates. It is currently a quite active research component of the UNO Ph.D. Program in Engineering and Applied Science.

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### References

[1] P. H. Van Cittert, *Zum Einfluss der Spaltbreite auf die Intensitätsverteilung in Spektrallinien*, Z. Physik, Vol. 69, pp. 298-308, 1931.

[2] R. N. Bracewell and J. A. Roberts, *Aerial smoothing in radio astronomy*, Austral. J. Phys., Vol. 7, pp. 615-640, 1954.

### Appendix A – Signal Analysis/Signal Processing Theses and Dissertations directed or co-directed by Dr. George E. Ioup or Dr. Juliette W. Ioup

#### Theses

Ambient Noise Modeling in the Southern Hemisphere, Matthew Barron, Aug 2000 (Dr. Stanley Chin-Bing, co-director)

Predictive Deconvolution Analysis in the Frequency

Domain, Viki N. Keaton, December 1999

Wavelet Multiscale Edge Detection for Extraction of Geographic Features from High Resolution Satellite Images to Improve Vector Map Databases, Marlin L. Gendron, August 1999

Wavelet Transforms in Geophysics, Craig E. Higgins, May 1998

A Method for Improving the Signal-to-Noise Ratio and Resolution of Stable Amplitude Signals, Susan Gardner, December 1995

Indications of Environmental Drivers for High Frequency Phase Fluctuations, Christine T. Mire, August 1995

Optimization of Constrained Iterative Spectral Deconvolution for Adjacent Peaks, Weidong Hu, May 1995

Convolution Modeling of Airborne Electromagnetic Data, Robert S. Drackett, August 1994 (Dr. Clyde J. Bergeron, co-director), MS in Electrical Engineering

Identification of the Symmetries of Nth-Order Autocorrelations and Their Spectra with the Nth-Order Symmetric Group,  $S_n$ , Stephen Michael Rodrigue, August 1994 (Dr. John J. Sullivan, co-director)

Optimization of Iterative Deconvolution for Autocorrelation Estimation, Raghu K. Chunduru, August 1992

Higher Order Correlations and Spectra for the Detection of Deterministic Transients, Lisa A. Pflug, M.S. in Mathematics, May 1990

Least Squares Minimization for Spectral Regions of Combined Lag Windows, Michael Kent Broadhead, December 1989

Optimization of Single Filter Application of Always-Convergent Iterative Deconvolution, Haihong Ni, August 1989

The Extraction of the Predictive Deconvolution Wavelet and Its Use in Iterative Deconvolution Multiple Removal, Richard Alexander, August, 1988

Expanded Analysis of Combined Window Power Spectral Estimate Channel Clearing, James Kreamer, August 1988

Underwater Acoustic Pressure to Modal Amplitude Mapping for Wind Generated Noise in a Waveguide, George Michael Frichter, December 1987

Gibbs Oscillations for Three Point Sources, William S. Kamminga, December 1986

Effect of Input on Optimization of Morrison's Iterative Noise Removal for Deconvolution, Aed M. El-Saba, December 1986

Optimization of Convergent Iterative Noise Removal and Deconvolution and an Evaluation of Phase Shift Migration, Abolfazl M. Amini, December 1986

Always-Convergent Iterative Deconvolution for Acoustic Non-Destructive Evaluation, Edward J. Murphy, December, 1986, MS in Geology, Geophysics Option

Creating Clear Channels by Minimizing Sidelobes in Power Spectral Estimates Using Linear Combinations of Autocorrelation Windows, Henry Mark Smith, December 1985

Autocorrelation Estimation Using Iterative Spectral Deconvolution, Murali Ramaswamy, December, 1985

A Comparison of Convergent Iterative Deconvolution Methods with the Least Squares Technique for Synthetic Seismic Data, Reginald Powe, Department of Mathematics, August, 1985

Optimum Use of Morrison's Iterative Method of Noise Removal for Deconvolution, James Henry Leclere, August, 1984

Channel Digit Response for a Stationary Source and Receiver, Nils Paz, December, 1983 (Dr. William J. Jobst, co-director)

A Comparison of Beam-Forming Techniques for Hydrophone Arrays with Missing Elements, Mimi Zebrick Lawrence, December 1981 (Dr. Dan J. Ramsdale, co-director)

Always-Convergent Iterative Noise Removal and Deconvolution for Image Data, Mark A. Whitehorn, December, 1981

A Comparison of Ambient Noise Models with Ambient Noise Measurements, Lawrence J. Fusillo, May, 1981 (Dr. Thomas M. Davis, co-director)

A Study of Morrison's Iterative Noise Removal Method, Karin A. R. Wright, July, 1980

A Study of Derivative Filters Using the Discrete Fourier Transform, Kathleen A. Whitehorn, May, 1980

Applications of Iterative Smoothing and Deconvolution Techniques to Two-Dimensional Images, Edward J. Yoerger, December, 1978

The Gibbs Phenomenon for Gaussian, Lorentzian, and Triangle Functions, Alan J. Zeringue, December, 1977

The Gibbs Phenomenon and Resolution Enhancement, Robert L. Field, August, 1976

Resolution Enhancement for Non-Fixed Linear Systems, William C. Bivens, May, 1976

Deconvolution for Resolution Enhancement, Norman Ross Hill III, December 1973

## Dissertations

Time Domain Study of Acoustic Pulse Propagation in an Ocean Waveguide Using a New Normal Mode Model, Natalia A. Sidorovskaia, PhD in Engineering and Applied Science, May 1997 (Dr. Michael F. Werby, co-director)

Comparison of MIM and Least Squares Inversions for Baratara Bay AEM Data, Melissa G. Whitten Bryan, Ph.D. in Engineering and Applied Science, December 2001 (Dr. Ken W. Holladay, co-director)

Prefiltering for Improved Unknown and Known Source Correlation Detection of Broadband Oscillatory Transients and Predicting the Onset of Paroxysmal

Atrial Fibrillation Using Feature Extraction and A Hamming Neural Network, Marcella E. Dean, May 2003

Channel Order Selection in Blind Deconvolution Based on Eigenvector Characteristics and Using Normal Modes in Conjunction with Multipath Compression for Source Identification, James P. Larue, August 2003

## Appendix B – UNO Department of Physics Signal Analysis/Signal Processing Courses

PHYS 4205 Physical Applications of the Fourier Transform. Physical application of the Fourier transform and series, convolution, and basic theorems; sampling and data treatment; and introduction to Fourier methods in geophysics and optics.

PHYS 6205 Digital Filtering and Image Processing. The discrete Fourier transform and the fast Fourier transform in physical applications; noise characteristics and techniques of noise removal; one-dimensional image enhancement and restoration; two-dimensional image processing; and applications to seismic data, pictures, and other physical data. Includes: Fourier series, Gibbs oscillations, the DFT, the FFT, FFT algorithms, DFT theorems, two-dimensional Fourier Transforms, two-dimensional DFTs, coordinate axes, origin location, symmetries, redundancies for the one- and two-dimensional DFTs of complex and real data, Laplace and Z transforms.

PHYS 6206 Image Restoration and Enhancement. Stochastic data and noise; windows; deconvolution techniques: Fourier, least squares, predictive, iterative, minimum entropy; Wiener filter; and noise removal.

PHYS 6207 Digital Filtering and Spectral Analysis I. There will first be a review of linear systems, Fourier transforms, matrices, and random processes. New content will include classical spectral estimation; parametric models of random processes; autoregressive, moving average, and autoregressive-moving average models; AR spectrum properties, AR spectral estimation, and AR block data algorithms.

PHYS 6208 Digital Filtering and Spectral Analysis II. Autoregressive spectral estimation: sequential data algorithms; ARMA spectral estimation; Prony's method; minimum variance spectral estimation; and Eigenvector approaches.

PHYS 6191 Introduction to Wavelets. Time, frequency, and scale; comparison to Fourier transforms, time-frequency analysis and sampling,

wavelet bases, useful theorems, dilation and wavelet equations, filters and filter banks, bases and frames, down- and up-sampling, wavelet and scaling equations, perfect reconstruction, orthonormality, biorthogonality, accuracy, recursion and cascades, eigenvalues and eigenvectors

PHYS 6195 Wavelet Applications. Review of wavelet basics, filter banks, wavelet families, design methods, compression, denoising, geophysical applications, underwater acoustic applications, medical applications, miscellaneous applications