Chad M. Spooner

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cyclostationary.blog

OBJECTIVE

To contribute to the advanced R&D of signal-processing methods for scientific, medical, industrial, and military applications involving natural or manmade signals and systems.

EDUCATION

Ph.D. in Electrical Engineering, University of California, Davis, 1992, with an emphasis on signal processing and a minor in pure mathematics. Winner of two best-dissertation awards. Dissertation title: "Theory and Application of Higher-Order Cyclostationarity."

MS in Electrical Engineering, University of California, Davis, 1988. Thesis title: "Performance Evaluation of Detectors for Cyclostationary Signals."

BS in Electrical Engineering, University of California, Berkeley, 1986.

AS, Santa Rosa Junior College, Santa Rosa, CA, 1984, with *High Honors*.

PROFESSIONAL EXPERIENCE

Board of Directors Member (Elected), NorthWest Research Associates, 2020-present.

Vice President, NorthWest Research Associates, 2024-present.

Senior Scientist/Engineer, NorthWest Research Associates, Monterey, CA, 10/05-present. Principal investigator on multiple contracts involving advanced signal-processing research and development. Customers include the Naval Research Lab, Air Force Research Lab, Johns Hopkins University Applied Physics Lab, NASA, Lockheed Martin Company, Tektronix, Echo Ridge, BAE Systems, Alpine Method Technologies, Expedition Technology, and Virginia Polytechnic Institute and State University.

Applications for the developed technology include RF surveillance; government regulation of public bands; RF equipment failure diagnosis; spectrum monitoring, survey, and planning; interference characterization and mitigation for radio astronomy and industry; preprocessing for signal separation; and signal detection, classification, and white-space detection for cognitive radio networks.

Other work includes: wavelet-based signal processing for EEG-based brain-state classification, adaptive transmit filtering using the modified DFT filterbank, signal-processing algorithms for wideband ionospheric probes, design of modulation-recognition and parameter-estimation algorithms to facilitate interference cancellation, development of low-cost noise-tolerant signal detection and classification algorithms for modern communication standards such as ATSC DTV, 802.11a/b/g, Bluetooth, etc.

Author of the Cyclostationary Signal Processing Blog, cyclostationary.blog, 2015-present. The blog presents all aspects of the theory and practice of cyclostationary signal processing, providing accessible explanations and illustrations of mathematical results, algorithms, and applications found in the literature. The intersection of CSP and modern machine-learning algorithms, which is the application of modulation recognition, is also explored by extensive analysis and critical review of the open literature. The CSP Blog also features a sequence of posts called the Signal Processing ToolKit, which covers all relevant aspects of basic signal processing as applied to the analysis of communication signals. The CSP Blog receives over 70,000 page views a year from more than 17,000 visitors per year from over 75 countries.

Organizer and Principal Architect of the AFRL/NSIN *RF Spectrum-Sharing Challenge*, 2023-2025.

Visiting Scholar, Nanyang Technical University, Singapore, February 2017.

Lecturer, **Naval Postgraduate School, 2008-2010 and 2021**: *Introduction to Linear Systems* and *Digital Signal Processing*. Responsible for all aspects of courses.

Scientist/Engineer, ATK Mission Research, Monterey, CA, 9/99-10/05.
Responsible for obtaining funding and providing technical labor for government contracts and commercial opportunities involving communication theory, system design, and performance evaluation. Areas of expertise include automatic signal detection and classification, cyclostationary signal processing, error-control coding including turbo codes, wavelet-based image classification, spectral analysis, higher-order statistics, and scientific computing.

Scientist/Engineer, Statistical Signal Processing, Inc., 4/97-6/99.
I performed R&D in the area of communication systems with emphasis on signals intelligence applications.

Scientist/Engineer, Mission Research Corporation, Monterey, CA, 2/94-3/97.
R&D on sophisticated digital signal processing algorithms for problems in the area of communication signal processing.

Visiting Professor, University of Naples "Federico II", Naples ITALY, 11/94.
Presented a series of six lectures on statistical signal processing using higher-order moments and cumulants.

Postdoctoral Researcher, UC Davis, 6/92-1/94.
Research focused on the further development of the theory of higher-order cyclostationarity.

Programmer, SSPI, 1/90-6/95.
Implemented in C a commercially available cyclic spectrum analyzer program and associated data-handling routines.

Engineering Consultant, SSPI, 11/88-1/94.

Responsible for the continuing development of signal processing algorithms for signal detection and parameter estimation.

System Administrator, UC Davis, 6/92-1/94.
Responsible for maintaining Unix workstations and peripherals for the Cyclostationarity Signal Processing Laboratory staff.

Teaching Assistant, UC Davis, 9/86-10/87, 1/89-4/89.
Responsible for instructing upper-division students in analog and digital circuit theory and practice, and digital signal processing.

Instructor, Far West High School, Oakland, CA, 1/86-5/86.
Taught computer familiarization and the BASIC programming language to sophomore high-school students.

Student Engineering Assistant, **Hewlett-Packard Corp., 6/84-9/84**.

ACADEMIC SERVICE

Lead Mentor (Coach). FIRST Robotics Competition, Carmel High School (FRC Team 2035, The Rockin' Bots), Carmel, CA, 2024-present.

Adjunct Research Professor, Virginia Tech, 2008-2012.

Academic Advisor to MS students at the Naval Postgraduate School, 1995-2000, 2019; PhD Students at SUNY Buffalo (2008-2015); PhD students at Old Dominion University; PhD and MS students at Virginia Tech (2007-2011); PhD students at West Virgina University (current).

Technical Reviewer for multiple IEEE journals, ongoing.

Student Representative (Elected) to the Graduate Program and Research Committee of the faculty of the Department of ECE, UC Davis, 1990-1992.

Organizer of the *Second Workshop on Cyclostationary Signals*, The DoubleTree Hotel, Monterey, CA, Aug. 1-2, 1994.

Organizer of a special session on cyclostationary signals, *The Twenty-Ninth Asilomar Conference on Signals, Systems, and Computers*, Pacific Grove, CA, Oct. 31-Nov. 2, 1995.

President, Treasurer, and Founding Member of The Engineering Club (TEC), Santa Rosa Junior College, Santa Rosa, CA, 1982-1984.

HONORS

Lockheed Martin MUOS Program Award for Technical Excellence, 7/2007 and 1/2011.

Mission Research Corporation's Technical Achievement Award: Best MRC Paper of 1996 for *Algorithm Development for Signals Intelligence Applications*.

The Allen G. Marr Prize for Distinguished Doctoral Dissertation in Mathematics, Engineering, and the Physical Sciences (UCD) 6/95.

The Sigma Xi Award of Recognition for Doctoral Research, 5/94.

Toward Outstanding Post-Graduate Studies Award (UCD), 2/89.

William Carr Memorial Scholarship for Transferring Engineering Students (SRJC), 6/84.

Milton Hoehn Mathematics Scholarship (SRJC), 6/84.

The SRJC Engineering Department Scholarship, 6/84.

MEMBERSHIP IN PROFESSIONAL ASSOCIATIONS

The Institute of Electrical and Electronics Engineers, Senior Member, 1988-present.

Sigma Xi, The Scientific Research Society, 1992-present.

LINKS

Research Gate:
https://www.researchgate.net/profile/Chad_Spooner/

Google Scholar:
http://scholar.google.com/citations?user=hwCQv-4AAAAJ&hl=en&oi=ao

NorthWest Research Associates:
http://www.nwra.com/people.php#chadspooner

LinkedIn:
http://www.linkedin.com/in/chad-spooner-9991602

Cyclostationary Signal Processing Blog:
https://cyclostationary.blog

SELECTED INVITED PRESENTATIONS

Association of Old Crows, March 2022**,** "Introduction to Cyclostationary Signal Processing with Application to Signal Detection, Characterization, and Recognition."

The Mitre Corporation, April 2022, "Cyclostationary Signal Processing."

West Virginia University, Department of Physics and Astronomy, February 2021. "Introduction to Cyclostationary Signal Processing for Blind Signal Detection and Characterization."

National Radio Astronomy Observatory, December 2020. "Introduction to Cyclostationary Signal Processing for Blind Signal Detection and Characterization."

Nanyang Technological University, Singapore, February 2017. "Introduction to Cyclostationary Signal Processing," and "Modulation Recognition in CSP."

Drexel University, Department of Electrical and Computer Engineering, "Tunnelized Cyclostationary Signal Processing: Low-Cost Noise- and Interference-Tolerant Signal Detection and Modulation Recognition."

US Navy Hack-The-Machine Event, Boston, September 2017. "Cyclostationary Signal Processing: Noise- and Interference-Tolerant Blind Detection and Modulation Recognition Using the NWRA Whisper System."

IEEE 802.22 Sensing Tutorial at the IEEE 802 Plenary Meeting, San Diego, 2014. "Spectrum Occupancy Sensing."

Carmel High School Career Day, Carmel CA, 2011, 13, 15, 17. "A Career in Research Engineering."

PUBLICATIONS

Peer-reviewed journal papers (1992-2024): *IEEE Transactions on Signal Processing*, *IEEE Transactions on Communications*, *IEEE Transactions on Wireless Communications*, *IEEE Transactions on Cognitive Communication and Networking, EURASIP Journal on Advances in Signal Processing*; *IEEE Transactions on Broadcasting*; *IEEE Trans Aerospace and Electronic Systems; IEEE Signal Processing Letters.*

Book chapters and theses: Six book chapters, two academic theses.

Conference papers: Over thirty-five.

Internal technical reports: Over one hundred.

Journal Papers

W. A. Gardner and C. M. Spooner, "Signal Interception: Performance Advantages of Cyclic-Feature Detectors," *IEEE Transactions on Communications*, **40**, 1, Jan. 1992, pp. 149-159.

W. A. Gardner and C. M. Spooner, "Comparison of Auto- and Cross-Correlation Methods for Signal-Selective TDOA Estimation," *IEEE Transactions on Signal Processing*, **40**, 10, Oct. 1992, pp. 2606-2608.

C. M. Spooner and W. A. Gardner, "Robust Feature Detection for Signal Interception," *IEEE Transactions on Communications*, **42**, 5, May 1994, pp. 2165-2173.

W. A. Gardner and C. M. Spooner, "Detection and Source Location of Weak Cyclostationary Signals: Simplifications of the Maximum-Likelihood Receiver," *IEEE Transactions on Communications*, **41**, 6, June1993, pp. 905-916.

W. A. Gardner and C. M. Spooner, "The Cumulant Theory of Cyclostationary Time-Series, Part I: Foundation," *IEEE Transactions on Signal Processing*, **42**, 12, Dec. 1994, pp. 3387-3408.

C. M. Spooner and W. A. Gardner, "The Cumulant Theory of Cyclostationary Time-Series, Part II: Development and Applications," *IEEE Transactions on Signal Processing*, **42**, 12, Dec. 1994, pp. 3409-3429.

A. Napolitano and C. M. Spooner, "Median-Based Cyclic Polyspectrum Estimation," *IEEE Transactions on Signal Processing*, **48**, 5, May 2000, pp. 1462-1466.

A. Napolitano and C. M. Spooner, "Cyclic Spectral Analysis of Continuous-Phase Modulated Signals," *IEEE Transactions on Signal Processing*, **49**, 1, Jan. 2001, pp. 30-44.

A. Punchihewa, Q. Zhang, O. A. Dobre, C. M. Spooner, S. Rajan, and R. Inkol, "On the Cyclostationarity of OFDM and Single Carrier Linearly Digitally Modulated Signals in Time Dispersive Channels: Theoretical Developments and Applications," *IEEE Transactions on Wireless Communications*, **9**, 8, August 2010, pp 2588-2599.

P. H. Sahmel, J. H. Reed, and C. M. Spooner, "Eigenspace Approach to Specific Emitter Identification," *Frequenz*, December 2010.

C. M. Spooner and N. Khambekar, "A Signal-Processing Perspective on Signal-Statistics Exploitation in Cognitive Radio," *Journal of Communications*, **7**, 7, July 2012.

C. M. Spooner and A. N. Mody, "Wideband Cyclostationary Signal Processing Using Sparse Subsets of Narrowband Subchannels," *IEEE Trans. Cognitive Communications and Networking*, **4**, 2, pp. 162-176, June 2018.

M. Carrick, J. H. Reed, and C. M. Spooner, "Paramorphic Multicarrier Communications for Interference Mitigation," *EURASIP Journal on Advances in Signal Processing*, January 2018.

M. Carrick, J. H. Reed, and C. M. Spooner, "OFDM and Radar Co-Existence using Frequency Shift Filters," *IEEE Trans Aerospace and Electronic Systems*, **55**, pp. 1146-1159, 2019.

J. Hofmann, A. Knopp, C. M. Spooner, G. Minelli, and J. Newman, "Spectral Correlation for Signal Presence Detection and Frequency Acquisition of Small Satellites," Multidisciplinary Digital Publishing Institute (MDPI), *Aerospace*, 2021.

J. A. Snoap, D. C. Popescu, J. A. Latshaw, and C. M. Spooner, "Deep-Learning-Based Classification of Digitally Modulated Signals Using Capsule Networks and Cyclic Cumulants," *MDPI Sensors*, June 2023, https://www.mdpi.com/1424-8220/23/12/5735/pdf, DOI: 10.3390/s23125735.

J. A. Snoap, D. C. Popescu, and C. M. Spooner, "Deep-Learning-Based Classifier with Custom Feature-Extraction Layers for Digitally Modulated Signals," *IEEE Transactions on Broadcasting,* May 2024.

C. J. Li , R. Rademacher, D. Boland, C. T. Jin, C. M. Spooner, P. H. W. Leong, "S3CA: A Sparse Strip Spectral Correlation Analyzer," *IEEE Signal Processing Letters*, February 2024, DOI: 10.1109/LSP.2024.3364062.

Book Chapters and Academic Theses

C. M. Spooner, "Performance Evaluation of Detectors for Cyclostationary Signals," MS Thesis, University of California, Davis, June 1998.

C. M. Spooner, "Theory and Application of Higher-Order Cyclostationarity," Ph.D. Dissertation, University of California, Davis, June 1992.

C. M. Spooner, "Higher-Order Statistics for Nonlinear Processing of Cyclostationary Signals," Chapter in *Cyclostationarity in Communications and Signal Processing*, New York: IEEE Press, 1994, pp. 91-167.

W. A. Gardner and C. M. Spooner, "Cyclostationary Signal Processing," Chapter in *Control and Dynamic Systems, Vol. 65, Stochastic Techniques in Digital Signal Processing Systems, Part 2 of 2*, New York: Academic Press, 1994, pp. 1-92.

C. M. Spooner and R. B. Nicholls, "Spectrum Sensing Based on Spectral Correlation," Chapter 18 in *Cognitive Radio Technology*, Second Edition, Ed. Bruce Fette, 2009.

Conference Papers

W. A. Gardner and C. M. Spooner, "Cyclic Spectral Analysis for Signal Detection and Modulation Recognition," *Proceedings of the Conference on Military Communications (MILCOM)*, San Diego, CA, Oct. 1988, pp. 419-423.

W. A. Gardner and C. M. Spooner, "Higher-Order Cyclostationarity, Cyclic Cumulants, and Cyclic Polyspectra," *Proceedings of the International Symposium on Information Theory and Its Applications (ISITA)*, Honolulu, HI, Nov. 27-30, 1990, pp. 355-358.

C. M. Spooner and W. A. Gardner, "Estimation of Cyclic Polyspectra," (invited paper) *Proceedings of the Twenty-Fifth Annual Asilomar Conference on Signals, Systems, and Computers*, Pacific Grove, CA, Nov. 4-6, 1991, pp. 370-376.

C. M. Spooner and W. A. Gardner, "An Overview of the Theory of Higher-Order Cyclostationarity," *Proceedings of the Workshop on Nonstationary Stochastic Processes*, Singapore: World Scientific, 1992, pp. 110-125.

C. M. Spooner and W. A. Gardner, "Exploitation of Higher-Order Cyclostationarity for Weak-Signal Detection and Time-Delay Estimation," *Proceedings of the Sixth Workshop on Statistical Signal & Array Processing*, Victoria, British Columbia, Canada, Oct. 7-9, 1992, pp. 197-201.

C. M. Spooner and W. A. Gardner, "Performance Evaluation of Cyclic Polyspectrum Estimators," (invited paper) *Proceedings of the Twenty-Sixth Annual Asilomar Conference on Signals, Systems, and Computers*, Pacific Grove, CA, Oct. 26-28, 1992, pp. 477-483.

W. A. Gardner, C. M. Spooner, and G. K. Yeung, "Frequency-Shift Filtering for Cochannel Signal Separation,*" Proceedings of the CRASP Conference on Cochannel Demodulation*, Fort Meade, MD, June 2, 1994.

G. Fong, C. M. Spooner, and W. A. Gardner, "An Algorithm for Further Improvements in Signal-Selective Time-Difference Estimation,*" Proceedings of the Second Workshop on Cyclostationary Signals*, Monterey, CA, Aug. 1-2, 1994, pp. 10.1-10.7.

C. M. Spooner, "An Overview of Recent Developments in Cyclostationary Signal Processing," *Proceedings of the Second Workshop on Cyclostationary Signals*, Monterey, CA, Aug. 1-2, 1994, pp. 1.1-1.17.

C. M. Spooner, "Classification of Cochannel Communication Signals using Cyclic Cumulants," (invited paper) *Proceedings of the Twenty-Ninth Annual Asilomar Conference on Signals, Systems, and Computers*, Oct. 31-Nov. 2, 1995, pp. 531-536.

C. M. Spooner, W. A. Brown, and G. K. Yeung, "Automatic Radio-Frequency Environment Analysis," *Proceedings of the Thirty-Fourth Annual Asilomar Conference on Signals, Systems, and Computers*, Oct. 31, 2000.

C. M. Spooner, M. P. Clark, and L. T. McWhorter, "Wavelet-Based Compression of HRR Radar Data for Moving Targets,*" Proceedings of the Thirty-Fourth Annual Asilomar Conference on Signals, Systems, and Computers*, Oct. 31, 2000.

C. M. Spooner, "On the Utility of Sixth-Order Cyclic Cumulants for RF Signal Classification," *Proceedings of the Thirty-Fifth Annual Asilomar Conference on Signals, Systems, and Computers*, Nov. 4-7, 2001.

C. M. Spooner, "Applications of Local Discriminant Bases to HRR-Based ATR," *Proceedings of the Thirty-Fifth Annual Asilomar Conference on Signals, Systems, and Computers*, Nov. 4-7, 2001.

K. Kim, I. A. Akbar, K. K. Bae, J. Um, C. M. Spooner, and J. H. Reed, "Cyclostationary Approaches to Signal Detection and Classification in Cognitive Radio," *Proceedings of DySPAN 2007*.

C. M. Spooner, "Filterbanks for Adaptive Transmit Filtering," Proceedings *of MILCOM 2007*, Orlando FL, October 2007.

C. M. Spooner, "Multi-Resolution White-Space Detection for Cognitive Radio," *Proceedings of MILCOM 2007*, Orlando FL, October 2007.

K. Kim, C. M. Spooner, I. Akbar, and J. H. Reed, "Specific Emitter Identification in Cognitive Radio Applications," *Global Communications Conference 2008*, New Orleans, LA, December 2008.

N. V. Khambekar, C. M. Spooner, and V. Chaudhary, "Listen-While-Talk for Primary User Protection," *Wireless Communications and Networking Conference*, Budapest, Hungary, April 2009.

C. M. Spooner and N. Khambekar, "Spectrum Sensing for Cognitive Radio: A Signal Processing Perspective on Signal-Statistics Exploitation," Invited Position Paper for the *International Conference on Computing, Networking, and Communications*, Maui, Hawaii, January 2012.

C. M. Spooner, E. Viirre, and B. Chase, "From Explicit to Implicit Speech Recognition," Invited Paper in *Proceedings of the 2013 HCI International Conference*, Las Vegas, NV, July 2013.

D. L. Knepp, C. M. Spooner, and M. A. Hausman, "A Wideband Channel Probe for Space Situational Awareness," *2013 Beacon Satellite Symposium*, Bath, UK, July 8-10, 2013.

C. M. Spooner, A. N. Mody, J. Chuang, and M. P. Anthony, "Tunnelized Cyclostationary Processing: A Novel Approach to Low-Energy Spectrum Sensing," Invited Paper in *Proceedings of the 32nd Annual Conference on Military Communications (MILCOM '13),* San Diego, CA, November 2013.

N. V. Khambekar, C. M. Spooner, and V. Chaudhary, "On Improving Serviceability with Quantified Dynamic Spectrum Access," *Proceedings of DySPAN 2014*, McLean, VA, April 2014.

N. V. Khambekar, V. Chaudhary, and C. M. Spooner, "Estimating the Use of Spectrum for Defining and Enforcing the Spectrum Access Rights," *Proceedings of the 34th Annual Conference on Military Communications (MILCOM '15)*, Tampa, Florida, October 2015.

N. V. Khambekar, C. M. Spooner, V. Chaudhary, "Quantified Discrete Spectrum Access (QDSA) Framework", *Telecommunications Policy Research Conference (TPRC),* Sep. 2015 (Poster Presentation).

N. V. Khambekar, C. M. Spooner, V. Chaudhary, "Characterization of the Missed Spectrum-Access Opportunities Under Dynamic Spectrum Sharing," *Proceedings of COMSNETS 2016*, Bangalore, India, Jan. 2016 (in press).

N. V. Khambekar, C. M. Spooner, and V. Chaudhary, "MUSE: A Methodology for Quantifying Spectrum Usage," *Proceedings of Globecom 2016*, Washington DC, December 2016.

C. M. Spooner, A. N. Mody, J. Chuang, and J. Petersen, "Modulation Recognition Using Second- and Higher-Order Cyclostationarity," *Proceedings of DySPAN 2017*, Baltimore, MD, March 2017.

J. Hofmann, A. Knopp, C. M. Spooner, G. Minelli, and J. Newman, "Spectral Correlation Based Detection of GFSK Modulated LEO Satellite Signals at Very Low SINR," *Asilomar Conference on Signals, Systems, and Computers*, Pacific Grove, CA, 2020.

J. Hofmann, C. M. Spooner, and A. Knopp, "Conjugate Cyclic Feature Detection in the Presence of LEO-Satellite Doppler Effects," *Asilomar Conference on Signals, Systems, and Computers*, Pacific Grove, CA, 2021.

J. A. Snoap, D. C. Popescu, and C. M. Spooner, "On Deep Learning Classification of Digitally Modulated Signals Using Raw I/Q Data," *IEEE Consumer Communications and Networking Conference*, Jan. 2022.

J. A. Latshaw, D. C. Popescu, J. A. Snoap, and C. M. Spooner, "Using Capsule Networks to Classify Digitally Modulated Signals with Raw I/Q Data," *The 14th International Conference on Communications (COMM2022)*," Bucharest, Romania, June 2022.

J. A. Snoap, J. A. Latshaw, D. C. Popescu, and C. M. Spooner, "Robust Classification of Digitally Modulated Signals Using Capsule Networks and Cyclic Cumulant Features," *Proceedings of the Conference on Military Communications (MILCOM)*, Rockville, MD, November 2022.

D. Roy, V. Chaudhury, C. Tassie, C. M. Spooner, and K. Chowdhury, "ICARUS: Learning on IQ and Cycle Frequencies for Detecting Anomalous RF Underlay Signals," *Proceedings of InfoCom 2023*, New York, May 2023.

J. A. Snoap, D. C. Popescu, and C. M. Spooner, "Novel Nonlinear Neural-Network Layers for High Performance and Generalization in Modulation-Recognition Applications," *Proceedings of the Conference on Military Communications (MILCOM)*, Boston, MA, November 2023.

K. Witham, N. M. Prabhu, A. Sultan, M. Necsoiu, C. M. Spooner, and G. Schirner, "Utilizing Terrain-Generation to Derive Realistic Channel Models for Automatic Modulation Recognition," *SPIE Conference on Synthetic Data for Artificial Intelligence and Machine Learning: Tools, Techniques, and Applications II*, National Harbor, MD, Apr. 2024 (poster presentation).