Advanced Radar Detection and Applications
Tutorial for 2024 International Radar Conference, Rennes - France

Tutorial Abstract:

We teach advanced radar detection from first principles and develop the concepts behind Space-Time Adaptive Processing (STAP) and advanced, yet practical, adaptive algorithms for realistic data environments. Detection theory is reviewed to provide the student with both the understanding of how STAP is derived, as well as to gain an appreciation for how the assumptions can be modified based on different signal and clutter models. Radar received data components are explained in detail and the mathematical models are derived so that the student can program their own MATLAB or other simulation code to represent target, jammer and clutter from a statistical framework and construct optimal and suboptimal radar detector structures. The course covers state-of-the-art STAP techniques that address many of the limitations of traditional STAP solutions, offering insight into future research trends.

Instructors:

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Dr. Michael Picciolo, Anduril Industries, picciolo@ieee.org

Dr. Robert Lee, Parsons Corporation, robert.lee@parsons.us

Bio-sketches:

Dr. Scott Goldstein is a Senior Vice President at Parsons Corporation and has served at executive levels in government, industry and academia. He achieved the rank of Major General in the United States Air Force and has led organizations in industry as well as served as a Chief Technology Officer, Chief Strategy Officer and Chief Scientist. He has performed fundamental research and development in radar detection and estimation theory, Space Time Adaptive Processing and advanced systems concepts. He is a Fellow of the IEEE and a member of the IEEE Radar Systems Panel. He received the 2002 IEEE Fred Nathanson Radar Engineer of the Year Award and the 2019 IEEE Warren D. White Award for Excellence in Radar Engineering.

Dr. Mike Picciolo is Senior Radar and EW Architect at Anduril Industries, in the Electronic Warfare organization. Previously, he was Director of Mission Engineering in the Engineering, Integration and Logistics Division at SAIC. Previously he served as Chief Technology Officer, NSS Division, at ENSCO. Prior, he was the Associate Chief Technologist for Dynetics and Chief Engineer of the Advanced Missions Solutions Group in Chantilly, VA. He has in-depth expertise in Radar, ISR systems, Space Time

Adaptive Processing and conducts research in advanced technology development programs. Has deep domain expertise in SAR/GMTI radar, communications theory, waveform diversity, wireless communications, hyperspectral imagery, IMINT, SIGINT, and MASINT intelligence disciplines. He is a member of the IEEE Radar Systems Panel, received the 2007 IEEE Fred Nathanson Radar Engineer of the Year Award, the 2018 IEEE AESS Outstanding Organizational Leadership Award, and founded the IEEE Radar Summer School series.

Dr. Robert Lee is a Vice President at Parsons Corp. He has performed research and development in electronic warfare systems and advanced systems multidomain concepts involving ISR, space superiority, and remote sensing. Dr. Lee has authored 32 refereed publications in a variety of technical disciplines, including high-energy, nuclear, and solar physics, hypersonics, applied mathematics, and laser spectroscopy. He has been recognized nationally for his space resiliency and multidomain operations work, including being awarded the National Reconnaissance Office's Gold Medal..

Intended Audience:

This tutorial is for anyone interested in learning advanced concepts and practical solutions to modern radar detection and estimation problems with emphasis on statistical adaptive signal processing. The students will also be able to use the course notes to simulate the radar target, clutter, jamming and processing algorithms using programming languages such as MATLAB.

Suggested Prerequisites:

Students should have some basic background in areas of radar, signal processing and linear algebra to get the most benefit.

Learning Outcomes:

This tutorial is very important to bridge the gap between radar detection theory and practice; the concepts behind adaptive detectors; constant false alarm rate (CFAR) detectors; STAP; and practical algorithms to implement viable processing approaches in real systems. Many examples are presented that illustrate how the core processing algorithms can be applied to all aspects of radar.

Topics (over 4 hours):

Part 1 – Introduction, Classic Radar Detection cases.

Part 2 - Space-Time Radar Signal Environment, Optimal Wiener Filter.

Part 3 – Adaptive algorithms, Reduced rank algorithms, Multistage Wiener Filter.

Part 4 – Real world data environments, robust STAP algorithms, Summary.

Prior Presentations:

This tutorial has evolved at the IEEE Radar and International Radar Conferences almost every year since 1997. As the more relevant material becomes available over time the content has been modified to ensure students are presented with timely, useful and currently relevant information and practical examples.

Typical attendance has been strong throughout the ~27 years with excellent reviews (about 25-40 students per event), even from students who took it more than once as the content evolved.

Appendix: Selected papers, All Presenters

1. H.E. Witzgall and J.S. Goldstein, **Reduced-rank spectrum estimation with ROCKET**, *IEEE Transactions on Signal Processing*, Vol. 51, No. 7, July 2003.

2. S. Chowdhury, M.D. Zoltowski and J.S. Goldstein, **Reduced-rank Chip-level MMSE equalization for the 3G CDMA forward link with code multiplexed pilot**, invited paper, *EURASIP Journal on Applied Signal Processing*, special issue on 3G wireless communications and beyond, August 2002.

3. D.A. Garren, A.C. Odom, M.K. Osborn, J.S. Goldstein, S.U. Pillai and J.R. Guerci, **Full-polarization matched-illumination for target detection and identification**, *IEEE Transactions on Aerospace and Electronic Systems*, Vol. 38, No. 3, July 2002.

4. M.L. Honig and J.S. Goldstein, **Adaptive reduced-rank interference suppression based on the multistage Wiener filter**, *IEEE Transactions on Communications*, Vol. 50, No. 6, June, 2002.

5. D.A. Garren, M.K. Osborn, A.C. Odom, J.S. Goldstein, S.U. Pillai and J.R. Guerci, **Enhanced target detection and estimation via optimized radar transmission pulse shape**, *IEE Proc.-Radar, Sonar Navig*., special issue on modeling and simulation, June 2001.

6. J.R. Guerci, J.S. Goldstein and I.S. Reed, **Optimal and adaptive reduced-rank STAP**, invited paper, *IEEE Transactions on Aerospace and Electronic Systems*, special section on space-time adaptive processing, Vol. 36, No. 2, pp. 647-663, April 2000.

7. C.D. Peckham, A.M. Haimovich, T.F. Ayoub, J.S. Goldstein and I.S. Reed, **Reduced-rank STAP performance analysis**, *IEEE Transactions on Aerospace and Electronic Systems*, special section on space-time adaptive processing, Vol. 36, No. 2, pp. 664-676, April 2000.

8. I.S. Reed, J.S. Goldstein, X. Yu and P. Singer, **A multidisciplinary perspective on adaptive sensor array processing**, invited paper, *IEE Proc.-Radar, Sonar Navig.*, Vol. 146, No. 5, pp. 221-234, October 1999.

9. J.S. Goldstein, I.S. Reed and P.A. Zulch, **Multistage partially adaptive STAP detection algorithm**, *IEEE Transactions on Aerospace and Electronic Systems*, Vol. 35, No. 2, pp. 645-662, April 1999.

10. J.S. Goldstein, I.S. Reed and L.L. Scharf, **A multistage representation of the Wiener filter based on orthogonal projections**, *IEEE Transactions on Information Theory*, Vol. 44, No. 7, pp. 2943-2959, November 1998.

11. J.S. Goldstein and I.S. Reed, **Theory of partially adaptive radar**, *IEEE Transactions on Aerospace and Electronic Systems*, Vol. 33, No. 4, pp. 1309-1325, October 1997.

12. J.S. Goldstein and I.S. Reed, **Subspace selection for partially adaptive sensor array processing**, *IEEE Transactions on Aerospace and Electronic Systems*, Vol. 33, No. 2, pp. 539-544, April 1997.

13. J.S. Goldstein and I.S. Reed, **Reduced-rank adaptive filtering**, *IEEE Transactions on Signal Processing*, Vol. 45, No. 2, pp. 492-496, February 1997.

14. J.S. Goldstein and I.S. Reed, **Performance measures for optimal constrained beamformers**, *IEEE Transactions on Antennas and Propagation*, Vol. 45, No. 1, pp. 11-14, January 1997.

15. Gerlach, K., Picciolo, M., **Robust, Reduced Rank Loaded Reiterative Median Cascaded Canceller**, IEEE Trans. Aerospace and Electronic Systems (AES) journal, Vol. 47, No. 1, January 2011, pp. 15 - 25.

16. Picciolo, M.L., Gerlach, K, **A Reiterative Median Cascaded Canceller for Robust Adaptive Array Processing**, IEEE Trans. Aerospace and Electronic Systems (AES) journal, Vol. 43, No.2, April, 2007, pp. 428–442.

17. Gerlach, K.; Blunt, S.D.; Picciolo, **Robust adaptive matched filtering using the FRACTA algorithm**, M.L., IEEE Transactions on Aerospace and Electronic Systems, Volume: 40, Issue: 3, July 2004, pp. 929–945.

18. Picciolo, M.L.; Gerlach, K., **Median cascaded canceller for robust adaptive array processing**, IEEE Transactions on Aerospace and Electronic Systems, Volume: 39, Issue: 3, July 2003, pp. 883–900.

19. Gerlach, K.; Picciolo, **Airborne/spacebased radar STAP using a structured covariance matrix**, M.L., IEEE Transactions on Aerospace and Electronic Systems, Volume: 39, Issue: 1, January 2003, pp. 269–281.

20. Michael L. Picciolo, J. Scott Goldstein, Wilbur L. Myrick, *Invited Paper*, **M-Cancellers: Tunable, Robust, Rapid Converging, Parallel/Pipeline Adaptive Processors**, Special Session in Memoriam of Dr. Karl Gerlach, IEEE International Radar Conference, Washington, DC, April 27-May1, 2020.

21. M. Picciolo, W. Myrick, J. S. Goldstein, **A Quadrature Median Matched Filter For Robust Detection and Estimation**, Paper #303, IEEE/SEE International Radar Conference, Toulon, France, Sept. 24-26, 2019.