

# ULTRASONIC SIGNAL PROCESSING FOR DETECTION, ESTIMATION AND IMAGING

Jafar Saniie, Ramazan Demirli and Erdal Oruklu

**Course Description:** In ultrasonic imaging systems, the patterns of detected echoes, often complex and non-stationary, correspond to the shape, size, and orientation of the reflectors and the scattering properties of the propagation path. Therefore, signal modeling and parameter estimation of the nonstationary ultrasonic echoes is critical for image analysis, target detection, object recognition, deconvolution and data compression. In this short course, we present (1) modeling and classification of reverberant echoes, (2) time-frequency analysis and chirplet echo estimations, (3) detection and deconvolution of ultrasonic backscattered echoes using expectation-maximization and matching pursuit methods, (4) statistical signal processing techniques based on split-spectrum processing for detecting flaw echoes masked by high grain scattering noise, and (5) system-on-chip realization of detection and estimation algorithms using reconfigurable FPGA devices. This course will cover several case studies such detecting defects in steam generator tubes used in nuclear power plants, transducer pulse-echo wavelet estimation, subsample time delay estimation, thickness sizing of thin layers, and flaw detection in large grained materials.

**Jafar Saniie** received his B.S. degree in Electrical Engineering from the University of Maryland in 1974. He received his M.S. degree in Biomedical Engineering in 1977 from Case Western Reserve University, Cleveland, OH, and his Ph.D. degree in Electrical Engineering in 1981 from Purdue University, West Lafayette, IN. In 1981 Dr. Saniie joined the Department of Applied Physics, University of Helsinki, Finland, to conduct research in photothermal and photoacoustic imaging. Since 1983 he has been with the Department of Electrical and Computer Engineering at Illinois Institute of Technology where he is the Filmer Professor, Director of the Embedded Computing and Signal Processing (ECASP) Research Laboratory, and Associate Chair and Director of Graduate Program. Dr. Saniie's research interests and activities are in ultrasonic signal and image processing, statistical pattern recognition, estimation and detection, embedded digital systems, digital signal processing with field programmable gate arrays, and ultrasonic nondestructive testing and imaging. In particular, he has performed extensive work in the areas of frequency diverse ultrasonic flaw enhancement techniques, ultrasonic data compression, ultrasonic imaging of reverberant multilayer structures, time-frequency analysis of ultrasonic signals, and applications of neural networks for detecting flaw echoes and classifying microstructural scattering. Dr. Saniie has been a Technical Program Committee member of the IEEE Ultrasonics Symposium since 1987 (currently he is the chair of Sensors, NDE and Industrial Applications), Associate Editor of the *IEEE Transactions on Ultrasonics, Ferroelectrics, and Frequency Control* since 1994. He has over 190 publications and supervised 22 Ph.D. dissertations.

**Ramazan Demirli** received the B.S. degree in electronics and communications engineering from the University of Uludag, Bursa, Turkey, in 1991. In 1993, he won a scholarship from the Turkish Ministry of Education to study abroad. He received his M.S. and Ph.D. degree in Electrical and Computer Engineering from the Illinois Institute of Technology, Chicago, IL, in 1995 and 2000 respectively. He specializes in statistical signal processing with extensive emphasis on ultrasonic applications. In particular, he has developed model-based estimation techniques for ultrasonic signal analysis and parameter estimation. From 2000 to 2003 Dr. Demirli was with BrainMedia, LLC, New York, NY, where he worked on the development of a proprietary audio codec. Dr. Demirli is currently with Canfield Scientific, Inc., Fairfield, NJ, where he conducts research for skin imaging systems.

**Erdal Oruklu** received his B.S. degree in Electronics and Communications Engineering from Technical University of Istanbul, Turkey in 1995, his M.S. degree in Electrical Engineering from Bogazici University, Istanbul, Turkey in 1999 and his Ph.D. degree in Computer Engineering from Illinois Institute of Technology, Chicago, Illinois in 2005. He joined Department of Electrical and Computer Engineering, Illinois Institute of Technology as an Assistant Professor in 2005. He is the director of VLSI and SoC Design Research Laboratory. Dr. Oruklu's research interests are reconfigurable computing, advanced computer architectures, hardware/software co-design, embedded systems and high-speed computer arithmetic. In particular, he focuses on the research and development of system-on-chip (SoC) frameworks for FPGA and VLSI implementations of realtime ultrasonic detection, estimation and imaging applications. Dr. Oruklu has more than 45 technical publications. He is a senior member of IEEE.