Introduction to the Special Issue on Novel Equipment for Ultrasound Research

This special issue is dedicated to novel ultrasound research equipment and its applications. Ultrasound research laboratories, especially in academia, are typically expected to propose novel approaches for, e.g., transmission or reception of ultrasound, signal and image processing methods, theoretical investigations, or experimental procedures. Usually less effort is dedicated to hardware developments. However, available commercial systems do not always fit the needs for testing the proposed novel approaches, and dedicated equipment has thus to be made. A large amount of development work is indeed performed in many research laboratories, as testified by the large number of papers (24) submitted to this special issue.

The 15 papers selected for publication report the contributions from several groups, which have been engaged in a broad range of hardware design. Novel transducers, dedicated electronic systems, research interfaces, and development platforms are described. In most cases, the novel systems enabled research which otherwise was difficult or not feasible with existing commercial equipment.

The issue starts with five papers describing the development of novel ultrasound transducers. The ultrasonic ring transducer system described by Waag and Fedewa (Rochester, NY, USA) consists of 2048 elements and is capable of synthesizing arbitrary transmit and receive apertures, producing steered beams as well as spatially limited plane waves. A new approach for fabricating high frequency linear array transducers, based on laser micromachining, is reported by Lukacs *et al.* (Toronto, ON, Canada), who also present a 30-MHz 64-element, 74-micron pitch linear array design. Two different transducers have been implemented in the laboratories of Rotterdam, Utrecht, and Twente (The Netherlands). One is a prototype by Merks *et al.* of a multi-layer transducer (a PZT transducer for transmission and a PVDF layer for reception) dedicated to noninvasive bladder volume measurements. The second, by Voormolen *et al.*, is a special ultrasound transducer based on a 64-element phased array that, for acquisition of a full 3-D dataset, can rotate with a maximum speed of 8 Hz. The paper by Harvey and Gachagan (Glasgow, Scotland) describes a novel system employing laser interferometry and tomographic reconstruction for field measurements of transducers used inside sealed vessels.

The 5 papers following describe research interfaces and platforms suitable for use in a variety of applications. M. Ashfaq *et al.* in Germany (Bochum) and the United States (Issaquah, WA; Urbana, IL; and Durham, NC) describe a research interface to a commercial ultrasound system which can store beamformed radio-frequency data and provide additional control over the machine. The paper by Wilson *et al.* (Memphis, TN, and Madison, WI) reports on a complete ultrasound system which provides access to the data at multiple points in the signal processing chain and allows control over most imaging parameters. The FEMMINA system described by Masotti *et al.* (Florence, Italy) can use RF data from a scanner and then perform real-time processing on it and display the result. The system is highly configurable and has standard libraries for processing. Lu *et al.* (Toledo, OH) illustrate a general purpose high frame rate medical imaging system with 128 independent linear transmitters and receiver channels, and its application to a new limited-diffraction array beam imaging method. Ricci *et al.* (Florence, Italy) present a compact real-time development system capable of simultaneously transmitting arbitrary waveforms to two probes, storing the received RF echo data in a file, and/or processing them in real-time according to programmable algorithms.

Systems developed to test new methods for improving the quality of ultrasound images are described in the next two papers. The work developed in Madrid, Spain, by Fritsch *et al.* introduces a novel approach for digital ultrasound beam forming using programmable look-up tables, and reports on the implementation of a modular prototype based on low-cost FPGAs. Dahl *et al.* (Durham, NC, and Rochester, NY) present a versatile adaptive imaging system capable of compensating for phase errors by updating arrival time profiles at up to 2 frames per second.

Finally, the last group of papers reports on the implementation of original ultrasound systems dedicated to specific applications. Frijlink *et al.* (Rotterdam and Utrecht, The Netherlands) describe a prototype intravascular ultrasound system that can operate in both fundamental frequency and second harmonic imaging modes by using a continuously-rotating single-element catheter (transmit 20 MHz, receive 40 MHz). The cooperation between the Universities of Leicester, UK, and Florence, Italy, has led to the development by Fan *et al.* of an integrated system for acquisition and processing of both intra- and extracranial Doppler signals, and automatic embolic signal detection. Finally, a different application field is explored in the paper by Álvarez *et al.* (Cáceres and Madrid, Spain), who describe a sonar prototype employing pulse compression techniques to reduce the collision probability in outdoor operations with hostile atmospheric conditions.

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The Guest Editors wish to thank all the authors who have submitted papers to this special issue, demonstrating the large and important efforts dedicated by research laboratories to the development of novel ultrasound equipment. We wish also to gratefully acknowledge the high quality work of the reviewers, who have patiently dedicated a great deal of their time to improving the quality of submitted manuscripts.

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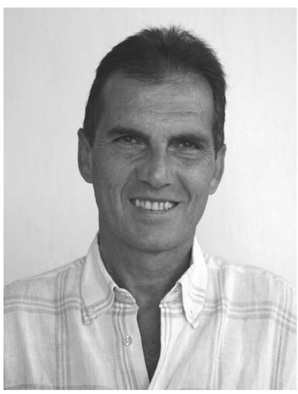

Piero Tortoli (M'91–SM'96) received the Laurea degree in Electronic Engineering from the University of Florence, Italy, in 1978. Since then, he has been with the Electronics and Telecommunications Department of the University of Florence, where he is currently a full professor of Electronics. His main interests are in the area of signal processing algorithms and systems with application in the field of biomedical ultrasound.

Piero has been a member of the IEEE International Ultrasonics Symposium Technical Program Committee since 1999. He was Chairman of the 22nd International Symposium on Acoustical Imaging (1995), co-Chairman of the ICB Seminar on Ultrasound in Biomeasurements, Diagnostics and Therapy (1998), and Chairman of the 12th New England Doppler Conference (2003). In 2000 he was nominated Honorary Member of the Polish Academy of Sciences. He has published over 120 papers related to his research activity on ultrasonic imaging and Doppler techniques.

Jørgen Arendt Jensen (M'93–SM'02) earned his Master of Science in electrical engineering in 1985 and the Ph.D. degree in 1989, both from the Technical University of Denmark. He received the Dr.Techn. degree from the university in 1996. He has published more than 150 journal and conference papers on signal processing and medical ultrasound and the book *Estimation of Blood Velocities Using Ultrasound*, Cambridge University Press, in 1996.

He is also developer of the Field II simulation program. He has been a visiting scientist at Duke University, Stanford University, and the University of Illinois at Urbana-Champaign. He is currently full professor of Biomedical Signal Processing at the Technical University of Denmark at Ørsted•DTU, adjunct professor at the Faculty of Health Sciences, University of Copenhagen, and head of Center for Fast Ultrasound Imaging. He has given courses on blood velocity estimation at both Duke University and University of Illinois and teaches biomedical signal processing and medical imaging at the Technical University of Denmark. He has given several short courses on simulation, synthetic aperture imaging, and flow estimation at international scientific conferences. He is also the co-organizer of a new biomedical engineering education program offered by the Technical University of Denmark and the University of Copenhagen. His research is centered around simulation of ultrasound imaging, synthetic aperture imaging and blood flow estimation, and constructing systems for such imaging.