2005 IEEE International Ultrasonics Symposium
September 18 - 21, 2005

Rotterdam - The Netherlands

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Getting Started

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Welcome

2005 IEEE International Ultrasonics Symposium
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Be sure to read the "Getting Started" section for useful recommendations on how to use this electronic guide.

Thank you and enjoy!

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Welcome

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Editor's Note 2005

The 2005 IEEE Ultrasonics Symposium is the third time in history that the Ultrasonics Symposium has been held in a European venue, Rotterdam, Netherlands. As with the preceding symposia at Cannes in 1994 and at Munich in 2002, this year's symposium has exceeded the expectations of the organizers. Once again, the abstracts, manuscripts and copyright were all submitted electronically. Over 90 percent of those papers submitted have been included in the proceedings.

I would like to thank the staff at FASS and IEEE for their extraordinary publishing support.

To all the authors who contributed manuscripts for these Proceedings, THANK YOU, for making this conference a success and supporting the documentation of such a strong technical exchange.

Additional copies of the Proceedings may be obtained by contracting the IEEE Service Center, 445 Hoes Lane, P.O. Box 1331, Piscataway, NJ 08855-1331.

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2005 IEEE International Ultrasonics Symposium
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Welcome to Rotterdam

It is indeed a pleasure to welcome you to the 2005 IEEE International Ultrasonics Symposium. It will be held in Rotterdam, The Netherlands, from September 18 through September 21, 2005. The conference will be held in "De Doelen", a conference centre at Rotterdam Central Railway Station, which is a 40-minute train ride from Schiphol, Amsterdam International Airport. It is a modern, very well equipped conference centre that is perfectly suited for conferences around 1000 delegates.

Rotterdam is a multicultural city that has an interesting mixture of traditional and modern architecture. It has many museums, covering art, natural history, cultural anthropology, maritime life and many other topics with art collections ranging from Dutch masters through African sculptures to contemporary art. All museums are within easy walking distance from the conference centre. Rotterdam hosts the largest port in the world and both the river and the harbor create a special atmosphere in the city. The Pilgrim fathers started their journey from the Pilgrims' church in the harbor of Rotterdam and Hotel New York, the cruise terminal of the Holland America Line, the main historic cruise line between the USA and Europe can also be found here.

Other than the museums and historic sites, Rotterdam has an extensive cultural and sports program. At the Doelen the grand finale of the Gergiev festival of the Rotterdam Philharmonic Orchestra will be given the Saturday night before the IEEE conference. The final of the World Championship Baseball will be on the same evening in the Neptunus stadium, the home of the European champion and since Feyenoord, one of the top 3 soccer teams of the Netherlands plays a home match on Sunday, we will try to arrange tickets for delegates. Please check the conference website for details.

It will be the third visit to Europe for the IEEE International Ultrasonics Symposium, and we trust that the Rotterdam conference in 2005 will be as successful as the Cannes conference in 1994 and the Munich conference in 2002.

Hope to meet you all in Rotterdam, Best Regards,

Ton van der Steen

General chair

WELCOME FROM THE TECHNICAL PROGRAM CHAIR

On behalf of the Technical Program Committee (TPC), I welcome you to the 2005 IEEE International Ultrasonics Symposium.

This year we had 876 abstract submissions. This is approximately 100 submissions more than submitted in both of the previous two years. In order to accommodate this growth, we have added an additional parallel oral session that is shared among the different subgroups that make up the overall symposium. Planning for the symposium required extensive effort by the Technical Program Committee leading up to the TPC meeting held on June 18th and 19th, 2005 in Chicago, IL. The acceptance rate was approximately 75% and is in line with historical levels. In particular, we have observed significant growth in Sensors and Physical Acoustics this year. This is likely a function of the physical location of the conference (i.e. Europe) where the balance of medical related, versus non medical related, funding is more even than is found in North America (for example). (A similar trend can also be observed in the distribution of abstracts at the successful 2002 Munich conference.)

In line with previous years, we have held the total length of the conference to one day of short courses and a full three days of six oral sessions in parallel and three large poster sessions, without a single gap any where in the program. In view of the increased number of parallel sessions, I ask that all concerned (speakers and session chairs) keep the conference strictly on time.

We have 18 eminent invited speakers providing a range of talks spanning a historical review of a famous scientist (Lord Rayleigh) to overviews of exciting and new technical growth areas. We will also continue our tradition of holding a student poster competition. These posters will remain on display for the entire conference. The winners of the competition will each receive a certificate and a $100 cash prize.

Regards,

John A. Hossack
2005 IEEE Ultrasonics Symposium Technical Chair

SYMPOSIUM ORGANIZING COMMITTEE



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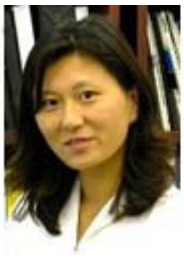
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Peter Smith: McMaster University, Canada
Robert Weigel: University of Erlangen-Nuremberg, Germany

GROUP 5: Transducers and Transducer Materials
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Short Courses
September 18, 2005

1 - Medical Ultrasound Transducers
8 -12 am
Douglas G. Wildes & L. Scott Smith
GE Global Research Center - Niskayuna, NY, USA

2 - Elasticity Imaging: Principles, Systems, Approaches and Applications
8 -12 am
Stanislav Emelianov
University of Texas - Austin, Texas, USA

3 - Ultrasound Contrast Agents: Theory and Experimental Results
8 -12 am
Nico de Jong & Michel Versluis
Erasmus MC - Rotterdam, the Neth. & University of Twente - Enschede, the Neth.

4 - Recent Trends in Beam formation in Medical Ultrasound
1 - 5 pm
Kai Thomenius
General Electric's Corporate R&D - Niskayuna, NY, USA

5 - Micromachined Ultrasonic Sensors and Actuators
1 - 5 pm
Ville Kaajakari, Amit Lal, and Richard White
Cornell University - Ithaca, NY & University of California - Berkeley, CA

6 - Clinical Applications of Diagnostic Ultrasound
1 - 5 pm
Folkert ten Cate and Juiry W. Wladimiroff
Erasmus MC - Rotterdam, the Netherlands

7 - Non-linear Acoustics and Harmonic Imaging
6 - 10 pm
Victor Humphrey
Southampton University - Southampton, UK

8 - Finite Element Modelling of Ultrasound Applications
6 - 10 pm
Paul Reynolds
Weidlinger Associates Inc - Los Altos, USA

9 - Flow Measurements and Doppler
6 - 10 pm

Hans Torp
Norwegian University of Science and Technology - Trondheim, Norway

Short Course Abstracts and Instructor Information

1 - Medical Ultrasound Transducers

This course will provide an introduction to the design, fabrication, and testing of medical ultrasound transducers. Starting from an overview of the basic types of phased-array transducers (linear, convex, sector), we will discuss how the design for a probe is derived from its target application and how equivalent-circuit, finite-element, and acoustic field models can be used to optimize the design and accurately predict performance. A discussion of the structure of an ultrasound probe will lead to a survey of the different types of materials used in probes and their critical properties. Typical fabrication processes will be introduced and common problems in probe manufacturing will be summarized. Methods for evaluating completed transducers will be discussed. The course will highlight recent developments in probe technology, including. single crystal piezoelectrics, cMUT transducers, multi-row and 2D arrays, and electronics in probes, and will discuss performance advantages and fabrication difficulties which may be associated with each.

Douglas G. Wildes is a physicist with GE Global Research. He earned an A.B. in physics and mathematics from Dartmouth College and a Ph.D. in low-temperature physics from Cornell University, then joined GE in 1985. Since 1991, Dr. Wildes' research has focused on aperture design, fabrication processes, and high-density interconnect technology for multi-row and 2D transducers for medical ultrasound. Dr. Wildes has 19 issued patents and 18 external publications. He is a member of the American Physical Society and a Senior Member of the IEEE.

L. Scott Smith is a physicist with GE Global Research. He earned B.S. and Ph.D. degrees in physics from the University of Rochester and the University of Pennsylvania respectively. Joining GE in 1976, he developed phased array probes for medical ultrasound. More recently, he examined novel probe materials and led projects on pediatric endoscopes and adaptive acoustics. Dr. Smith has 37 issued patents and over 35 refereed publications. He is a member of the American Physical Society and a Senior Member of the IEEE where he serves as Vice Chair for Transducers on the Ultrasonics Symposium's Technical Program Committee.

2 - Elasticity Imaging: Principles, Systems, Approaches and Applications

Elasticity imaging is rapidly evolving into a new diagnostic and treatment-aid tool. The primary purpose of this course is to provide both a broad overview and comprehensive understanding of elasticity imaging, and, as such, it is well suited for both newcomers and active researchers in the field. Starting with a historical

introduction to elasticity imaging, we begin to lay a foundation for static and dynamic approaches in elasticity imaging with a brief discussion of theory of elasticity including both the equation of equilibrium and the wave equation. We will also review the mechanical properties of soft tissues. Then, experimental aspects of elasticity imaging will be discussed with emphasis on data capture, signal and image processing algorithms to measure internal tissue motion induced by either internally or externally applied forces. Motion tracking methods will be introduced, and techniques to increase and optimize signal-to-noise ratio in strain imaging will be overviewed. Finally, techniques to map elasticity and other mechanical properties of tissue will be presented and discussed. Following an overview of elasticity imaging, the ultrasound elasticity imaging techniques and their biomedical and clinical applications will be presented. Advantages and limitations of each approach will be discussed and contrasted with other elasticity imaging techniques such as MRI or optical elastography. The course will conclude with overview of several experimental and commercial systems capable of ultrasound elasticity imaging, and discussion of current and potential clinical applications of elasticity imaging.

Stanislav Emelianov received the B.S. and M.S. degrees in physics and acoustics in 1986 and 1989, respectively, from the Moscow State University, and the Ph.D. degree in physics in 1993 from Moscow State University, and the Institute of Mathematical Problems of Biology of the Russian Academy of Sciences, Russia. In 1989, he joined the Institute of Mathematical Problems of Biology, where he was engaged in both mathematical modeling of soft tissue biomechanics and experimental studies of noninvasive visualization of tissue mechanical properties. Following his graduate work, he moved to the University of Michigan, Ann Arbor, as a post-Doctoral Fellow in the Bioengineering Program, and Electrical Engineering and Computer Science Department. From 1996 to 2002, Dr. Emelianov was a Research Scientist at the Biomedical Ultrasonics Laboratory at the University of Michigan. During his tenure at Michigan, Dr. Emelianov was involved primarily in the theoretical and practical aspects of elasticity imaging. Dr. Emelianov is currently an Assistant Professor of Biomedical Engineering at the University of Texas, Austin. His research interests are in the areas of medical imaging for therapeutics and diagnostic applications, ultrasound microscopy, elasticity imaging, photoacoustical imaging, cellular/molecular imaging, and functional imaging.

3 - Ultrasound Contrast Agents: Theory and Experimental Results

The course consists of 6 mean topics:
a) First an overview will be presented of the (clinical and pre-clinical available) contrast agents, including the properties and characteristics of the gas inside the bubble and the shell surrounding it.
b) Models of the behavior of small bubbles in a ultrasound field will be discussed. Simple models based on a one dimensional mass-spring system and more complicated models including gas and shell properties.

c) Experimental ultrasound methods for UCA will be presented for characterizing the bubbles in a UCA, like harmonic and subharmonic scattering, absorption and attenuation. Also the influence of ambient pressure, temperature and gas concentration will be discussed.
d) Experimental optical methods for characterizing individual bubbles.
e) Imaging methods for contrast agents, like fundamental, harmonic, subharmonic and superharmonic and multi-pulse methods like pulse inversion, power modulation etc. and new methods like chirp excitation.
f) Ultrasound mediated drug delivery: Interaction between mammalian cells and ultrasound in the vicinity of bubbles will be discussed.

Nico de Jong graduated from Delft University of Technology, The Netherlands, in 1978. He got his M.Sc. in the field of pattern recognition. Since 1980, he has been a staff member of the Thoraxcenter of the Erasmus University Medical Center, Rotterdam, The Netherlands. At the Dept. of Biomedical Engineering, he developed linear and phased array ultrasonic probes for medical diagnosis, especially compound and transesophageal transducers. In 1986 his interest in ultrasound applications shifted toward the theoretical and practical background of ultrasound contrast agents. In 1993 he received his Ph.D. for "Acoustic properties of ultrasound contrast agents." Currently he is interested in the development of 3-D transducers and fast framing camera systems. De Jong is the project leader of STW and FOM projects on ultrasound contrast imaging and drug delivery systems. Together with Folkert ten Cate, MD, he is organizer of the annual European Symposium on Ultrasound Contrast Imaging, held in Rotterdam and attended by approximately 175 scientists from all over the world. Since 2003 Nico de Jong is part-time professor at the University of Twente.

Michel Versluis graduated in Physics in 1988 at the University of Nijmegen, the Netherlands, with a special interest in Molecular Physics and Astrophysics. Later, he specialized in the application of intense tunable UV lasers for flame diagnostics resulting in a successful defense of his PhD thesis in 1992. Michel Versluis is now a lecturer at the University of Twente, the Netherlands, in the Physics of Fluids group working on the experimental study of bubbles and jets in multiphase flows and granular flows. He also works on the use of microbubbles as a tool for medical diagnosis and therapy. Dr. Versluis teaches various courses in Fluid Mechanics, one of them focusing on the physics of bubbles.

4 - Recent Trends in Beamformation in Medical Ultrasound
The goal of this introductory course is to review the design of ultrasound front ends and beamformers from a linear systems point of view including transduction, beamformation, and image formation functions. We will discuss analytical methods used in developing the design of a typical beamformer in use in diagnostic ultrasound today. The key points to be covered deal with methods of analysis of arrays and beamformers, the interaction of transmit and receive beams with clinically relevant targets, and how this interaction is used in image formation. The means by which these analytical methods contribute to a

beamformer design and the trade-offs involved are reviewed. The techniques developed for such analysis will be applied to topics of current interest involving beamformation such as system miniaturization, 2D arrays, synthetic aperture techniques, and aberration correction.

Kai E. Thomenius is a Chief Technologist in the Imaging Technologies Organization at General Electric's Global Research facility in Niskayuna, NY. His focus is on Ultrasound and Biomedical Engineering. Previously, he has held senior R&D roles at ATL Ultrasound, Inc., Interspec Inc., Elscint, Inc., Inc as well as several other ultrasound companies, and is currently an Adjunct Professor in the Electrical, Computer, and Systems Engineering Department at Rensselaer Polytechnic Institute where he teaches a course in general imaging. Dr. Thomenius' academic background is in electrical engineering with a minor in physiology; all of his degrees are from Rutgers University. His long-term interests have been in ultrasound beamformation and miniaturization of ultrasound scanners, propagation of acoustic waves in inhomogeneous media such as tissue, the potential of bioeffects due to those acoustic beams, and determination of additional diagnostic information from the echoes that arise from such beams. Recently he has contributed to work on coherent beamformers in millimeter wave radar applications. He is a Fellow of the American Institute of Ultrasound in Medicine.

5 - Micromachined Ultrasonic Sensors and Actuators

Part A: The goal of this part is to introduce the fundamentals of micromachining, and the way they affect the design and performance of ultrasonic sensors and actuators. We will cover established micromachining techniques, such as bulk micromachining and surface micromachining on silicon. Material on thin film deposition and foundries will be presented. The relevant acoustic and ultrasonic properties of materials used in MEMS will be discussed for predictable device design. Nonlinearities, material property gradients, and internal stresses will be covered to describe their effect on design.

Part B: Case studies of sonic MEMS will be presented. These include (1) electrostatic actuation of micromachined membranes, nonlinearities and effective electromechanical coupling, (2) comparison of PZT and thin-film piezoelectric actuation of silicon bulk and surface micromachined structures (silicon horn design, microphones, speakers, flexural plate waves, FBARS), and (4) nonlinear ultrasound in microfluidic devices, and (5) Micro resonators for RF communications.

Amit Lal is an associate professor of electrical and computer engineering at Cornell University. He received his Ph. D. in electrical engineering from the University of California, Berkeley in 1996, and the B.S. degree from the California Institute of Technology in 1990. Amit Lal is the leader of the SonicMEMS group

at Cornell University, which focuses on ultrasonics, micromachining, modeling of piezoelectric systems, use of radioactive energy sources in microsystems, and design and analysis of integrated circuits. He has published papers on ultrasonic sensors and actuators at conferences in ultrasonics and micromachining. He serves on the Technical Committee on Physical Acoustics in the IEEE Ultrasonics, Ferroelectrics, and Frequency Control Society. He holds patents on micromachined acoustic sources/receivers, and silicon-based high-intensity ultrasonic actuators. He is also the recipient of the NSF CAREER award for research on applications of ultrasonic pulses to MEMS.

Richard M. White is a professor of EECS and a founding co-director of the Berkeley Sensor & Actuator Center at the University of California at Berkeley, Dick White has concentrated on ultrasonics and microsensors. He has published on thermoelastic wave generation, SAW transduction, and flexural plate-wave sensors. He has co-authored three books - a text for freshmen, a book on solar cells, and the reference book "Acoustic Wave Sensors". White is a member of the National Academy of Engineering, and has received awards for his contributions to ultrasonics from the IEEE and the Ultrasonics and Frequency Control societies of the UFFC. His present research interests include ultrasonic airborne particulate monitoring and wireless passive proximity metering of AC power use in dwellings.

Ville Kaajakari received his M.S. and Ph.D. degrees in electrical and computer engineering fromUniversity of Wisconsin-Madison in 2001 and 2002, respectively. He is currently Senior Research Scientist at VTT Information Technology, Finland, where his research interest is RF-MEMS.

6 - Clinical Applications of Diagnostic Ultrasound
The goal of this introductory course is to review the clinical applications of ultrasound imaging in cardiology. The presentation will be illustrated with realtime 2D and 3D Echoimages.

Folkert J ten Cate MD is director of the clinical echolaboratory of the Thoraxcenter , Erasmus MC in Rotterdam.His main interest is in cardiomyopathies and ultrasound contrast both for diagnosis and treatment. He is a Fellow of the American College of Cardiology and the European Society of Cardiology.

Professor Juiry W. Wladimiroff was born in The Hague. He graduated from the school of medicine in Leiden in 1965 and was Board certified in Obstetrics and Gynecology in 1972. After some initial endeavours, Wladimiroff soon went down to London to study with Professor Stuart Campbell at the Post-graduate Institute at the Queen Charlotte's Hospital. In the late 1970s he field tested Organon Teknika's original real-time equipments from the Netherlands (in collaboration with Nicolaas Bom, the original inventor) and demonstrated the usefulness of the MiniVisor in the rapid measurement of the biparietal diameter at the bedside. His

research at Queen Charlotte's started with the measurement of fetal urinary production rate, which he continued to expand after returning to the Netherlands, looking at fetal urinary production under a variety of physiological and pathological situations. From then on Professor Wladimiroff became particularly interested in the physiology and patho-physiology of pregnancy and the fetus and his group was very productive in researches pertaining to fetal cardiology, fetal vascular and cerebral function and fetal blood flow as assessed by doppler velocimetry. In 1974, he received his PhD at the University of Nijmegen with a thesis on fetal monitoring. In 1973, he started work as a consultant at the department of obstetrics and gynecology of Erasmus University Rotterman at Dijkzigt Hospital; in 1977, he was appointed reader at this department, and in 1980 full professor. Since 1984, he was head of the division of prenatal diagnosis and since 1996, when the two divisions were merged, head of the division of obstetrics and prenatal diagnosis at Rotterdam University Hospital. In 1981, his group reported fetal left ventricular volume determination from a study of two-dimensional measurement of real-time ultrasonic images of the left ventricle. Their group was the first to describe doppler studies of the middle cerebral arteries and the carotid carteries, and popularizing the carotid artery/ umbilical artery PI ratio for the assessment of fetal compromise. Professor Wladimiroff was the President of the Dutch Society of Obstetrics and Gynecology from 1993 to 1995 and was the Chairman of the National Liason Committee for Medical Research Committees in the Netherlands. He has organized numerous National and International Scientific meeetings and Symposia and was the Chairman of the Education Committee of the International Society for Ultrasound in Obstetrics and Gynecology (ISUOG). He is also a board member of the Society of the "Fetus as a Patient" and executive board member of the European Board and College of Obstetrics and Gynecology and has carried out visitations in departments from Slovenia to Portugal. Professor Wladimiroff has produced over 300 important scientific papers and contributed to over 20 books and monographs. He is well regarded by his colleagues as a great teacher and investigator. Since 1977, he has supervised 25 PhDs on many different aspects of prenatal diagnosis, of obstetrical, gynecological and Doppler ultrasound, and of fetal monitoring. His PhD students came from Holland, Switzerland, Britain, Indonesia and Austria. In recognition of his contributions to the advancement of ultrasound in Obstetrics and Gynecology, he was presented the Ian Donald Gold Medal by the ISUOG in 1997. In 1999 he received the Gold Medal from the Drs. Haackert Foundation for "Lifetime Achievements in the field of Prenatal Diagnosis and Therapy".

7 - Non-linear Acoustics and Harmonic Imaging

This course will provide an introduction to the origins of non-linear propagation, and its consequences and applications in medical ultrasound.

The first section will review the basic physics of non-linear propagation, and discuss the propagation of plane waves as a means of introducing non-linear acoustics terminology. This will be followed by a discussion of the techniques

used to numerically model non-linear propagation and the specific problems of performing measurements in high amplitude fields with their associated distortion and harmonic content.

The effects of diffraction and attenuation on non-linear propagation will then be introduced by considering the fields of transducers and arrays, and the fields they generate in tissue; this will be illustrated by a combination of experimental results and model predictions. This will lead on to a discussion of the consequences for medical ultrasound of non-linear propagation. Finally the application to harmonic imaging will be described.

Victor Humphrey is a Professor of Acoustics at the Institute of Sound and Vibration Research (ISVR) in Southampton, U.K. He received his BSc and PhD degrees from the University of Bristol in 1975 and 1981 respectively. He then moved to the School of Physics at the University of Bath where was promoted to Senior Lecturer. In 2004 he took up his current position at ISVR. His initial research was in the area of laboratory applications of non-linear parametric arrays in underwater acoustics. For this work he was awarded the Institute of Acoustics A.B. Wood Medal 1988. Subsequently he helped to develop a research programme on the non-linear propagation of ultrasound in medical fields that investigated these fields both numerically and experimentally. He was awarded the University of Bath Mary Tasker Award for excellence in teaching in 1995.

8 - Finite Element Modelling of Ultrasound Applications.

Finite Element Modelling (FEM) of ultrasound devices has been growing since its early use in the late 1980s and early 1990s. It is now common, and likely soon to be universal, to find industrial and academic groups with a significant ultrasound research component to utilize computer simulations of one form or another in their work. While the researchers are experts in their own field of ultrasound, they rarely have such extensive knowledge of the field of finite element modelling and consequently often have difficulty in making appropriate choices and decisions regarding their modelling needs and approach. It is the aim of this course to educate the ultrasound expert in the important considerations with regards to the finite element modelling of ultrasound applications, with particular emphasis on phenomena occurring in front of the transducer. By the end of the course, it is our intention that the attendees will have the basic information on finite element simulations, and several common but varied applications, with which to make informed decisions in regards to simulating their own particular problems, and therefore make best use of the resources available to them. The course will be divided in four parts.

Part 1: Finite Element Basics

The first section will involve an introduction to the field of finite element modelling, in order to ensure that all participants are aware of the basic assumptions inherent in the various modelling approaches. Common

terminology, types of analysis (harmonic, transient etc), types of solution methods (implicit, explicit), types of numerical solver (direct, iterative), and typical boundary conditions, such as symmetry and infinite element (e.g. absorbers and PML), validation and verification methods will be detailed.

Part 2 : Wave Propagation
The second section will concentrate on the modelling of wave propagation through various media. Initial consideration will be given to the simple, linear, elastic cases and then moving to include the effects of long distance propagation, material discontinuities, frequency dependant attenuation, and non-linearity (such as is prominent in higher-harmonic imaging).

Part 3: Ultrasound Applications
The third section will consider a variety of ultrasound applications. This includes accidental or intentional tissue heating (such as with HIFU). Appropriate and accurate calculation of thermal generation (sometimes called the Bioheat Equation) and its application as a load to a thermal model will be detailed. Aspects of ultrasound/thermal coupling will be compared to acoustic radation force calculation, which bear significant resemblance in approach.

Part 4: Efficient Application of Modelling Software on Available Hardware
The ability to economically answer the questions posed often marks the difference between a successful and a failed project. We cover simple and effective approaches for ensuring maximum return on time invested in FEM, and important considerations for ensuring sufficiently accurate answers. This will then extend to discussion of numerical optimization techniques, and the relative costs compared to the potential benefits considered. We will discuss common computer architectures, the 32 to 64 bit transition, and multi-processing, in order to leave the potential user somewhat more comfortable in this rapidly changing and bewildering field.

Paul Reynolds received B.Eng in Electrical and Mechanical Engineering from the University of Strathclyde, Scotland, in 1994, and Ph.D in 1998 for his work on finite element modelling of piezoelectric transducers. Since 1999 he has worked at WAI using the PZFlex finite element package to model a wide range of ultrasound and piezoelectric applications, including medical imaging, therapeutics, SONAR, and sensors.

John Mould received B.Sc. and M.Sc. in Civil Engineering from Virginia Tech in 1978 and 1979 respectively. He received a Ph.D. in Civil Engineering from the University of Colorado in 1983. Since joining WAI in 1983 he has been an analyst and a major contributor to the development of the entire FLEX family of codes for Nonlinear Solids, Acoustics, Thermal, Piezoelectric and Electromagnetic analyses.

9 - Flow Measurements and Doppler

This course provides basic understanding of physical principles and signal processing methods for flow measurements and visualization; with emphasis on Doppler methods and blood flow applications. The course starts with an overview of currently used techniques for velocity estimation in pulsed and continuous wave Doppler and color flow imaging. Statistical models for the received signal, as well as commonly used velocity and flow estimators are developed. Several different simulation methods for ultrasound signals from moving blood and clutter signals will be discussed. This includes fast simulation methods, as well as full 3D point scatter models using spatial impulse response techniques or k-space analysis. Efficient simulation tools to explore estimator properties are derived, and examples on implementation in Matlab will be shown. Methods to suppress clutter signals from slowly moving targets, including regression filter will be discussed. Elements from classical estimation theory will be applied to develop minimum variance velocity estimators in the presence of clutter noise. The performance will be compared with commonly used approaches for clutter rejection and velocity estimation, and practical implementations will be discussed. Velocity components transversal to the ultrasound beam can not be measured by Doppler techniques. However, several approaches to overcome this limitation has been proposed, including speckle tracking, transit time measurements, and lateral beam modulation. Principples and practical limitations will be discussed. Methods for visualisation of 2D vector flow information will be shown.

Hans Torp received the MS degree in mathematics in 1978, and the Dr. Techn. degree in electrical engineering in 1992; both from the University of Trondheim, Norway. Since 1980 he has been working with ultrasound technology applied to blood flow measurements and imaging at the university of Trondheim, in cooperation with GE-Vingmed Ultrasound. He is currently professor of medical technology at the Norwegian University of Science and Technology, and has since 1987 given courses on ultrasound imaging and blood flow measurements for students in electrical engineering and biophysics. His research interests includes statistical signal- and image processing with applications in medical ultrasound imaging.

INVITED SPEAKERS

GROUP 1:
Patrick W. Serruys: "Biomedical Engineering in the Catheterization Laboratory"
Timothy Leighton: "Bubble Acoustics: from Seas to Surgeries"
Peter Wells: "Lord Rayleigh"
Jaques Souquet: "Telemedicine: What is in Place Today? What are the Challenges for the Future?"
Kathy Ferrara: "Targeted Ultrasound Imaging and Drug Delivery Vehicles"
Ralph Sinkus: "Dynamic MR-Elastography as a Non-Invasive Imaging Modality: In Vivo Application to Breast, Liver, and Brain"

GROUP 2:
Chris Lowe: "Novel Acoustic Biosensors"
K. Yamanaka: "Diffraction-Free Propagation of Collimate Surface Acoustic Wave on a Sphere Applied for Innovative Gas Sensors"
Ute Rabe: "Surface Characterization using Ultrasonic Vibration Modes of Atomic Force Microscope Cantilevers"

GROUP 3:
Paul Muralt: "Is There a Better Material for Thin Film BAW Applications than AlN?"
S. V. Krishnaswamy: "Piezoelectric/Ferroelectric Films for Microwave/MEMS Application--Historical Perspective"
E. V. Charnaya: "Ionic Conductivity in Acoustic Crystals"

GROUP 4:
Meirion F. Lewis: "SAW and Optical Signal Processing"
Peter Wright: "Trends in Integrated Front-End Modules for Cellular Handsets"

GROUP 5:
Christopher Daft: "cMUTs and Electronics for 2-D and 3-D Imaging: Monolithic Integration, In-Handle Chip Sets and System Implications"
Stephen M. Fry: "A Glimpse into the Future of Intravascular Ultrasound Technology"
Tim Proulx: "Advances in Catheter-Based Ultrasound Imaging "
Jie Chen: "Commercialization of Piezoelectric Single Crystals for Medical Imaging Applications"

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2005 IEEE International Ultrasonics Symposium - Condensed Program						
Saturday, Sept. 17	***Registration (WBZ entrance De Doelen), 6:00 p.m. – 9:00 p.m.***					
Sunday, Sept. 18	***Registration (WBZ entrance De Doelen), 7:00 a.m. – 7:00 p.m.***					
8:00 a.m. – 10:00 p.m.	***SHORT COURSES (Rooms 4, 5a/5b) Please see listing on pages 10–19.***					
Monday, Sept. 19	***Registration (WBZ entrance De Doelen), 7:00 a.m. – 6:00 p.m.***					
8:30 a.m. – 10:00 a.m.	***Plenary Session and UFFC Awards (Room: Willem Burger Zaal [room 1])***					
10:00 a.m. – 10:30 a.m.	***Refreshments (lobby room 1, lobby room 2, Expohal)***					
10:00 a.m. – 11:30 a.m.	**Posters** (Location: Expohal, ground floor)					
	PS Student Paper Finalists P1A Blood Flow P1B Elastography P1C Tissue Characterization P1D Beamformer Implementation		P1E Medical Imaging P1F Acoustic Sensors P1G NDE Modeling and Measurements P1H Ultrasonic Motors/Lab on a Chip P1I Piezoelectrical Transformers/Motors		P1J Simulation of SAW Devices P1K SAW Devices I P1L Materials for Transducers P1M Transducer Modeling	
	Room 1	**Room 2**	**Room 3**	**Room 4**	**Room 5**	**Room 6**
11:30 a.m. – 1:00 p.m.	1A Local Drug Delivery UCA/Therapeutic	2A Static Elasticity	3A Biosensors	4A Phononic Crystals	5A BAW Thin Film Filters	6A High Frequency Arrays
1:00 p.m. – 2:30 p.m.	***Lunch***					
2:30 p.m. – 4:00 p.m.	1B IVUS I	2B Blood Flow	3B NDE Imag. and Signal Processing	4B Optical Interactions	5B Thin Film BAW Materials	6B Piezo. Single Crystal Trans.
4:00 p.m. – 4:30 p.m.	***Refreshments (Location: Expohal, Foyer room 1, Foyer room 2)***					
4:30 p.m. – 6:00 p.m.	1C IVUS II	2C Ultrasound 19th Cent. to 21st Cent.	3C NDE-Wave Propagation	4C Ultrasonic Motors	5C THIN Film BAW Materials II	6C Trans. and Mater. Modeling
6:00 p.m. – 8:30 p.m.	***Reception (Location: Expohal on ground floor and Foyer room 2 on the first floor, [exhibits])***					

Tuesday, Sept. 20	***Registration (WBZ entrance De Doelen), 7:00 a.m. – 5:30 p.m.***					
8:30 a.m. – 10:00 a.m.	1D Mouse Imaging	2D Vascular	3D NDE-General Methods	4D Physical Acoustics 1	5D Novel SAW Dev. and Analysis	6D Ultra. MEMS Technology
10:00 a.m. – 10:30 a.m.	***Refreshments (lobby room 1, lobby room 2, Expohal)***					
10:00 a.m. – 11:30 a.m	**Posters** (Location: Expohal, ground floor)					
	P2A Tissue Characterization P2B Contrast Agents I P2C Therapeutics and Hyperthermia P2D Elasticity Imaging		P2E NDE Signal Processing & Modeling P2F BAW Piezoelectric Films P2G BAW Materials and Propagation II P2H SAW Materials and Propagation		P2I SAW Devices II P2J Trans. Materials & Comp. Materials P2K Micromachined Transducers	
11:30 a.m. – 1:00 p.m.	1E Portable Devices & Other Neat Stuff	2E Cardiovascular	3E NDE Signal Processing	4E Physial Acoustics 2	5E RF Filters and Modules	6E cMUTS
1:00 p.m. – 2:30 p.m.	***Lunch***					
2:30 p.m. – 4:00 p.m.	1F Elasticity Dynamic	2F Contrast Agents: Imaging I	3F Gas-Liquid Sensors	4F Medical Transducers I	5F SAW Analysis	6F Ind. Measur. & Applications
4:00 p.m. – 4:30 p.m.	***Refreshments (Location: Expohal, Foyer room 1, Foyer room 2)***					
4:30 p.m. – 6:00 p.m.	1G Elasticity	2G Contrast Agents: Imaging II	3G Ultrasonic Flowmeters	4G Interventional Ultrasound	5G SAW System Applications	6G Tissue Characterization
7:00 p.m. – 12:00 p.m.	***Conference Dinner Party***					
Wednesday, Sept. 21	***Registration (WBZ entrance De Doelen), 7:00 a.m. – 1:00 p.m.***					
8:30 a.m. – 10:00 a.m.	1H Contrast Agents: Effects	2H Acoustic Proper. Cells & Tis.	3H Acoustical Imaging	4H BAW Resonators	5H SAW Propagation	6H Energy Harv. & Nov. Trans.
10:00 a.m. – 10:30 a.m.	***Refreshments (lobby room 1, lobby room 2, Expohal)***					
10:00 a.m. – 11:30 a.m.	**Posters** (Location: Expohal, ground floor)					
	P3A Beamforming P3B Contrast Agents II P3C Bone P3D Modeling and Visualization P3E Signal Processing		P3F NDE Transducers P3G General Physical Acoustics P3H BAW Materials and Propagation I P3I SAW Filters and Devices		P3J SAW System Applications P3K Transducer Fabrication Technology P3L High Frequency Transducers P3M Medical Transducers II	
11:30 a.m. – 1:00 p.m.	1I Contrast Agents Fundmentals	2I Ultrasound & Therapeutics	3I NDE Material & Defect Charac.	4I Fluidic Actuation	5I SAW Filters and Transducers	6I Transducer Materials
1:00 p.m. – 2:30 p.m.	***Lunch***					
2:30 p.m. – 4:00 p.m.	1J Quantitative Cardiac Imaging	2J Therapy Monitoring	3J Materials Characterization	4J Ultras. Micro. & Bulk Effects	5J BAW Resonator Design and Analysis	6J Beamforming II
4:00 p.m. – 4:30 p.m.	***Refreshments (Location: Expohal, Foyer room 1, Foyer room 2)***					
4:30 p.m. – 6:00 p.m.	1K 3D/4D Cardiac Imaging	2K Cavitation	3K Acoustic Sensors	4K Physical Acoustics III	5K Micromec. & SAW Resonators	6K Med. Sig. Proc. & Contrast
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