

ISSN 1726-5479

# SENSORS & TRANSDUCERS

vol. 112  
**1** / 10



## Sensor Instrumentation, DAQ and Virtual Instruments

International Frequency Sensor Association Publishing





**Editors-in-Chief:** professor Sergey Y. Yurish,  
Phone: +34 696067716, fax: +34 93 4011989, e-mail: editor@sensorsportal.com

**Editors for Western Europe**

Meijer, Gerard C.M., Delft University of Technology, The Netherlands  
Ferrari, Vittorio, Università di Brescia, Italy

**Editor South America**

Costa-Felix, Rodrigo, Inmetro, Brazil

**Editor for Eastern Europe**

Sachenko, Anatoly, Ternopil State Economic University, Ukraine

**Editors for North America**

Datskos, Panos G., Oak Ridge National Laboratory, USA  
Fabien, J. Josse, Marquette University, USA  
Katz, Evgeny, Clarkson University, USA

**Editor for Asia**

Ohyama, Shinji, Tokyo Institute of Technology, Japan

**Editor for Asia-Pacific**

Mukhopadhyay, Subhas, Massey University, New Zealand

## Editorial Advisory Board

- Abdul Rahim, Ruzairi**, Universiti Teknologi, Malaysia  
**Ahmad, Mohd Noor**, Northern University of Engineering, Malaysia  
**Annamalai, Karthigeyan**, National Institute of Advanced Industrial Science and Technology, Japan  
**Arcega, Francisco**, University of Zaragoza, Spain  
**Arguel, Philippe**, CNRS, France  
**Ahn, Jae-Pyoung**, Korea Institute of Science and Technology, Korea  
**Arndt, Michael**, Robert Bosch GmbH, Germany  
**Ascoli, Giorgio**, George Mason University, USA  
**Atalay, Selcuk**, Inonu University, Turkey  
**Atghiaee, Ahmad**, University of Tehran, Iran  
**Augutis, Vygantas**, Kaunas University of Technology, Lithuania  
**Avachit, Patil Lalchand**, North Maharashtra University, India  
**Ayesh, Aladdin**, De Montfort University, UK  
**Bahreyni, Behraad**, University of Manitoba, Canada  
**Baliga, Shankar, B.**, General Monitors Transnational, USA  
**Baoxian, Ye**, Zhengzhou University, China  
**Barford, Lee**, Agilent Laboratories, USA  
**Barlingay, Ravindra**, RF Arrays Systems, India  
**Basu, Sukumar**, Jadavpur University, India  
**Beck, Stephen**, University of Sheffield, UK  
**Ben Bouzid, Sihem**, Institut National de Recherche Scientifique, Tunisia  
**Benachaiba, Chellali**, Universitaire de Bechar, Algeria  
**Binnie, T. David**, Napier University, UK  
**Bischoff, Gerlinde**, Inst. Analytical Chemistry, Germany  
**Bodas, Dhananjay**, IMTEK, Germany  
**Borges Carval, Nuno**, Universidade de Aveiro, Portugal  
**Bousbia-Salah, Mounir**, University of Annaba, Algeria  
**Bouvet, Marcel**, CNRS – UPMC, France  
**Brudzewski, Kazimierz**, Warsaw University of Technology, Poland  
**Cai, Chenxin**, Nanjing Normal University, China  
**Cai, Qingyun**, Hunan University, China  
**Campanella, Luigi**, University La Sapienza, Italy  
**Carvalho, Vitor**, Minho University, Portugal  
**Cecelja, Franjo**, Brunel University, London, UK  
**Cerda Belmonte, Judith**, Imperial College London, UK  
**Chakrabarty, Chandan Kumar**, Universiti Tenaga Nasional, Malaysia  
**Chakravorty, Dipankar**, Association for the Cultivation of Science, India  
**Changhai, Ru**, Harbin Engineering University, China  
**Chaudhari, Gajanan**, Shri Shivaji Science College, India  
**Chavali, Murthy**, VIT University, Tamil Nadu, India  
**Chen, Jiming**, Zhejiang University, China  
**Chen, Rongshun**, National Tsing Hua University, Taiwan  
**Cheng, Kuo-Sheng**, National Cheng Kung University, Taiwan  
**Chiang, Jeffrey (Cheng-Ta)**, Industrial Technol. Research Institute, Taiwan  
**Chiriac, Horia**, National Institute of Research and Development, Romania  
**Chowdhuri, Arijit**, University of Delhi, India  
**Chung, Wen-Yaw**, Chung Yuan Christian University, Taiwan  
**Corres, Jesus**, Universidad Publica de Navarra, Spain  
**Cortes, Camilo A.**, Universidad Nacional de Colombia, Colombia  
**Courtois, Christian**, Université de Valenciennes, France  
**Cusano, Andrea**, University of Sannio, Italy  
**D'Amico, Arnaldo**, Università di Tor Vergata, Italy  
**De Stefano, Luca**, Institute for Microelectronics and Microsystem, Italy  
**Deshmukh, Kiran**, Shri Shivaji Mahavidyalaya, Barshi, India  
**Dickert, Franz L.**, Vienna University, Austria  
**Dieguez, Angel**, University of Barcelona, Spain  
**Dimitropoulos, Panos**, University of Thessaly, Greece  
**Ding, Jianning**, Jiangsu Polytechnic University, China  
**Djordjevic, Alexandar**, City University of Hong Kong, Hong Kong  
**Donato, Nicola**, University of Messina, Italy  
**Donato, Patricio**, Universidad de Mar del Plata, Argentina  
**Dong, Feng**, Tianjin University, China  
**Drljaca, Predrag**, Instersema Sensoric SA, Switzerland  
**Dubey, Venketesh**, Bournemouth University, UK  
**Enderle, Stefan**, Univ. of Ulm and KTB Mechatronics GmbH, Germany  
**Erdem, Gursan K. Arzum**, Ege University, Turkey  
**Erkmen, Aydan M.**, Middle East Technical University, Turkey  
**Estelle, Patrice**, Insa Rennes, France  
**Estrada, Horacio**, University of North Carolina, USA  
**Faiz, Adil**, INSA Lyon, France  
**Fericean, Sorin**, Balluff GmbH, Germany  
**Fernandes, Joana M.**, University of Porto, Portugal  
**Francioso, Luca**, CNR-IMM Institute for Microelectronics and Microsystems, Italy  
**Francis, Laurent**, University Catholique de Louvain, Belgium  
**Fu, Weiling**, South-Western Hospital, Chongqing, China  
**Gaura, Elena**, Coventry University, UK  
**Geng, Yanfeng**, China University of Petroleum, China  
**Gole, James**, Georgia Institute of Technology, USA  
**Gong, Hao**, National University of Singapore, Singapore  
**Gonzalez de la Rosa, Juan Jose**, University of Cadiz, Spain  
**Grael, Annette**, Goteborg University, Sweden  
**Graff, Mason**, The University of Texas at Arlington, USA  
**Guan, Shan**, Eastman Kodak, USA  
**Guillet, Bruno**, University of Caen, France  
**Guo, Zhen**, New Jersey Institute of Technology, USA  
**Gupta, Narendra Kumar**, Napier University, UK  
**Hadjiloucas, Sillas**, The University of Reading, UK  
**Haider, Mohammad R.**, Sonoma State University, USA  
**Hashsham, Syed**, Michigan State University, USA  
**Hasni, Abdelhafid**, Bechar University, Algeria  
**Hernandez, Alvaro**, University of Alcalá, Spain  
**Hernandez, Wilmar**, Universidad Politecnica de Madrid, Spain  
**Homentcovschi, Dorel**, SUNY Binghamton, USA  
**Horstman, Tom**, U.S. Automation Group, LLC, USA  
**Hsiai, Tzung (John)**, University of Southern California, USA  
**Huang, Jeng-Sheng**, Chung Yuan Christian University, Taiwan  
**Huang, Star**, National Tsing Hua University, Taiwan  
**Huang, Wei**, PSG Design Center, USA  
**Hui, David**, University of New Orleans, USA  
**Jaffrezic-Renault, Nicole**, Ecole Centrale de Lyon, France  
**Jaime Calvo-Galleg, Jaime**, Universidad de Salamanca, Spain  
**James, Daniel**, Griffith University, Australia  
**Janting, Jakob**, DELTA Danish Electronics, Denmark  
**Jiang, Liudi**, University of Southampton, UK  
**Jiang, Wei**, University of Virginia, USA  
**Jiao, Zheng**, Shanghai University, China  
**John, Joachim**, IMEC, Belgium  
**Kalach, Andrew**, Voronezh Institute of Ministry of Interior, Russia  
**Kang, Moonho**, Sunmoon University, Korea South  
**Kaniusas, Eugenijus**, Vienna University of Technology, Austria  
**Katake, Anup**, Texas A&M University, USA  
**Kausel, Wilfried**, University of Music, Vienna, Austria  
**Kavasoglu, Nese**, Mugla University, Turkey  
**Ke, Cathy**, Tyndall National Institute, Ireland  
**Khan, Asif**, Aligarh Muslim University, Aligarh, India  
**Sapozhnikova, Ksenia**, D.I.Mendeleyev Institute for Metrology, Russia

**Kim, Min Young**, Kyungpook National University, Korea South  
**Ko, Sang Choon**, Electronics. and Telecom. Research Inst., Korea South  
**Kockar, Hakan**, Balikesir University, Turkey  
**Kotulska, Malgorzata**, Wroclaw University of Technology, Poland  
**Kratz, Henrik**, Uppsala University, Sweden  
**Kumar, Arun**, University of South Florida, USA  
**Kumar, Subodh**, National Physical Laboratory, India  
**Kung, Chih-Hsien**, Chang-Jung Christian University, Taiwan  
**Lacnjevac, Caslav**, University of Belgrade, Serbia  
**Lay-Ekuakille, Aime**, University of Lecce, Italy  
**Lee, Jang Myung**, Pusan National University, Korea South  
**Lee, Jun Su**, Amkor Technology, Inc. South Korea  
**Lei, Hua**, National Starch and Chemical Company, USA  
**Li, Genxi**, Nanjing University, China  
**Li, Hui**, Shanghai Jiaotong University, China  
**Li, Xian-Fang**, Central South University, China  
**Liang, Yuanchang**, University of Washington, USA  
**Liawruangrath, Saisunee**, Chiang Mai University, Thailand  
**Liew, Kim Meow**, City University of Hong Kong, Hong Kong  
**Lin, Hermann**, National Kaohsiung University, Taiwan  
**Lin, Paul**, Cleveland State University, USA  
**Linderholm, Pontus**, EPFL - Microsystems Laboratory, Switzerland  
**Liu, Aihua**, University of Oklahoma, USA  
**Liu Changgeng**, Louisiana State University, USA  
**Liu, Cheng-Hsien**, National Tsing Hua University, Taiwan  
**Liu, Songqin**, Southeast University, China  
**Lodeiro, Carlos**, University of Vigo, Spain  
**Lorenzo, Maria Encarnacio**, Universidad Autonoma de Madrid, Spain  
**Lukaszewicz, Jerzy Pawel**, Nicholas Copernicus University, Poland  
**Ma, Zhanfang**, Northeast Normal University, China  
**Majstorovic, Vidosav**, University of Belgrade, Serbia  
**Marquez, Alfredo**, Centro de Investigacion en Materiales Avanzados, Mexico  
**Matay, Ladislav**, Slovak Academy of Sciences, Slovakia  
**Mathur, Prafull**, National Physical Laboratory, India  
**Maurya, D.K.**, Institute of Materials Research and Engineering, Singapore  
**Mekid, Samir**, University of Manchester, UK  
**Melnyk, Ivan**, Photon Control Inc., Canada  
**Mendes, Paulo**, University of Minho, Portugal  
**Mennell, Julie**, Northumbria University, UK  
**Mi, Bin**, Boston Scientific Corporation, USA  
**Minas, Graca**, University of Minho, Portugal  
**Moghavvemi, Mahmoud**, University of Malaya, Malaysia  
**Mohammadi, Mohammad-Reza**, University of Cambridge, UK  
**Molina Flores, Esteban**, Benemérita Universidad Autónoma de Puebla, Mexico  
**Moradi, Majid**, University of Kerman, Iran  
**Morello, Rosario**, University "Mediterranea" of Reggio Calabria, Italy  
**Mounir, Ben Ali**, University of Sousse, Tunisia  
**Mulla, Imtiaz Sirajuddin**, National Chemical Laboratory, Pune, India  
**Neelamegam, Periasamy**, Sastra Deemed University, India  
**Neshkova, Milka**, Bulgarian Academy of Sciences, Bulgaria  
**Oberhammer, Joachim**, Royal Institute of Technology, Sweden  
**Ould Lahoucine, Cherif**, University of Guelma, Algeria  
**Pamidighanta, Sayanu**, Bharat Electronics Limited (BEL), India  
**Pan, Jisheng**, Institute of Materials Research & Engineering, Singapore  
**Park, Joon-Shik**, Korea Electronics Technology Institute, Korea South  
**Penza, Michele**, ENEA C.R., Italy  
**Pereira, Jose Miguel**, Instituto Politecnico de Setebal, Portugal  
**Petsev, Dimiter**, University of New Mexico, USA  
**Pogacnik, Lea**, University of Ljubljana, Slovenia  
**Post, Michael**, National Research Council, Canada  
**Prance, Robert**, University of Sussex, UK  
**Prasad, Ambika**, Gulbarga University, India  
**Prateepasen, Asa**, Kingmoungut's University of Technology, Thailand  
**Pullini, Daniele**, Centro Ricerche FIAT, Italy  
**Pumera, Martin**, National Institute for Materials Science, Japan  
**Radhakrishnan, S.** National Chemical Laboratory, Pune, India  
**Rajanna, K.**, Indian Institute of Science, India  
**Ramadan, Qasem**, Institute of Microelectronics, Singapore  
**Rao, Basuthkar**, Tata Inst. of Fundamental Research, India  
**Raouf, Kosai**, Joseph Fourier University of Grenoble, France  
**Reig, Candid**, University of Valencia, Spain  
**Restivo, Maria Teresa**, University of Porto, Portugal  
**Robert, Michel**, University Henri Poincare, France  
**Rezazadeh, Ghader**, Urmia University, Iran  
**Royo, Santiago**, Universitat Politècnica de Catalunya, Spain  
**Rodriguez, Angel**, Universidad Politécnica de Catalunya, Spain  
**Rothberg, Steve**, Loughborough University, UK  
**Sadana, Ajit**, University of Mississippi, USA  
**Sadeghian Marnani, Hamed**, TU Delft, The Netherlands  
**Sandacci, Serghei**, Sensor Technology Ltd., UK  
**Saxena, Vibha**, Bhabha Atomic Research Centre, Mumbai, India  
**Schneider, John K.**, Ultra-Scan Corporation, USA  
**Seif, Selemani**, Alabama A & M University, USA  
**Seifter, Achim**, Los Alamos National Laboratory, USA  
**Sengupta, Deepak**, Advance Bio-Photonics, India  
**Shearwood, Christopher**, Nanyang Technological University, Singapore  
**Shin, Kyuho**, Samsung Advanced Institute of Technology, Korea  
**Shmaliy, Yuriy**, Kharkiv National Univ. of Radio Electronics, Ukraine  
**Silva Girao, Pedro**, Technical University of Lisbon, Portugal  
**Singh, V. R.**, National Physical Laboratory, India  
**Slomovitz, Daniel**, UTE, Uruguay  
**Smith, Martin**, Open University, UK  
**Soleymannpour, Ahmad**, Damghan Basic Science University, Iran  
**Somani, Prakash R.**, Centre for Materials for Electronics Technol., India  
**Srinivas, Talabattula**, Indian Institute of Science, Bangalore, India  
**Srivastava, Arvind K.**, Northwestern University, USA  
**Stefan-van Staden, Raluca-Ioana**, University of Pretoria, South Africa  
**Sumridetchka, Sarun**, National Electronics and Computer Technology Center, Thailand  
**Sun, Chengliang**, Polytechnic University, Hong-Kong  
**Sun, Dongming**, Jilin University, China  
**Sun, Junhua**, Beijing University of Aeronautics and Astronautics, China  
**Sun, Zhiqiang**, Central South University, China  
**Suri, C. Raman**, Institute of Microbial Technology, India  
**Sysoev, Victor**, Saratov State Technical University, Russia  
**Szewczyk, Roman**, Industrial Research Inst. for Automation and Measurement, Poland  
**Tan, Ooi Kiang**, Nanyang Technological University, Singapore  
**Tang, Dianping**, Southwest University, China  
**Tang, Jaw-Luen**, National Chung Cheng University, Taiwan  
**Teker, Kasif**, Frostburg State University, USA  
**Thumbavanam Pad, Kartik**, Carnegie Mellon University, USA  
**Tian, Gui Yun**, University of Newcastle, UK  
**Tsiantos, Vassilios**, Technological Educational Institute of Kaval, Greece  
**Tsigara, Anna**, National Hellenic Research Foundation, Greece  
**Twomey, Karen**, University College Cork, Ireland  
**Valente, Antonio**, University, Vila Real, - U.T.A.D., Portugal  
**Vaseashta, Ashok**, Marshall University, USA  
**Vazquez, Carmen**, Carlos III University in Madrid, Spain  
**Vieira, Manuela**, Instituto Superior de Engenharia de Lisboa, Portugal  
**Vigna, Benedetto**, STMicroelectronics, Italy  
**Vrba, Radimir**, Brno University of Technology, Czech Republic  
**Wandelt, Barbara**, Technical University of Lodz, Poland  
**Wang, Jiangping**, Xi'an Shiyou University, China  
**Wang, Kedong**, Beihang University, China  
**Wang, Liang**, Advanced Micro Devices, USA  
**Wang, Mi**, University of Leeds, UK  
**Wang, Shinn-Fwu**, Ching Yun University, Taiwan  
**Wang, Wei-Chih**, University of Washington, USA  
**Wang, Wensheng**, University of Pennsylvania, USA  
**Watson, Steven**, Center for NanoSpace Technologies Inc., USA  
**Weiping, Yan**, Dalian University of Technology, China  
**Wells, Stephen**, Southern Company Services, USA  
**Wolkenberg, Andrzej**, Institute of Electron Technology, Poland  
**Woods, R. Clive**, Louisiana State University, USA  
**Wu, DerHo**, National Pingtung Univ. of Science and Technology, Taiwan  
**Wu, Zhaoyang**, Hunan University, China  
**Xiu Tao, Ge**, Chuzhou University, China  
**Xu, Lisheng**, The Chinese University of Hong Kong, Hong Kong  
**Xu, Tao**, University of California, Irvine, USA  
**Yang, Dongfang**, National Research Council, Canada  
**Yang, Wuqiang**, The University of Manchester, UK  
**Yang, Xiaoling**, University of Georgia, Athens, GA, USA  
**Yaping Dan**, Harvard University, USA  
**Ymeti, Aurel**, University of Twente, Netherland  
**Yong Zhao**, Northeastern University, China  
**Yu, Haihu**, Wuhan University of Technology, China  
**Yuan, Yong**, Massey University, New Zealand  
**Yufera Garcia, Alberto**, Seville University, Spain  
**Zakaria, Zulkarnay**, University Malaysia Perlis, Malaysia  
**Zagnoni, Michele**, University of Southampton, UK  
**Zamani, Cyrus**, Universitat de Barcelona, Spain  
**Zeni, Luigi**, Second University of Naples, Italy  
**Zhang, Minglong**, Shanghai University, China  
**Zhang, Quintao**, University of California at Berkeley, USA  
**Zhang, Weiping**, Shanghai Jiao Tong University, China  
**Zhang, Wenming**, Shanghai Jiao Tong University, China  
**Zhang, Xueji**, World Precision Instruments, Inc., USA  
**Zhong, Haoxiang**, Henan Normal University, China  
**Zhu, Qing**, Fujifilm Dimatix, Inc., USA  
**Zorzano, Luis**, Universidad de La Rioja, Spain  
**Zourob, Mohammed**, University of Cambridge, UK

# Contents

Volume 112  
Issue 1  
January 2010

www.sensorsportal.com

ISSN 1726-5479

## Research Articles

<b>Design of an Acoustic Displacement Transducer</b> <i>Tariq Al Mograbi, Mohammad A. K. Alia, Mohammad Abuzalata</i> .....	1
<b>Vibration Analysis Based on Hammer Impact for Fouling Detection using Microphone and Accelerometer as Sensors</b> <i>Jaidilson Silva, Antonio Marcus Lima, Helmut Neff and José Sérgio Rocha Neto</i> .....	10
<b>Simulation of the Two-Phase Liquid – Gas Flow through Ultrasonic Transceivers Application in Ultrasonic Tomography</b> <i>Zulkarnay Zakaria, Mohd Hafiz Fazalul Rahiman, Ruzairi Abdul Rahim</i> .....	24
<b>Image Reconstructions of a Portable Optical CT-Scan Using an NIR Light Source</b> <i>Margi Sasono and Hariyadi Soetedjo</i> .....	39
<b>Statistical Feature Extraction and Recognition of Beverages Using Electronic Tongue</b> <i>P. C. Panchariya and A. H. Kiranmayee</i> .....	47
<b>Modeling and Verification of Heat Fields by Virtual Instrumentation</b> <i>Libor Hargaš, Dušan Koniar, Miroslav Hrianka, Anna Příkopová</i> .....	64
<b>PC Based Instrument for the Measurement of Dielectric Constant of Liquids</b> <i>V. V. Ramana C. H. and Malakondaiah K.</i> .....	73
<b>Development of Laser LEDs Based a Programmable Optical Sensor for Detection of Environmental Pollutants</b> <i>Amit K. Sharma and R. K. Tiwari</i> .....	80
<b>Performance Evaluation and Robustness Testing of Advanced Oscilloscope Triggering Schemes</b> <i>Shakeb A. Khan, Alka Nigam, A. K. Agarwala, Mini S. Thomas</i> .....	95
<b>Design and Development of an Embedded System for Testing the Potentiometer Linearity</b> <i>Raghavendra Rao Kanchi, Nagamani Gosala</i> .....	107
<b>Development of an FPGA Based Embedded System for High Speed Object Tracking</b> <i>Chandrashekar Matham, Nagabhushan Raju Konduru</i> .....	118
<b>A New Algorithm of Compensation of the Time Interval Error GPS-Based Measurements</b> <i>Jonny Paul Zavala de Paz, Yuriy S. Shmaliy</i> .....	124
<b>Colour Determination and Change of Sensory Properties of Mayonnaise with Different Contents of Oil depending on Length of Storage</b> <i>Višnja M. Sikimić, Jovanka V. Popov-Raljić, Branislav P. Zlatković, Nada Lakić</i> .....	138
<b>Dynamically Functioning Structure and Problem of Measurements of Rapidly Time-Varying Processes: Dream or Reality</b> <i>George Abramchuk, Kristina Abramchuk</i> .....	166

# SENSORDEVICES 2010:

The First International Conference  
on Sensor Device Technologies and Applications

July 18 - 25, 2010 - Venice, Italy



The inaugural event SENSORDEVICES 2010, The First International Conference on Sensor Device Technologies and Applications, initiates a series of events focusing on sensor devices themselves, the technology-capturing style of sensors, special technologies, signal control and interfaces, and particularly sensors-oriented applications. The evolution of the nano- and microtechnologies, nanomaterials, and the new business services make the sensor device industry and research on sensor-themselves very challenging.

## Conference tracks

Sensor devices  
Sensor device technologies  
Sensors signal conditioning and interfacing circuits

Medical devices and sensors applications  
Sensors domain-oriented devices, technologies, and applications  
Sensor-based localization and tracking technologies

## Important dates

**Submission (full paper):** February 20, 2010  
**Notification:** March 25, 2010  
**Registration:** April 15, 2010  
**Camera ready:** April 20, 2010



<http://www.iaria.org/conferences2010/SENSORDEVICES10.html>

# SENSORCOMM 2010:

The Fourth International Conference  
on Sensor Technologies and Applications

July 18 - 25, 2010 - Venice, Italy



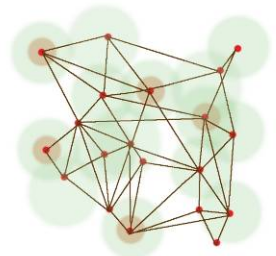
SENSORCOMM 2010 (The Fourth International Conference on Sensor Technologies and Applications) is a multi-track event covering related topics on theory and practice on wired and wireless sensors and sensor networks. The topics suggested can be discussed in term of concepts, state of the art, research, standards, implementations, running experiments, applications, and industrial case studies.

## Conference tracks

**APASN** Architectures, protocols and algorithms of sensor networks  
**MECSN** Energy, management and control of sensor networks  
**RASQOFT** Resource allocation, services, QoS and fault tolerance in sensor networks  
**PESMOSN** Performance, simulation and modelling of sensor networks  
**SEMOSN** Security and monitoring of sensor networks  
**SECSN** Sensor circuits and sensor devices  
**RIWISN** Radio issues in wireless sensor networks  
**SAPSN** Software, applications and programming of sensor networks  
**DAIPSN** Data allocation and information in sensor networks  
**DISN** Deployments and implementations of sensor networks  
**UNWAT** Under water sensors and systems  
**ENOPT** Energy optimization in wireless sensor networks

## Important dates

**Submission (full paper):** February 20, 2010  
**Notification:** March 25, 2010  
**Registration:** April 15, 2010  
**Camera ready:** April 20, 2010



<http://www.iaria.org/conferences2010/SENSORCOMM10.html>

Authors are encouraged to submit article in MS Word (doc) and Acrobat (pdf) formats by e-mail: [editor@sensorsportal.com](mailto:editor@sensorsportal.com)  
Please visit journal's webpage with preparation instructions: <http://www.sensorsportal.com/HTML/DIGEST/Submission.htm>

## Simulation of the Two-Phase Liquid – Gas Flow through Ultrasonic Transceivers Application in Ultrasonic Tomography

<sup>1</sup>Zulkarnay Zakaria, <sup>1</sup>Mohd Hafiz Fazalul Rahiman, <sup>2</sup>Ruzairi Abdul Rahim

<sup>1</sup>Tomographic Imaging Research Group,  
School of Mechatronic Engineering, Universiti Malaysia Perlis, 02600 Jejawi, Perlis, Malaysia.  
Tel.: +604-9798149, fax: +604-9798142

<sup>2</sup>Process Tomography Research Group (PROTOM),  
Control and Instrumentation Engineering Department,  
Faculty of Electrical Engineering, Universiti Teknologi Malaysia,  
81310 Skudai, Johor, Malaysia.  
E-mail: zulkarnay@unimap.edu.my

*Received: 28 October 2010 / Accepted: 22 January 2010 / Published: 29 January 2010*

---

**Abstract:** In this paper, ultrasonic transmission mode tomography was used to visualize the two phase liquid/gas flow in a pipe/vessel. The sensing element consists of 8, 16 and 32 units ultrasonic transceivers were used to cover the pipe cross-section at different time. The motivation of this paper is to analyze the optimum numbers of transceivers which can give the best performance in providing better image of the two phase liquid/gas flow. This paper also details the development of the system including the ultrasonic transduction circuits, the electronic measurement circuits, the data acquisition system and the image reconstruction techniques. Ten conditions of liquid-gas flow have been simulated. The system was found capable of visualizing the internal characteristics and provides the concentration profile for the corresponding liquid and gas phases while the 32 transceivers has provided the best image for the ten conditions applied. *Copyright © 2010 IFSA.*

**Keywords:** Ultrasonic tomography, Ultrasonic transceivers, Liquid and gas flow, Flow measurement system

---

### 1. Introduction

Real time process monitoring plays a dominant role in many areas of industry and scientific research [3, 12] since there is a widespread need for the direct analysis of the internal characteristics of process

plants in order to improve the design and operation of equipment. The measuring instruments for such applications must use robust non-invasive sensors which, if required, can operate in aggressive and fast moving fluids and multiphase mixtures. A good tomography sensor should have the features such as non-invasive and non-intrusive. It should not necessitate rupture of the walls of the pipeline and do not disturb the nature of the process being examined [10]. Process Tomography involves the use of instruments which provide cross sectional profile of the distribution of materials in a process vessel or pipeline [8] and can be used to obtain both qualitative and quantitative data needed in modeling a multi flow system [6]. A basic tomography system is constructed by the combination of sensor system, data acquisition system, image reconstruction system and display unit while the sensor system is the heart of any tomography system [10]. In the other hand, the transducers configuration is a key factor in the efficiency of data acquisition [6]. The number of transducers that can be used is functionally limited by the real time scheme, which in turns relies upon the available computing power and the physical dimension of the imaging cross section [9].

## **2. Ultrasonic Tomography**

Ultrasonic tomography technique is the use of ultrasound to detect the changes of acoustic impedance ( $Z$ ) which is closely related to density ( $\rho$ ) of the media ( $Z = \rho c$ , where  $c$  is the velocity of the sound) [1-3, 7] and thus complements other imaging technologies such as Electrical Capacitance Tomography (ECT) and Electrical Impedance Tomography (EIT) [3, 7]. An ultrasonic tomography system is based upon interaction between the incident ultrasonic waves (frequency of 20 kHz to 10 MHz) and the object to be imaged [1]. Whenever there is an interface between one substance and another, the ultrasonic wave is strongly reflected [2] and this type of tomography technique has the advantage of imaging two components flow and gives the opportunity of providing the quantitative and real time data on chemical media within a full scale industrial process [3]. However ultrasound has several specific problems which may limit its application. The speed of sound in gas limits the data acquisition rate and particle impact on the flow pipe may produce very high levels of noise at the transducer [8].

## **3. Ultrasonic Sensing Modes**

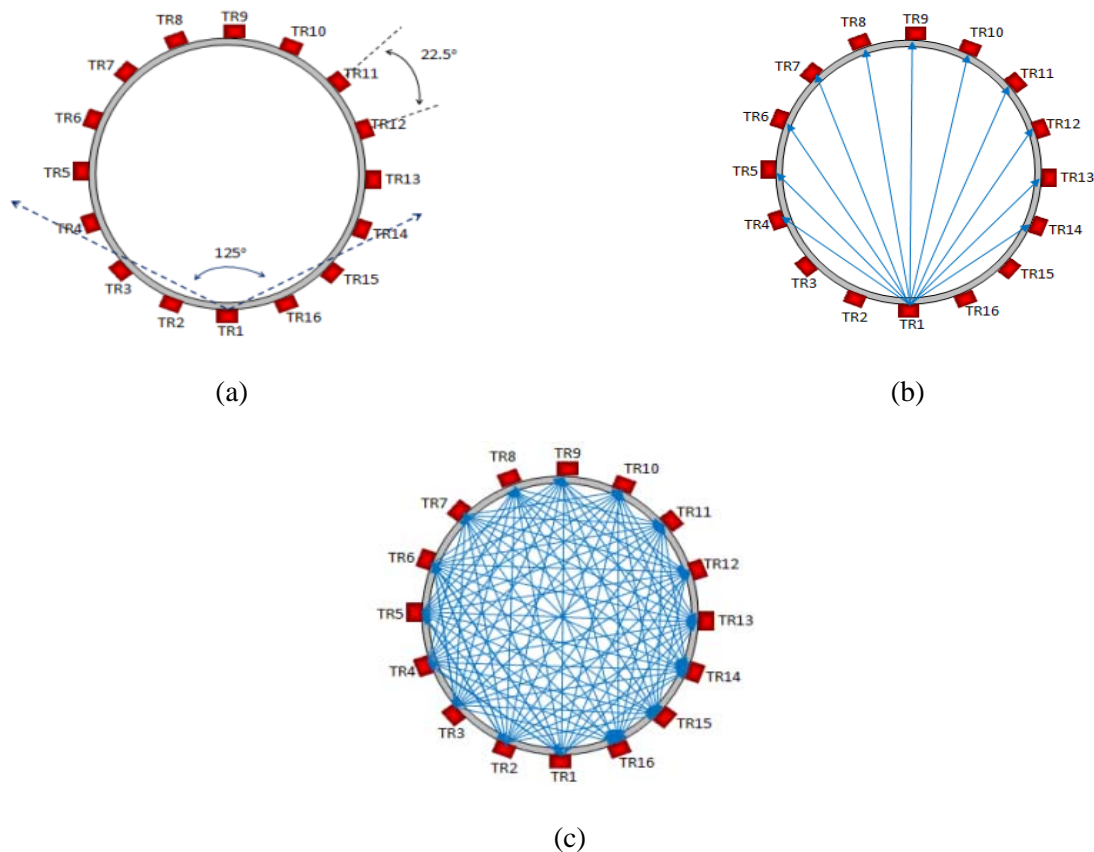
There are three modes of the ultrasonic tomography systems, the transmission mode, reflection mode and diffraction mode [1]. The transmission mode technique is based on the measurement of the changed in the properties of the transmitted acoustic wave, which are influenced by the material of the medium in the measuring medium. Transmission mode tomography is used when in the case of forward scattering, if the data acquired only concern the amplitude and/or time of flight and a reconstruction algorithm is based on the assumption of straight line propagation is applied. There are two major constraints in on the application of the transmission mode ultrasonic techniques that are limitation by media absorption and the limitation by complex sound field [2, 7]. The reflection mode technique is based on the measurement of the position and the change of the physical properties of wave or a particle reflected on an interface, while diffraction mode technique is based on diffraction or refraction of wave at a discrete or continuous interface in the object space. Ultrasonic tomography poses a problem where the real time performance is paramount: the complex sound field sensed by transducers often resulting in overlapped, or multiple reflected pulses which introduce errors; and the inherent slow propagation speed of ultrasound lowering the scanning speed. In order to eliminate these problems spectral analysis strategy is applied, which examined the phase information of reflected ultrasonic signals detected by a transducer [4, 5]. The behaviour of a normal ultrasonic wave front at interfaces in terms of power reflection ( $P_r$ ) and power transmission ( $P_T$ ) coefficient are given by the formula:

$$P_r = \left( \frac{P_r}{P_i} \right)^2 = \left[ \frac{(Z_2 - Z_1)}{(Z_2 + Z_1)} \right]^2, \quad (1)$$

where  $P_r$  is reflected sound pressures,  $P_t$  is transmitted sound pressures, and  $P_i$  is incident sound pressures. It is obvious in equation (1) that if the difference of the acoustic impedance between the two medium at an interface is greater, thus the reflected energy is also greater. If most of the energy is reflected so very less of it is received. This is the situation at the sensor and pipe interface. To overcome this problem, an acoustic coupling is introduced between the sensor's surface and the outer pipe wall. The function of this coupling is to match the acoustic impedances between two different mediums (by providing a free air region between the sensor's surface and the pipe wall) and will produce an optimum transference of the acoustic energy from the transmitter to the receiver [2, 3].

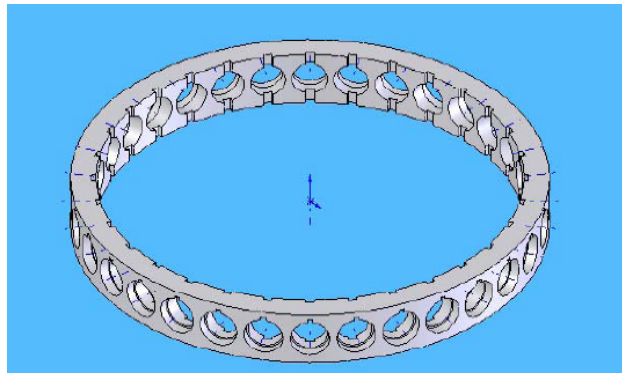
#### 4. Transceiver Sensing Method & Setup

Dual functional gives transceivers advantages since less number of sensors are enough to generate same quality of image compare to separate transmitter-receiver. Each time, transceiver can only be a transmitter or a receiver and cannot both. When a transceiver is set to be a transmitter, it then switched to a transmitter circuit and at the same time off from the receiver circuit. The same thing happen when it is set to be a receiver, it then be switched to a receiver circuit and at the same time off from the transmitter circuit. The timing for the switching is very important since wrong switching timing will give inaccurate measurement data. In this research quad analogue switch is used for the switching process. The cross sectional area of the process vessel (acrylic pipe is used in this experiment) is shown in Fig. 1 (a) with 16 transceivers, noted as TR1-TR16 and located in a sensor jig in Fig. 2.



**Fig. 1.** (a) Cross section of process vessel; (b) Single scanning geometry; (c) Sixteen scanning geometry.



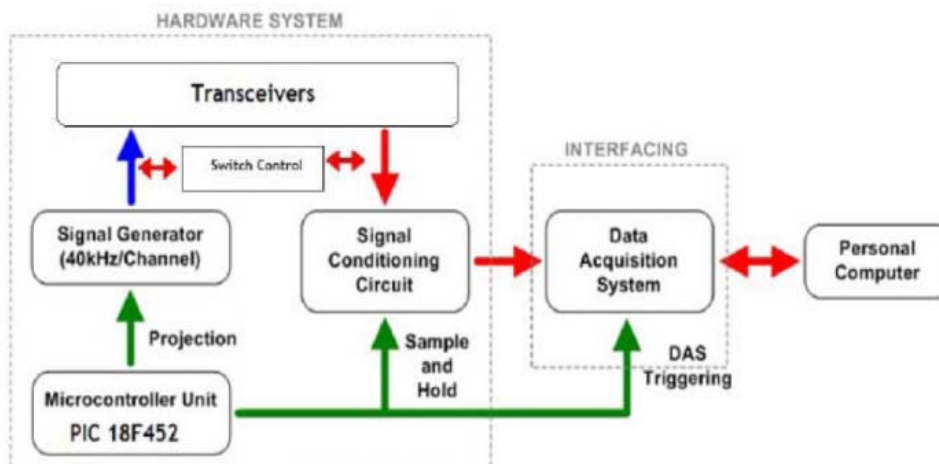


**Fig. 2.** Sensor jig.

Each transceiver has  $125^\circ$  beam angle. From the figure it is clearly shown that only 11 transceivers are located within this  $125^\circ$  beam angle at each projection. That mean only these 11 transceivers will received the projected signal. The rest 4 outside the beam angle will not be considered in the measurement due to Lamb wave propagation. From there it is clear that for one full scan a total of 16 observations are made with 11 received channels each, hence 176 independent measurements were obtained.

## 5. The Electronic Measurement Circuit

Getting accurate data is the essence and vital in any tomography technique since through these data image is reconstructed. In ultrasonic tomography system, the basic preparations of measurement system are the hardware part, interfacing and also computer part as shown in Fig. 3. In the hardware part there are signal generator and signal conditioning circuit. Microcontroller (PIC18F452) unit is used as signal generator to generate and control the projection of 40 kHz signals (the frequency depends on the types of sensors used) to transmitters while the receiver will received the projected signal [2, 3]. The projected signal is shown in Fig. 4. Since transceivers are dual functional transducers (transmitter and receiver), analogue switches are used in the switching circuit to switch the transceiver to transmitter circuit or receiver circuit. In the signal conditioning circuit, the received signal is filtered using suitable filter to reduce the noise effects and then amplified through some amplifier circuits. A received signal which has been directly transmitted (no obstacle) can therefore distinguish from a reflected signal (due to obstacle), which must have a longer delay time.



**Fig. 3.** Ultrasonic tomography system.

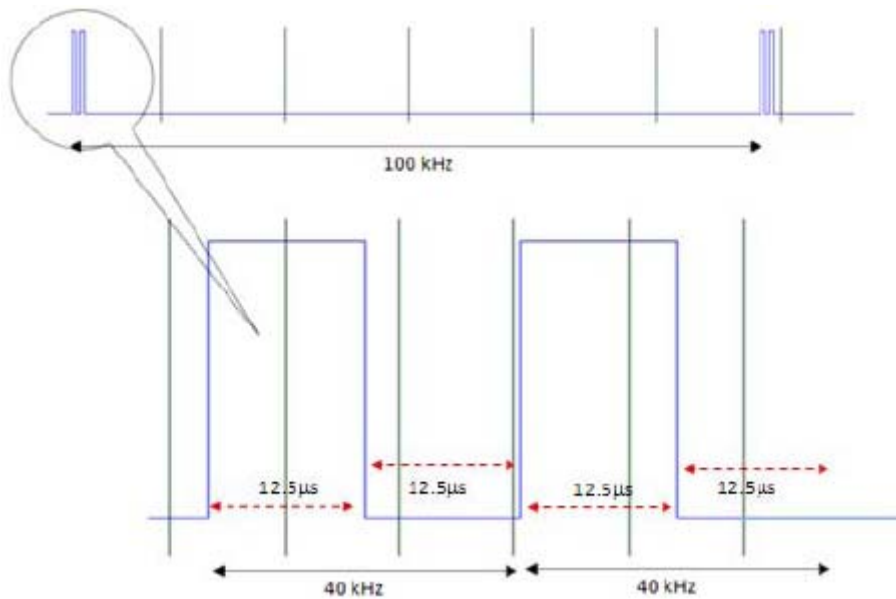


Fig. 4. Projected signal for a channel.

A sample and hold technique is used to capture (sample) and hold the analogue voltage in a specific point in time ( $t_s$ ) under control of an external circuit (microcontroller) as in Fig. 5. By using the data acquisition system, the sampled signals are acquired into the computer and at the same time, a suitable image reconstruction algorithm can be used for visualizing the internal characteristics of the corresponding process vessel [2].

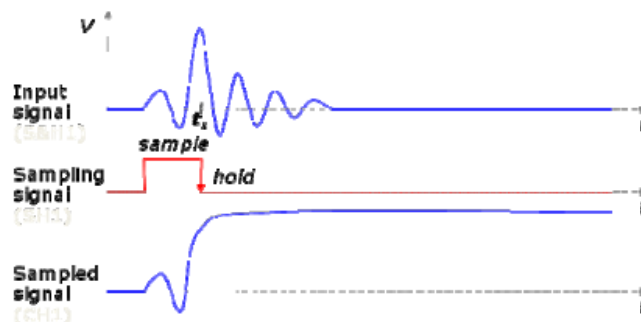
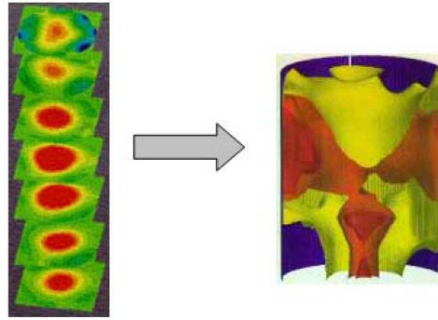


Fig. 5. Sample and hold technique.

## 6. Image Reconstruction Algorithm

After measurements have been done, the collected data will then be converted to the image through a suitable image reconstruction algorithm. If the scanning of each tomogram slice is fast and a set of axially spaced slice views is obtained, they can be assembled into a whole body image as shown in Fig. 6. There are many types of algorithm that can be used depends on the techniques that have been applied. They can be divided into two groups which are non iterative and iterative methods. The resolution of tomographic images that are reconstructed from measurements depends on the number of sensors arranged around the flow as well as the spatial resolution of each sensor array [13]. Artifacts and noise become more pronounced as the number of transducer positions is reduced [9].



**Fig. 6.** Image reconstruction concept.

Most of the work in process tomography has focused on the use of Linear Back Projection (LBP) algorithm. The LBP is computationally straight forward to implement besides low computation cost and is popular method for image reconstruction [3]. The measurements obtained at each projected data are the attenuated sensor values due to object space in the image plane. These sensor values are then back projected by multiply with the corresponding normalized sensitivity maps by using the formula:

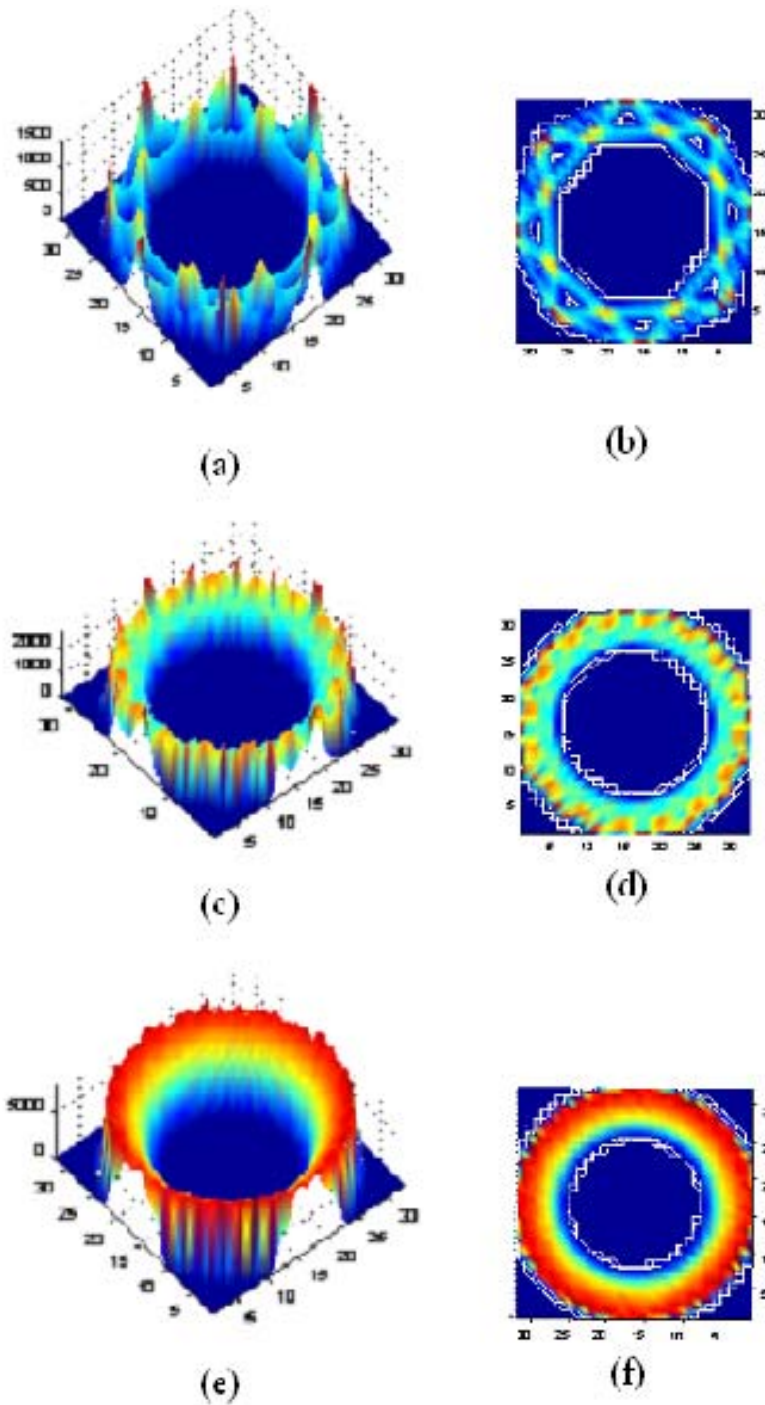
$$V_{LBP}(x, y) = \sum_{Tx=1}^{16} \sum_{Rx=1}^{16} S_{Tx, Rx} \times \overline{M}_{Tx, Rx}(x, y), \quad (2)$$

where  $V_{LBP}(x, y)$  = voltage distribution obtained using LBP,  $S_{Tx, Rx}$  = sensor loss voltage of transmitter ( $T_x$ ) and receiver ( $R_x$ ) and  $\overline{M}_{Tx, Rx}(x, y)$  = Normalized sensitivity maps.

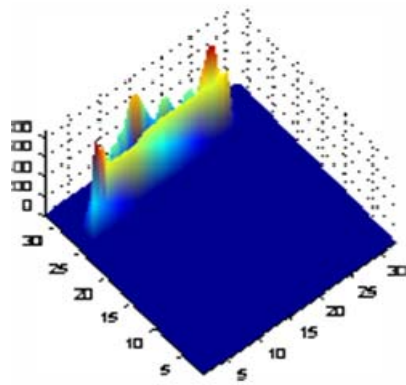
The back projected data values are smeared back across the unknown density function (image) and overlapped to each other to increase the projection data density. The smearing effects is the side effect of the LBP since each pixels are summations of the back projected signals. Therefore, in this case, the 'wrong' pixels are summed twice by the value of the smearing effect. This produces ambiguous image since the reconstructed image may represent two, three or four pixels [11].

## 8. Results

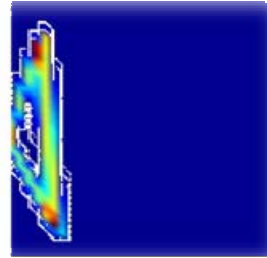
The investigations were based on the transmission and the reception of the ultrasonic transceivers that were mounted circularly on the surface of the test pipe (acrylic pipe). The experiment were carried out on the test pipe to simulate the flow of liquid (water) and gas (air) with ten static conditions as shown in Fig. 7 to Fig. 11 that are annular flow, quarter flow, half flow, three quarter flow, single gas bubble, and dual gas. For experimental purposes, the flows for these seven conditions were assumed static. This assumption is to ease the experiment and analysis of the two phase liquid/gas flow.



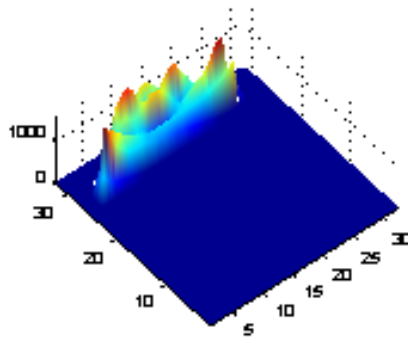
**Fig. 7.** Simulation result of annular flow for (a) and (b) eight transceivers; (c) and (d) sixteen transceivers; (e) and (f) 32 transceivers.



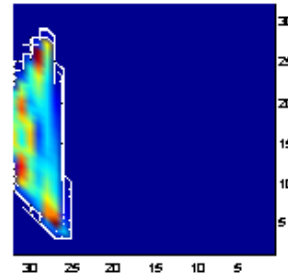
(a)



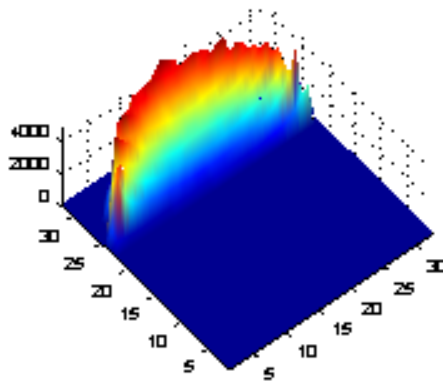
(b)



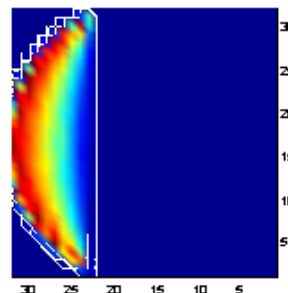
(c)



(d)

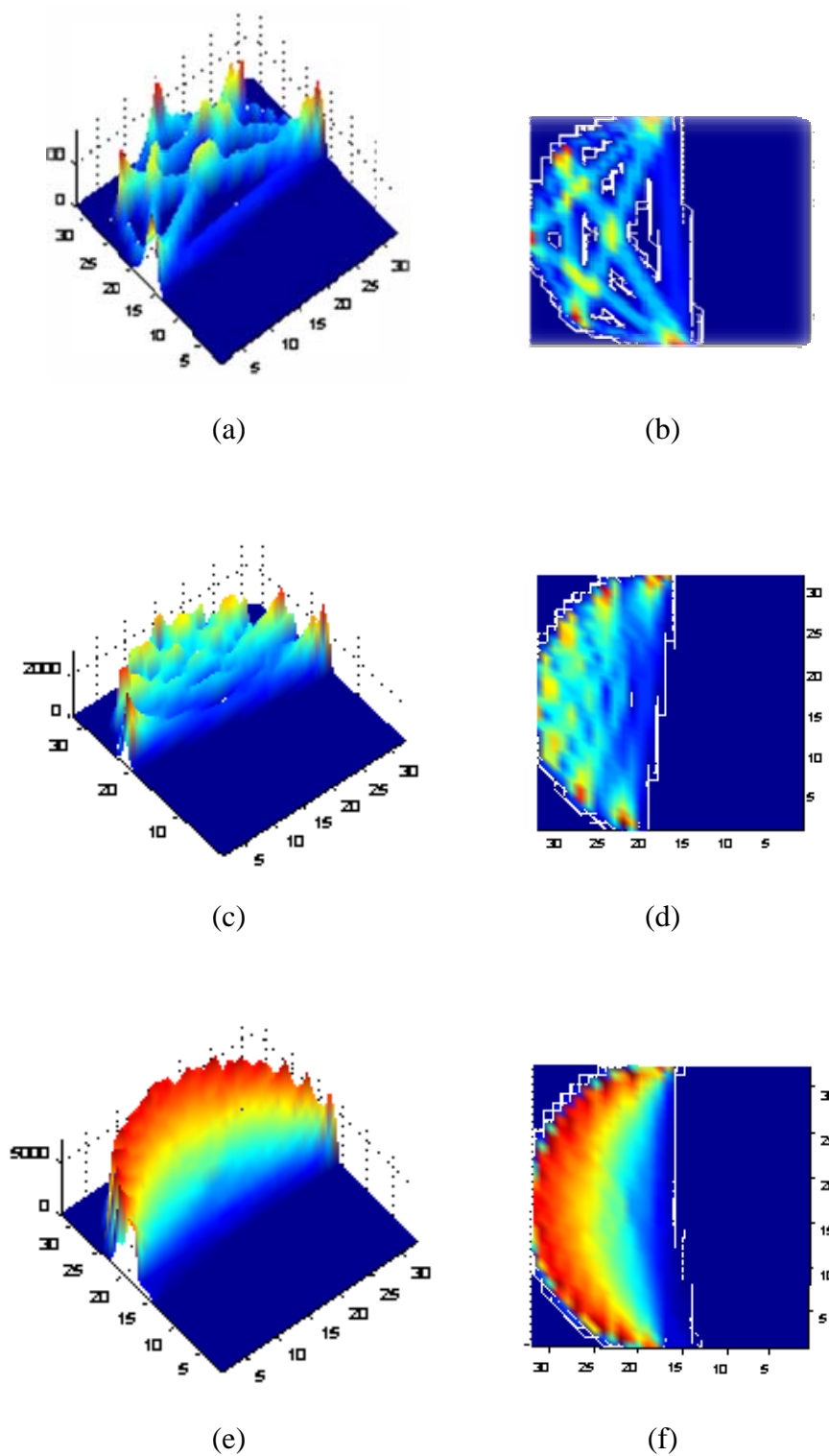


(e)

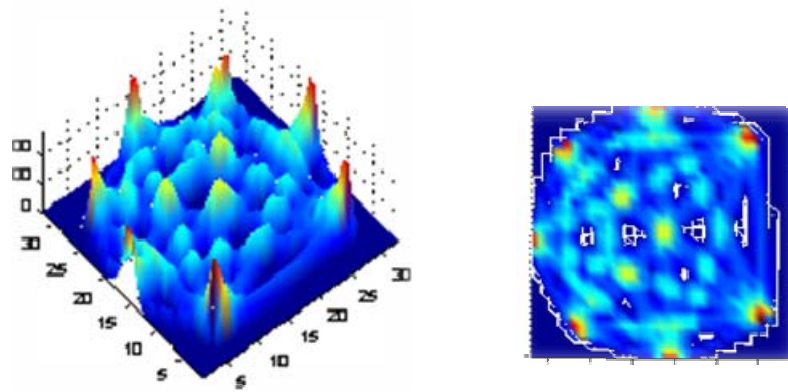


(f)

**Fig. 8.** Simulation result of quarter flow for (a) and (b) eight transceivers; (c) and (d) sixteen transceivers; (e) and (f) 32 transceivers.

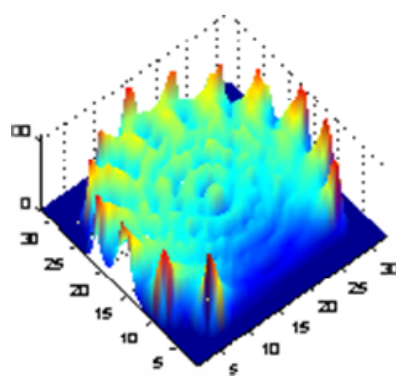


**Fig. 9.** Simulation result of half flow for (a) and (b) eight transceivers; (c) and (d) sixteen transceivers; (e) and (f) 32 transceivers.



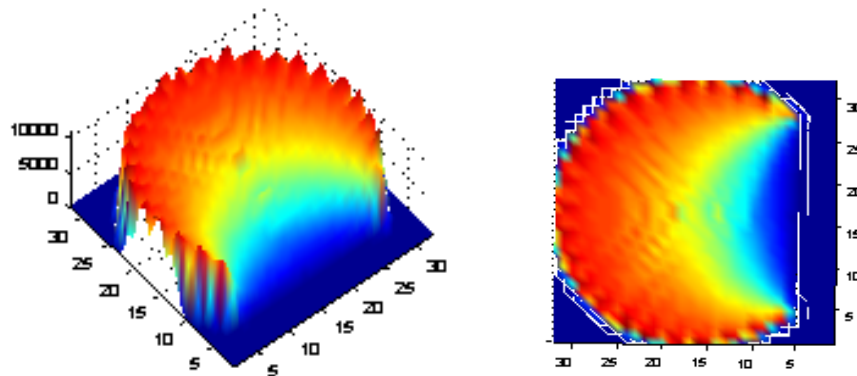
(a)

(b)



(c)

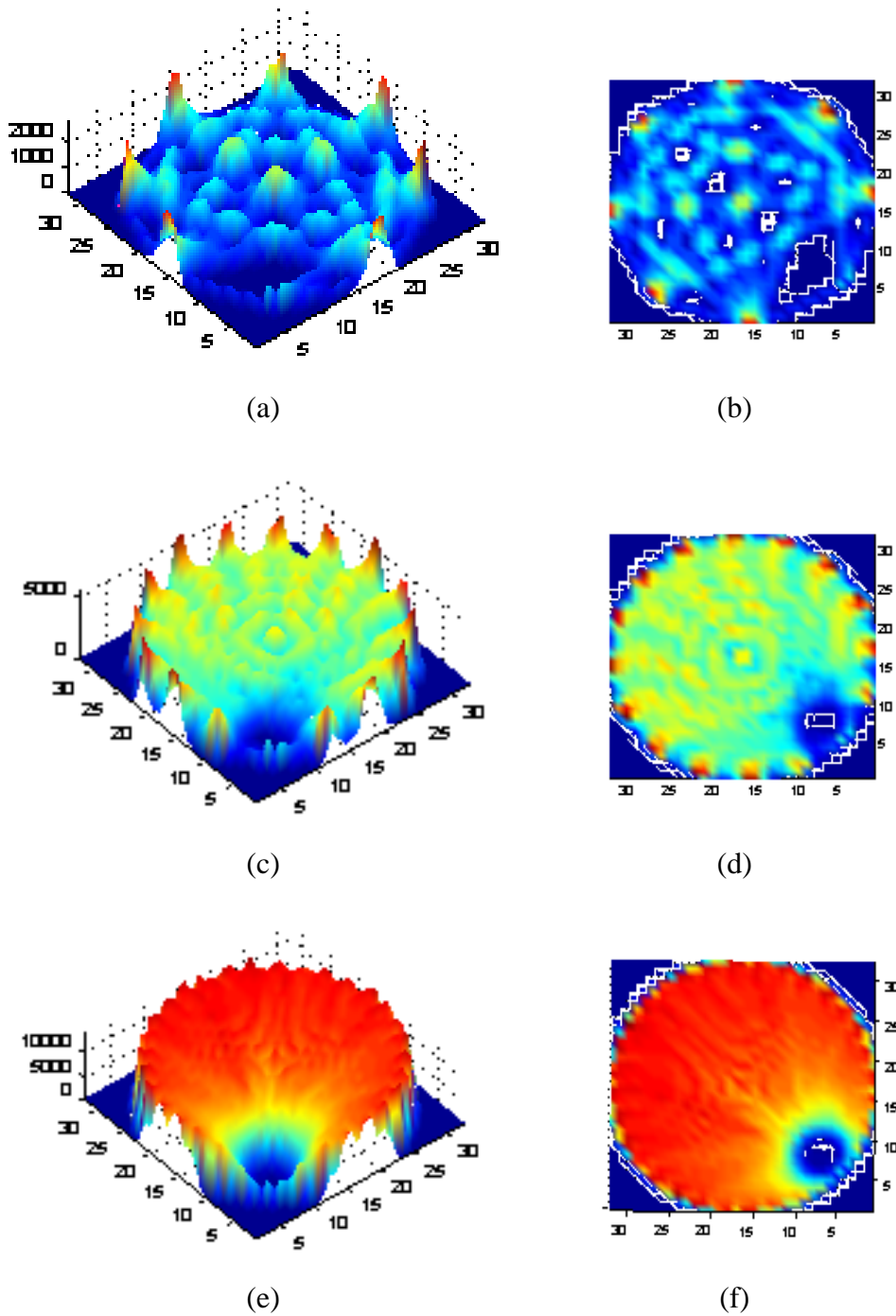
(d)



(e)

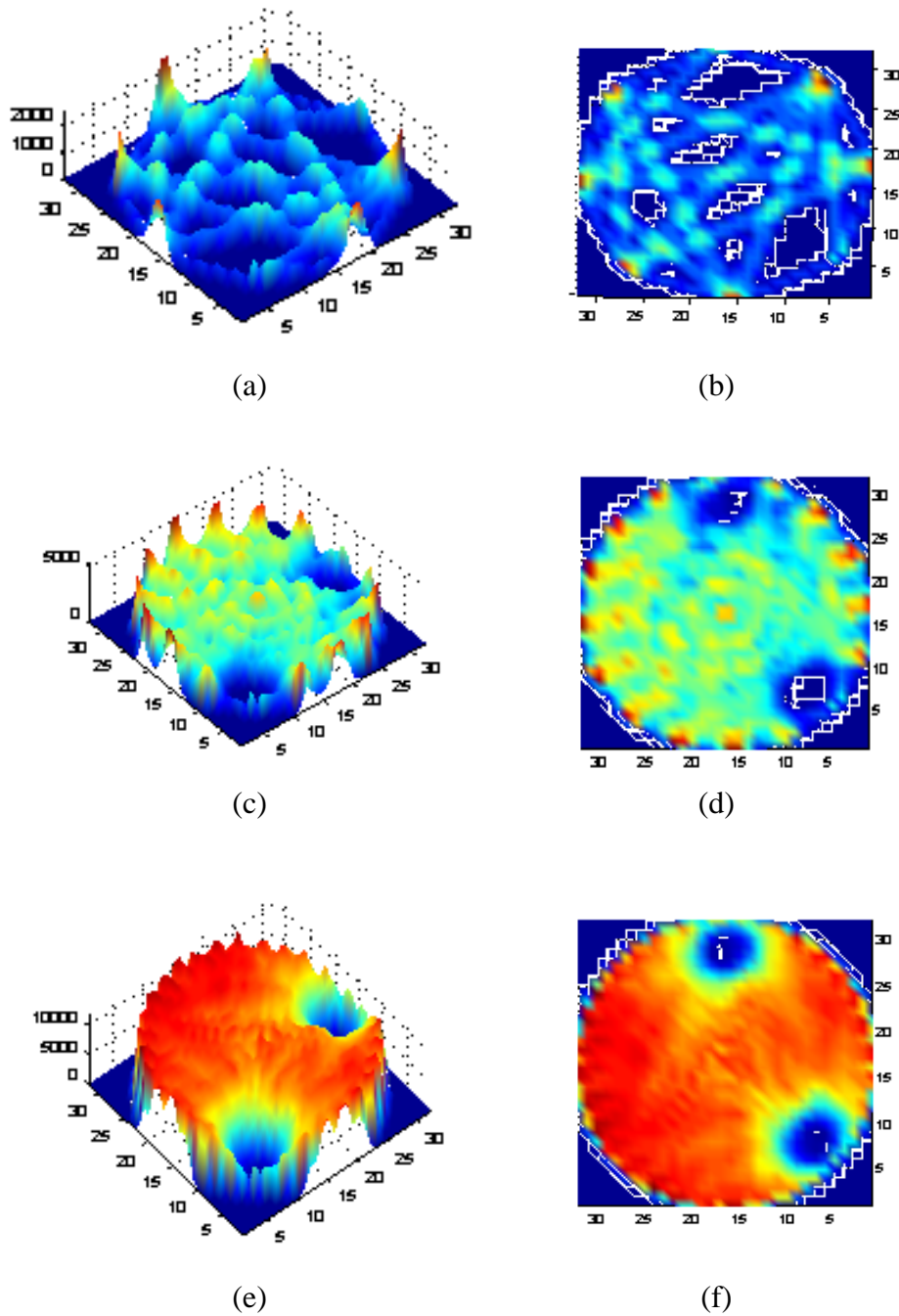
(f)

**Fig. 10.** Simulation result of three quarter flow for (a) and (b) eight transceivers; (c) and (d) sixteen transceivers; (e) and (f) 32 transceivers.



**Fig. 11.** Simulation result of single gas bubble for (a) and (b) eight transceivers; (c) and (d) sixteen transceivers; (e) and (f) 32 transceivers.





**Fig. 12.** Simulation result of dual gas bubble for (a) and (b) eight transceivers; (c) and (d) sixteen transceivers; (e) and (f) 32 transceivers.

## 9. Evaluation of Transceivers Performance

*Area Error, AE* as shown in Fig. 12 is used for *quantifying* the quality of the reconstructed images in this system. All the *AE* values have the negative sign (-) and this tell us that all the reconstructed images are smaller in size compare to standard model (actual size). The evaluation of transceivers performance is based on the percentage of area error, *AE* which is given by the formula:

$$AE = \frac{\sum_{j=1}^M G_s(p) - \sum_{j=1}^M G_g(p)}{\sum_{j=1}^M G_s(p)} = \frac{N_R - N_S}{N_S} = \frac{N_R}{N_S} - 1, \quad (3)$$

where  $G_s(p)$  is the standard (test) model pixels,  $G_g(p)$  is the binary reconstructed image pixels,  $N_R$  is the number of pixels with non-zero colour levels in the reconstructed images and  $N_S$  is the number of pixels with non-zero colour levels in the standard images.  $N_S$  is a ratio value achieved through manual calculation base on the real flow model while  $N_R$  is calculated from the generated concentration profile value. Total concentration profile value of full flow is taken for the reference.

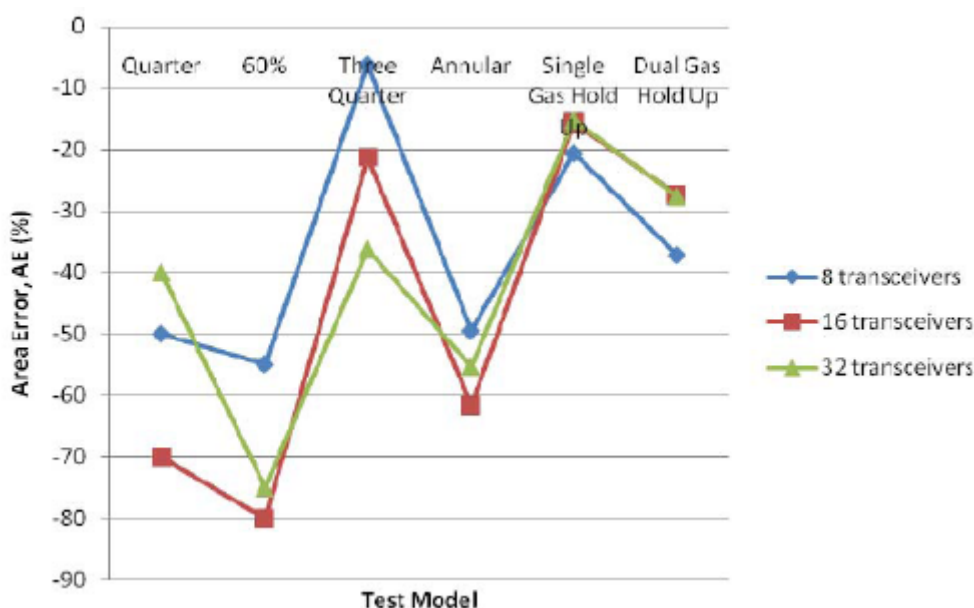


Fig. 12. Area error,  $AE$  of different flow for different numbers of transceivers.

## 10. Discussion

This research provides new technique in ultrasonic tomography by using ultrasonic transceivers instead of using separate transmitter-receiver. This separate ultrasonic transmitter-receiver sensor which is widely used in ultrasonic tomography research required large space when mounted on the surface of the measured area for example pipeline, vessel and so on. This is due to the needs of having pair of the sensors, which is transmitter (to transmit the ultrasonic signal) and the receiver (to receive the transmitted ultrasonic signal). In the separate transmitter-receiver case, the function of each sensor is fixed. This mean that the transmitter is only for transmitting purpose and the receiver is only for receiving. The function of each sensor cannot vice versa. Ultrasonic transceiver has an advantage compare to separate transmitter-receiver in terms of functioning since it has the capability of become a transmitter at one time while can be as a receiver at the other time. Due to this dual functioning, a number of transceiver that mounted on a vessel will have the capability which is almost doubled if the same number of separate transmitter-receiver is used. Thus the resolution of tomographic images that are reconstructed from measurements will be better since it depends on the number of sensors arranged around the flow as well as the spatial resolution of each sensor array [1, 2]. The result given by 32 transceivers are quality enough in determining the types of two phase flow including different position and sizes of gas hold ups in a vessel/pipe line. While image reconstructed through

8 transceivers are the worst since it cannot differentiate the presence of gas hold ups in the pipe but the image is acceptable without the gas hold ups. For 16 transceivers, the images are quite fair since it can detect and differentiate the presence of gas hold ups. The weakness of 16 transceivers is it cannot show clearly the image of gas hold ups with smaller diameter and located nearer to each other. From the result we can see that the area error,  $AE$  is quite large especially for small volume flow model that are quarter flow, 60% flow and annular flow. This type of problem exists because of the smearing effect in the Linear Back Projection Algorithm (LBPA) due to back projection technique applied. The blurring is due to projection along the straight lines which the intensity distribution is centre symmetrical and dependent on the projection angle where the blurring function is inversed of the corresponding pipe radius. Initial studies showed that this is method effective but further investigations should be continued to extract more quantitative information.

## 11. Conclusions

Transceivers have provided a new low cost technique in non-invasive ultrasonic tomography with low operating voltage as long as the acoustic energy could pass through the process vessel. By increasing the number of transducer it could cater the problem of measurement resolution, spatial image error as well as accurate measurement. The optimum numbers for transceivers of a pipe/vessel in providing good image is 32 transceivers. Instead of better image, the critical draw back to this number of transceivers is the slow of the system due to long time taken to process the data from these transceivers.

## References

- [1]. Brown, G. J., Reilly, D. and Mills, D., Development of an Ultrasonic Tomography System for Application in Pneumatic Conveying. *Measurement Science Technology*, 7, 1996, pp. 396-405.
- [2]. R Abdul Rahim, M H Fazalul Rahiman, K S Chan, S. W. Nawawi, 2007, Non-invasive Imaging of Liquid/Gas Flow using Ultrasonic Transmission-Mode Tomography, *Sensors and Actuators A: Physical*, Vol. 135, Issue 2, pp. 337-345.
- [3]. Aleman, C. O., Martin, R. and Gamio, J. C., Reconstruction of Permittivity Images From Capacitance Tomography Data by Using Very Fast Simulated Annealing, *Measurement Science Technology*, 15, 2004, pp. 1382–1390.
- [4]. Fazalul Rahiman, M. H., Abdul Rahim, R., Fazalul Rahiman, M. H., and Tajuddin, M., Ultrasonic Transmission-Mode Tomography Imaging for Liquid/Gas Two-Phase Flow, *IEEE Sensors Journal*, Vol. 6, 2006, pp. 1706-1715.
- [5]. R. Abdul Rahim and M. H. Fazalul Rahiman, A Novel Hybrid Binary Reconstruction Algorithm for Ultrasonic Tomography, *Sensors & Transducers Journal*, Vol. 89, 2008, Issue 3, pp. 93-100.
- [6]. Al-Salaymeh, A. and Durst, F., Development and Testing of a Novel Single-Wire Sensor For Wide Range Flow Velocity Measurements, *Measurement Science Technology*, 15, 2004, pp. 777–788.
- [7]. Brown, G. J., Reilly, D. and Mills, D., Ultrasonic Transmission-Mode Tomography Applied to Gas/Solids Flow, in *Proceedings of Process Tomography '95: Implementation for Industrial Processes*, Norway, Bergen, 1995, pp. 176-186.
- [8]. R Abdul Rahim L C Leong, K S Chan, M. H Rahiman and J F Pang, Real Time Mass Flow rate measurement using multiple fan beam optical tomography, *The Instrumentation, Systems and Automation Society (ISA) Transactions Journal*, USA, Vol. 47, 2008, Issue 1, pp. 3-14.
- [9]. Yang, M., Hermann, I. S., Hoyle, B. S., Beck, M. S., Lenn, C., 1999, Real Time Ultrasound Process Tomography for Two-Phase Flow Imaging Using a Reduced Number of Transducers, *IEEE Transactions on Ultrasonics, Ferroelectrics and Frequency Control*, Vol. 46.
- [10]. Zdzislaw, S., Zbigniew, R., Adam, K., Janusz, O., Mieczyslaw, L., Impedance Tomography System, in *Proc. of the 3<sup>rd</sup> International Symposium on Process Tomography*, Lodz, Poland, 2004, pp. 147-150.

- [11].Ahn, Y. C., Oh, B. D. and Kim, M. H., A Current-Sensing Electromagnetic Flowmeter for Two-Phase Flow and Numerical Simulation of the Three-Dimensional Virtual Potential Distribution: Fundamentals and Annular Flow, *Measurement Science Technology*, 14, 2003, pp. 239–250.
- [12].Davidson, J. L., Ruffino, L. S., Stephenson, D. R., Mann, R., Grieve, B. D. and York, T. A., Three-Dimensional Electrical Impedance Tomography Applied to a Metal-Walled Filtration Test Platform, *Measurement Science Technology*, 15, 2004, pp. 2263–2274.
- [13].Neal, D., Pierson, R., Chen, E., Bishop, K., McMackin, L., One Dimensional Wavefront Sensor Development For Tomographic Flow Measurements, *Sandia National Laboratories*, Albuquerque, 1995.

---

2010 Copyright ©, International Frequency Sensor Association (IFSA). All rights reserved.  
(<http://www.sensorsportal.com>)

ISSN 1726-5479

# Advertise in *Sensors & Transducers Journal* and Sensors Web Portal



[http://www.sensorsportal.com/DOWNLOADS/Media\\_Kit\\_2010.pdf](http://www.sensorsportal.com/DOWNLOADS/Media_Kit_2010.pdf)  
**sales@sensorsportal.com**

## Guide for Contributors

---

### Aims and Scope

*Sensors & Transducers Journal* (ISSN 1726-5479) provides an advanced forum for the science and technology of physical, chemical sensors and biosensors. It publishes state-of-the-art reviews, regular research and application specific papers, short notes, letters to Editor and sensors related books reviews as well as academic, practical and commercial information of interest to its readership. Because it is an open access, peer review international journal, papers rapidly published in *Sensors & Transducers Journal* will receive a very high publicity. The journal is published monthly as twelve issues per annual by International Frequency Association (IFSA). In addition, some special sponsored and conference issues published annually. *Sensors & Transducers Journal* is indexed and abstracted very quickly by Chemical Abstracts, IndexCopernicus Journals Master List, Open J-Gate, Google Scholar, etc.

### Topics Covered

Contributions are invited on all aspects of research, development and application of the science and technology of sensors, transducers and sensor instrumentations. Topics include, but are not restricted to:

- Physical, chemical and biosensors;
- Digital, frequency, period, duty-cycle, time interval, PWM, pulse number output sensors and transducers;
- Theory, principles, effects, design, standardization and modeling;
- Smart sensors and systems;
- Sensor instrumentation;
- Virtual instruments;
- Sensors interfaces, buses and networks;
- Signal processing;
- Frequency (period, duty-cycle)-to-digital converters, ADC;
- Technologies and materials;
- Nanosensors;
- Microsystems;
- Applications.

### Submission of papers

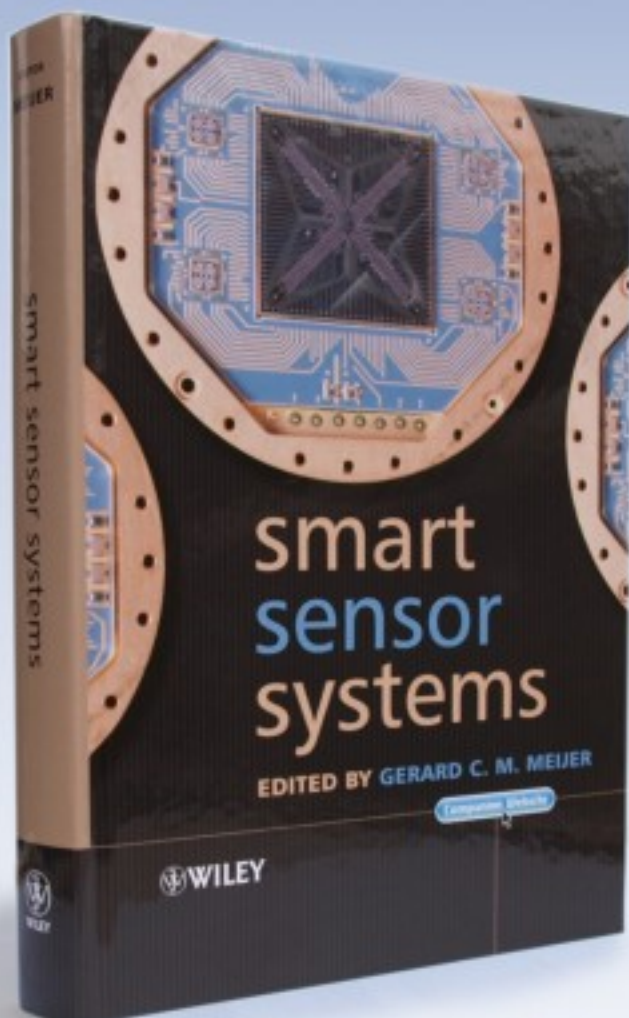
Articles should be written in English. Authors are invited to submit by e-mail [editor@sensorsportal.com](mailto:editor@sensorsportal.com) 8-14 pages article (including abstract, illustrations (color or grayscale), photos and references) in both: MS Word (doc) and Acrobat (pdf) formats. Detailed preparation instructions, paper example and template of manuscript are available from the journal's webpage: <http://www.sensorsportal.com/HTML/DIGEST/Submission.htm> Authors must follow the instructions strictly when submitting their manuscripts.

### Advertising Information

Advertising orders and enquires may be sent to [sales@sensorsportal.com](mailto:sales@sensorsportal.com) Please download also our media kit: [http://www.sensorsportal.com/DOWNLOADS/Media\\_Kit\\_2009.pdf](http://www.sensorsportal.com/DOWNLOADS/Media_Kit_2009.pdf)

 **WILEY**  
1807-2007

KNOWLEDGE FOR GENERATIONS



**'Written by an internationally-recognized team of experts, this book reviews recent developments in the field of smart sensors systems, providing complete coverage of all important systems aspects. It takes a multidisciplinary approach to the understanding, design and use of smart sensor systems, their building blocks and methods of signal processing.'**



**Order online:**

[http://www.sensorsportal.com/HTML/BOOKSTORE/Smart\\_Sensor\\_Systems.htm](http://www.sensorsportal.com/HTML/BOOKSTORE/Smart_Sensor_Systems.htm)

**[www.sensorsportal.com](http://www.sensorsportal.com)**