IEEE GEOSCIENCE and REMOTE SENSING Newsletter

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Table of Contents

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GRS-S Newsletter Schedule

Month	June	Sept	Dec	March
Input	April 15	July 15	Oct 15	Jan 15

IEEE GRS-S AdCom, Officers and Committee Chairs – 2005 GRS-29 (Division IX)

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Editor's Comments

Adriano Camps, Editor
Department of Signal Theorty
and Communications
Polytechnic University of Catalonia
UPC Campus Nord, D4-016
E-08034 Barcelona, SPAIN
TEL: (34)-934.054.153
FAX: (34)-934.017.232

First of all, I would like to welcome back Mrs. Tariro Charakupa-Chingono, our Associate Editor for African Affairs, who has recently recovered from a severe illness. From these lines I also want to congratulate Prof. Reagan, Dr. Goodenough, and Prof. LeDrew for the awards they have recently received in recognition of their work, and the 17 GRS-S members elevated to Senior Member since January 2005.

Again, this is a full 32 page issue and some of the contributions received have had to be postponed to the December 2005 issue. Since, at the time of preparing this issue we are also making the final preparations for our trip to IGARSS, the December issue will also include the reports on IGARSS 05 and the Awards presented.

In this September issue you will find plenty of pieces of information that may be of your interest, and three main articles:

- A University Profile describing the very interesting activities carried out in the field of remote sensing at the Chalmers University of Technology, in Sweden,
- An Industrial Profile describing the activities of ZAX Millimeter Wave Corporation, and
- A feature article describing some experiences in development and field evaluation of a dual sensor for humanitarian demining carried out in Afghanistan.

I hope you enjoy them, and see you in Seoul.

President's Message

Dr. Albin J. Gasiewski
President, IEEE GRSS
NOAA Environmental
Technology Lab
325 Broadway R/ET1
Boulder, CO 80305-3328,
USA
Phone: 303-497-7275
E-Mail:
al.gasiewski@noaa.gov

Arguably, we live in a rapidly changing world where economic and political boundaries are continually being redrawn. Upon the end of the cold war many respected thinkers justifiably believed the stage to be set for world-wide economic growth and stability – but particularly within the North American and Eurasian populations who were relieved of the immediate burden of detante. Who could have anticipated that we would witness such major shifts as we see today in manufacturing and information services to India and Asia? The rapid growth in prosperity within these regions is a testimony to both the inventiveness and tenacity of all peoples, but also the flow of information in an electronically connected world managed by stable governments. As we see clearly in retrospect, complex systems support inherently unpredictable modes.

Along with economic success, however, we are also witnessing very predictable strains on both world resources and the environment. While population growth may be stabilizing in a number of countries, the per capita usage of resources and associated generation of by-products continues, on average, to grow. One can hope that the gains that accompany this newfound prosperity will be invested in ways that optimize our use of minerals, fossil fuels, agricultural land, fresh water, and marine resources while maintaining the stability of our natural environment. As our IGARSS 2005 conference theme, "Harmony between Man and Nature" alluded, geoscience and remote sensing play major roles in the observation and control of our highly nonlinear and dynamic global system.

Observability and controllability are not only fundamental to the global economy and environment, but also to the Geoscience and Remote Sensing Society per se. During the late 1990s the GRS-S AdCom was keenly aware of the breadth of geopolitical change taking place and the potential impacts on our Society. To accommodate the conditions of the time the AdCom elected to begin formal strategic planning as a means of identifying the state of the Society and defining and maintaining a desired direction in the face of uncertainty. The process began during a two-day retreat in the fall of 1997 in Helsinki, and culminated in the identification of a set of strategic overarching goals which have become cornerstones of GRS-S management for the past eight years. These goals, all of which are rooted in improved members services and growth of the Society within the global remote sensing community, have emphasized expansion in the following areas:

- Conference offerings
- Continuing education offerings
- Journal offerings
- Trans-organizational interfaces

continued on page 4

Cover Information: The Odin satellite. The main antenna is 1.1 m in diameter and the satellite weight 230 kg. (Picture courtesy of the Swedish Space Corporation). See University Profile article for more details.

- Industry interaction
- Geopolitical impact of remote sensing technology

Eight years later we can claim significant strides in virtually every one of the above categories. The Society now cosponsors several specialty symposia annually, organizes at least a half dozen professional tutorials at each IGARSS, publishes the successful new GRS Letters journal, holds joint symposia with associated organizations such as the Canadian Remote Sensing Society and IEEE Oceanic Engineering Society, hosts a growing IGARSS trade and exhibit show, and is an active and recognized contributor to the international Group on Earth Observations.

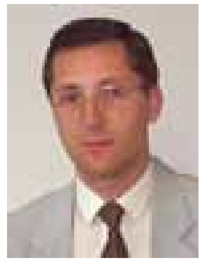
Recognizing the value of the assessment, strategy, action, and review elements of strategic planning, the GRS-S AdCom plans to begin its strategic planning process anew during the upcoming fall AdCom meeting in Boulder, Colorado. Being aware of the need to respond ever more quickly to events that affect our members, I can already envision a number of likely outcomes of this process. For example, as a means of responding to members' evolving concerns and needs I can foresee the institution of an annual GRS-S Members' Forum at IGARSS. I can also foresee a renewed commitment on behalf of the GRS-S AdCom to maintain the ability of our members' to contribute their technical expertise in the Society's fields of interest at all IEEE sponsored meetings in the face of complex and potentially contentious geopolitics.

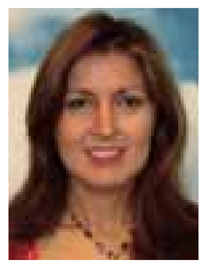
With regard to our successful IGARSS in Seoul this past July, I would like to extend our thanks to Professor Wooil M. Moon, Technical Program Co-chairs Professors Sang Hoon Lee and William J. Emery, and the IGARSS 2005 local organizing team consisting of Joong-Sun Won, Yisok Oh, Chulhee Lee, Jeong Woo Kim, Myunghee Jung, and Yong Sung Kim. Their outstanding organizational effort culminated in one of the best venues ever for an IGARSS, and one well remembered for Korean hospitality.

I would also like to congratulate Professor Werner Wiesbeck, Director of the Institut für Höchstfrequenztechnik und Elektronik (IHE) at the Univesity of Karlsruhe and Past President of the GRS-S, upon his recent election as an Honorary Life Member of the GRS-S. His election as an HLM - only the fourth such conferment in the history of the Society - occurred at the July 2005 AdCom meeting in Seoul, Korea.

One final closing note: I am pleased to be able to report that the GRS-S AdCom has elected to proceed with the digitization of all of the Society's pre-1988 peer-reviewed publications, including pre-TGARS publications in the Transactions on Geoscience Electronics dating back to 1963. The digitization of all of our Society's peer-reviewed publications will significantly enhance the base of archival material accessible to our members through the IEEE Electronic Library (IEL) system. Concomitant with this activity is a complete overhaul of the Society's web site - our portal to the world - available for immediate use at http://www.grss-ieee.org . The upgraded site was designed by GRS-S webmaster Dr. Jay Pearlman and provides several new features including an interactive forum and link to GEOSS activities. I encourage you to "surf" on by for a visit!

Newsletter Editorial Board Members:





2005 ADCOM MEMBERS' NAMES AND ADDRESSES

Dr. Albin J. Gasiewski
President, IEEE GRS-S
NOAA Environmental Technology Lab
325 Broadway R/ET1
Boulder, CO 80305-3328, USA
E-Mail: al.gasiewski@noaa.gov

Dr. Leung Tsang
Executive VP, IEEE GRS-S
University of Washington
Box 352500
Seattle, WA 98195, USA
E-Mail: tsang@ee.washington.edu

Dr. Thomas J. Jackson
Secretary, IEEE GRS-S
USDA-ARS Hydrology and Remote Sensing Lab
104 Bldg 007 BARC-West
Beltsville, MD 20705, USA
E-Mail: tjackson@hydrolab.arsusda.gov

Dr. Karen M. St. Germain
VP for Operations and Finance, IEEE GRS-S
NPOESS Integrated Program Office
8455 Colesville Road, Suite 1450
Silver Spring, MD 20910, USA
E-Mail: Karen.StGermain@noaa.gov

Dr. Kamal Sarabandi
VP for Professional Activities, IEEE GRS-S
Dept. of Electrical Eng. & Computer Science
Ann Arbor, MI 48109-2122, USA
E-Mail: saraband@eecs.umich.edu

Dr. Paul Smits
VP for Technical Activities, IEEE GRS-S
Joint Research Centre Institute for Env. And Sustainability
TP262
I-21020 Ispra, ITALY
E-Mail: paul.smits@ieee.org

Dr. Melba M. Crawford
VP for Meetings & Symposia, IEEE GRS-S
Center for Space Research
3925 W. Braker La., Suite 200
The University of Texas at Austin
Austin, TX 78712-5321, USA
E-Mail: crawford@csr.utexas.edu

Dr. Jon A. Benediktsson
Transactions Editor, IEEE GRS-S
Department of Electrical and Computer Engineering
University of Iceland
Hjardarhaga 2-6
107 Reykjavik, ICELAND
E-Mail: benedikt@hi.is

Dr. Andrew J. Blanchard
University of Texas Dallas
Johnson School
P. O. Box 830688
EC32
Richardson, TX 75083, USA
E-Mail: ablanch@utdallas.edu

Dr. William J. Emery
Letters Editor, IEEE GRS-S
CCAR Box 431
University of Colorado
Boulder, CO 80309-0431, USA
E-Mail: Emery@colorado.edu

Dr. William B. Gail
Vexcel Corporation
1690 38th St.
Boulder, CO 80301, USA
E-Mail: bill.gail@vexcel.com

Dr. James A. Gatlin
Director of Finance, IEEE GRS-S
Code 922 (Emeritus)
Goddard Space Flight Center
Greenbelt, MD 20771, USA
E-Mail: j.gatlin@ieee.org

Dr. David G. Goodenough
Pacific Forestry Centre
Natural Resources Canada
506 West Burnside Road
Victoria, BC V8Z 1M5, CANADA
E-Mail: dgoodeno@nrcan.gc.ca

Dr. Martti T. Hallikainen
Helsinki University of Technology
Laboratory of Space Technology
P. O. Box 3000
FIN-02015 HUT, FINLAND
E-Mail: Martti.Hallikainen@avasun.hut.fi

Dr. Nahid Khazenie
NASA Headquaters
Earth Science Enterprise
8509 Capo Ct.
Vienna, VA 22182, USA
E Mail: nkhazenie@hq.nasa.gov

Dr. Ellsworth LeDrew
University of Waterloo
Faculty of Environmental Studies
200 University Ave. West
Waterloo, Ontario N2L 3G1, CANADA
E-Mail: ells@watleo.uwaterloo.ca

Dr. David M. Le Vine
NASA Goddard Space Flight Center
Code 975.0
Greenbelt, Maryland 20771, USA
E-Mail: David.M.LeVine@nasa.gov

Mr. Charles A. Luther
Past President, IEEE GRS-S
Office of Naval Research
800 N. Quincy Street
Arlington, VA 22217, USA
E-Mail: lutherc@onr.navy.mil

Dr. Anthony K. Milne
University of New South Wales
School of Biological, Earth and Env. Sciences
Sydney, NSW 2052, AUSTRALIA
E-Mail: t.milne@unsw.edu.au

Dr. Alberto Moreira
German Aerospace Center (DLR)
Microwaves and Radar Institute
P.O. Box 1116
82230 Wessling/Oberpfaffenhofen, GERMANY
E-Mail: alberto.moreira@dlr.de

Dr. Jay Pearlman
The Boeing Company
PO Box 3707 MS 84-24
Seattle, WA 98124, USA
E-Mail: jay.pearlman@boeing.com

Dr. Steven C. Reising
Electrical and Computer Engineering Dept.
Colorado State University
1373 Campus Delivery
Fort Collins, CO 80523-1373, USA
E-Mail: reising@ieee.org

Dr. Werner Wiesbeck
Past President, IEEE GRS-S; IEEE GRS-S Awards Committee Chair
University of Karlsruhe
Institute for High Frequency and Electronics
Kaiserstrasse 12
76128 Karlsruhe, GERMANY
E-Mail: werner.wiesbeck@ihe.uka.de

Dr. Kiyo Tomiyasu, IEEE GRS-S
Honorary Life Member
Lockheed Martin Corp.
366 Hilltop Road
Paoli, PA 19301-1211, USA
E-Mail: k.tomiyasu@ieee.org; kiyo.tomiyasu@lmco.com

Dr. Keith R. Carver
Honorary Life Member, IEEE GRS-S
University of Massachusetts
Dept. of Electrical & Computer Engineering
Amherst, MA 01003, USA
E-Mail: kcarver@ecs.umass.edu

Dr. Fawwaz T. Ulaby
Honorary Life Member, IEEE GRS-S
The University of Michigan
4080 Fleming Building
Ann Arbor, MI 48109-1340, USA
E-Mail: ulaby@eecs.umich.edu

Ms. Lisa Ostendorf
Director of Conferences, IEEE GRS-S
IEEE Geoscience and Remote Sensing Society
63 Live Oak Lane
Stafford, VA 22554, USA
E-Mail: ieeegrss@adelphia.net

Ms. Kimberley Jacques
Director of Information Services, IEEE GRS-S
8521 Trail View Drive
Ellicott City, MD 21043, USA
E-Mail: ieeegrss@comcast.net

Mr. Granville E. Paules III
Education Director
Mission Infrastructure Management Division
Science Mission Directorate
NASA Headquarters Code SMD
Washington, DC 20546, USA
E-Mail: granville,paules@nasa.gov

Dr. David Weissman
Publicity and Public Relations
Hofstra University, Dept. of Engineering
104 Weed Hall
Hempstead, NY 11549, USA
Email: eggdew@hofstra.edu

Dr. Adriano Camps
GRS-S Newsletter Editor
Dept. of Signal Theory and Communication
Technical University of Catalonia (UPC),
Campus Nord, D4-016
E-08034 Barcelona, SPAIN
E-Mail: camps@tsc.upc.edu

Dr. R. Keith Raney
GRS-S Rep. on Social Implications of Technology
Johns Hopkins Univ. Applied Physics Lab
Space Dept.
Johns Hopkins Rd.
Laurel, MD 20723-6099, USA
E-Mail: keith.raney@jhuapl.edu

Mr. Paul Racette
GRS-S PACE Rep.
NASA/GSFC Code 555
Greenbelt, MD 20771, USA
E-Mail: Paul. E.Racette@nasa.gov

Dr. Wooil M. Moon
IGARSS05 General Chairman
Seoul National University
Dept. of Earth System Science
Kwanak-gu Shilim-dong San 56-1
Seoul, 151-742, KOREA
E-Mail: wmoon@eos1.snu.ac.kr
or
University of Manitoba
Geophysics Dept.
Winnipeg, MD R3T 2NT, CANADA
E-Mail: wmoon@cc.umanitoba.ca

Dr. V. Chandrasekhar
IGARSS06 General Co-Chairman
Colorado State University
Electrical and Computer Engineering Dept.
Fort Collins, CO 80523-1373, USA
E-Mail: chandra@engr.colostate.edu

Dr. Ignasi Corbella
IGARSS07 General Chairman
Dept. of Signal Theory and Communication
Technical University of Catalonia (UPC),
Campus Nord, D3-208
E-08034 Barcelona, SPAIN
E-Mail: corbella@tsc.upc.edu

Dr. John Kerekes
IGARSS08 General Co-chairman
MIT Lincoln Lab S4-223
244 Wood Street
Lexington, MA 02420-9185, USA
E-Mail: kerekes@ll.mit.edu

Dr. Eric Miller
IGARSS08 General Co-chairman
Electrical and Computer Engineering
315 Sterns Center
Northeastern University
Boston, MA 02116, USA
E-Mail: elmiller@ece.new.edu

Dr. Harold Annegarn
IGARSS09 General Chairman
Department of Geography and Environmental Management
Rand Afrikaans University
P O Box 524
Auckland Park 2006 Johannesburg, REPUBLIC OF SOUTH AFRICA
E-Mail: : han@rau.ac.za

Dr. Roger King
Data Archiving and Distribution Committee Chair
Mississippi State University
Box 9571
Mississippi State, MS 39762-9571, USA
E-Mail: rking@ece.msstate.edu

Dr. Lori Mann Bruce
Data Fusion Technical Committee Chair
Mississippi State University
Electrical and Computer Engineering Dept.
Box 9571
Mississippi State, MS 39762-9571, USA
E-Mail: bruce@ece.msstate.edu

Dr. Jeffrey Piepmeier
Instrumentation and Future Technologies Technical Committee Chair
NASA Goddard Space Flight Center
Code 555
Greenbelt, MD 20771, USA
E-Mail: Jeff.Piepmeier@nasa.gov

Dr. David B. Kunkee
Frequency Allocations in Remote Sensing Committee Chair
The Aerospace Corp.
Sensing and Exploitation Department
P.O. Box 92957, MS M4-927
Los Angeles, CA 90009-2957, USA
E-Mail: David.Kunkee@aero.org

Dr. Venkat Lakshmi
User Applications in Remote Sensing Committee
Department of Geological Sciences
University of South Carolina
Columbia SC 29208 USA
E-Mail: venkat-lakshmi@sc.edu

Dr. Robert A. Shuchman
GRS-S Ad Hoc Industry Liaison Committee
Altarum Institute
P.O. Box 134001
Ann Arbor, MI, USA
E-Mail: robert.shuchman@altarum.org

Dr. Sonia Gallegos
South American Liason
Naval Reserach Laboratory, Code 7333
Stennis Space Center
MS 39529, USA
E-mail: gallegos@nrlssc.navy.mil

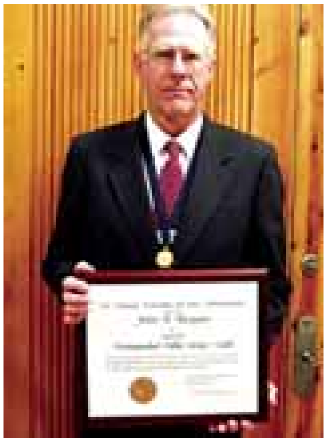
GRS-S Chapters and Contact Information

Chapter Location	Joint with (Societies)	Chapter Chair	E-mail Address
Region 1: Northeastern USA			
Boston Section, MA	GRS	William Blackwell	wjb@ll.mit.edu
Springfield Section, MA	AP, MTT, ED, GRS, LEO	Paul Siqueira	siqueira@ecs.umass.edu
Region 2: Eastern USA			
Washington / Northern VA	GRS	James Tilton	j.tilton@ieee.org
Region 3: Southeastern USA			
Atlanta Section, GA	AES, GRS	Greg Showman	greg.showman@gtri.gatech.edu
Eastern North Carolina Section, NC	GRS	Linda Hayden	haydenl@mindspring.com
Region 4: Central USA			
Southeastern Michigan Section	GRS	Mahta Moghaddam	mmoghadd@eecs.umich.edu
Region 5: Southwestern USA			
Denver Section, CO	AP, MTT, GRS	Karl Bois	karl.bois@hp.com
Houston Section, TX	AP, MTT, GRS, LEO	Christi Madsen	cmadsen@ee.tamu,edu
Region 7: Canada			
Quebec Section, Quebec	AES, OE, GRS	Xavier Maldague	maldagx@gel.ulaval.ca
Toronto, Ontario	SP, VT, AES, UFF, OE, GRS	Konstantin Plataniotis	kostas@dsp.toronto.edu
Vancouver Section, BC	AES, GRS	Jerry Lim	jl@mda.ca
Region 8: Europe and Middle East			
Central and South Italy 1	GRS	Domenico Solimini	solimini@disp.uniroma2.it
Central and South Italy 2	GRS	Maurizio Migliaccio	maurizio.migliaccio@uninav.it
Germany	GRS	Alberto Moreira	Alberto.Moreira@dlr.de
Russia Section	GRS	Anatolij Shutko	anatoli.shutko@email.aamu.edu ashutko@mail.ru
Spain Section	GRS	Adriano Camps	camps@tsc.upc.es
Ukraine	AP, NPS, AES, ED, MTT, GRS	Anatoly Kirilenko	kirilenko@ire.kharkov.ua
UKRI Section	GRS, OE	Yong Xue	y.xue@londonmet.ac.uk
Region 10: Asia and Pacific			
Beijing Section, China	GRS	Chao Wang	cwang@public.bta.net.cn
Seoul Section, Korea	GRS	Wooil Moon	wmoon@cc.umanitoba.ca
Taipei Section, Taiwan	GRS	Kun-Shan Chen	dkshen@csrsr.ncu.edu.tw
Japan Council	GRS	Masanobu Shimada	shimada@eorc.jaxa.jp

GRS-S MEMBERS HIGHLIGHTS

UA ELECTRICAL ENGINEERING PROF JOHN REAGAN WINS TOP NASA AWARD

By Ed Stiles
May 23, 2005 (Reprinted with permission from UA web site)



Professor Emeritus John A. Reagan with his Distinguished Public Service Award medal and plaque following the award ceremony in Washington, D.C.

Professor Emeritus John A. Reagan has won the highest honor that NASA awards to researchers who are not federal government employees. He received NASA's Distinguished Public Service Medal on April 27 at NASA headquarters in Washington, D.C. NASA grants the award "only to individuals whose distinguished accomplishments contributed substantially to the NASA mission. The contribution must be so extraordinary that other forms of recognition would be inadequate."

Reagan, a professor emeritus in Electrical and Computer Engineering (ECE), is an internationally recognized authority on LIDAR (Light Detection And Ranging), which is similar to radar. But unlike radar, which uses radio waves, LIDAR transmits and receives laser light.

He was recognized for his "outstanding contributions to the advancement of active and passive atmospheric optical remote sensing techniques, which are critical toward understanding the optical properties of aerosols and their impact on the climate." Aerosols are tiny particles suspended in the atmosphere. Reagan has been working on NASA projects since the 1970s and has contributed to developing the LIDAR mission for NASA's CALIPSO satellite (Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observations), which will study the effects of clouds and aerosols on Earth's climate.

During his career at UA, which started in 1967, Reagan has contributed to aerosol research by developing and applying several solar radiometer instruments to research problems. One instrument is known as the "Reagan Sun Photometer." These devices measure the optical depth of aerosols in the atmosphere and have been used extensively by NASA researchers for ground-truthing and validating measurements taken by satellites.

Reagan has been instrumental in designing LIDAR retrieval algorithms, LIDAR calibration techniques, and in solving many of the technical problems that have arisen during LIDAR's development.

His contributions to aerosol research range from making LIDAR and solar-radiometer field measurements to pioneering work on LIDAR aboard NASA's space shuttle. Reagan has contributed to several NASA missions, including the LITE mission (Lidar in-space Technology Experiment) in 1994.

Reagan was also recognized in March for his outstanding research career when the Institute of Electrical & Electronics Engineers (IEEE) sponsored a "Remote Sensing of Atmospheric Aerosols" workshop in his honor. The workshop, which was held in Tucson, addressed current developments in LIDAR and passive radiometry sensing of atmospheric aerosols, as well as directions for future research.

LIDAR has many present and potential applications including:
- Monitoring air pollution.
- Mapping and characterizing aerosols.
- Measuring winds and trace gasses.
- Investigating atmospheres on other planets, such as Mars.

Reagan is:
- A member of the IEEE Board of Directors.
- Director of Division IX, Signals and Applications, which is within the IEEE Technical Activities Board.
- An IEEE Fellow Member for his work in LIDAR and radiometry.

He received:
- The IEEE GRSS (Geoscience and Remote Sensing Society) 1995 Distinguished Achievement Award "for pioneering and continuing contributions to Lidar and solar radiometry for atmospheric sensing."
- The NASA Group Achievement Award as a Science Team Member of the Space Shuttle Mission STS-64 LITE mission (1995).
- The IEEE Millennium Medal in 2000. As part of its celebration of the Third Millennium, IEEE awarded 3,000 Millennium Medals and certificates to members who had made outstanding contributions in their fields. In 1996, Reagan was the Invited MIT Distinguished Lecture Series Lecturer.

Reagan also established the Atmospheric Remote Sensing Laboratory (ARSL) in UA's ECE Department. On June 10, he attended a second Distinguished Public Service Medal ceremony at the NASA Langley Research Center in Hampton, Va. Reagan spent his sabbatical at NASA Langley in 1978 and 1979, where he began his long relationship with the agency. Most of his NASA LIDAR work has been conducted through the NASA Langley Research Center.

DR. DAVID GOODENOUGH RECEIVES THE 2004 CANADIAN REMOTE SENSING SOCIETY'S GOLD MEDAL AWARD

Dr. David Goodenough was awarded the 2004 Gold Medal at the Canadian Remote Sensing Society's (CRSS) Symposium in June 2005 in Wolfville, Nova Scotia. This is the highest award of the CRSS. Dr. David Goodenough's contributions to the field of remote sensing in general and to forwarding the field in Canada are particularly noteworthy. He contributed significantly to the development of the Canada Centre for Remote Sensing in the 1970's and 1980's, where he was instrumental in leading the development of the CCRS Image Analysis System (CIAS), one of the first special-purpose hardware and computer system dedicated to the analysis of satellite earth observation data. He and Ray Lowry were the first people in Canada to work on airborne synthetic aperture radar. Dr. Goodenough led the SAR/MSS project, the first project to fuse airborne and satellite SAR and multispectral scanner data over mountainous forested terrain in BC. He also led the Landsat Digital Image Analysis System (LDIAS) project for which he received a Government of Canada Award of Excellence. Dr. Goodenough has been responsible for a number of significant remote sensing projects in Canada including two jointly funded by NASA and the Government of Canada: SEIDAM (System of Experts for Intelligent Data Management) and EVEOSD (Evaluation and Validation of EO-1 for Sustainable Development). Dr. Goodenough generated the successful national proposal for the Earth Observation for Sustainable Development of Forests (EOSD) and currently leads the automation team for this project. He was one of the first Canadian researchers to recognize the importance of hyperspectral data to the field of earth resource assessment, successfully promoting multiple missions of NASA's AVIRIS over various Canadian locations. He is currently one of the senior Canadian scientists developing an all-Canadian hyperspectral earth observing mission (HERO).

Dr. Goodenough is a Fellow of the IEEE and a Past-President of the IEEE Geoscience and Remote Sensing Society. He is an Adjunct Professor in the Department of Computer Science at the University of Victoria where he actively supervises masters and doctoral students. He is currently a Senior Research Scientist at the Pacific Forestry Centre of the Canadian Forest Service in Victoria, British Columbia.

Prepared by Olaf Niemann, Chair, Canadian Remote Sensing Society.

PROF. ELLSWORTH LEDREW RECEIVES THE 2005 CANADIAN REMOTE SENSING SOCIETY'S GOLD MEDAL AWARD

The 2005 Canadian Symposium on Remote Sensing, Ellsworth LeDrew received the Canadian Remote Sensing Society's Gold Medal Award. The award recognizes Ellsworth's many contributions to research, education and service in the remote-sensing community.

In the citation, it is stated that, "His research on arctic sea ice and atmospheric dynamics has been critical to our current understanding of climate change and global warming." His work on coral bleaching and ocean/atmosphere dynamics is also recognized as "leading-edge science, placing Canadian remote-sensing expertise within a global context."

To date, 14 Ph.D. students and 27 Master's students have completed their theses under Ellsworth's supervision. He has "populated Canada's universities, government agencies, and the international private sector with well-trained remote-sensing scientists. His extensive ties with the climatological, meteorological, engineering and physics communities has meant that all who were taught by him benefited from his breadth and depth of remote-sensing knowledge. Of his many accomplishments, this would surely rank as the greatest."

Ellsworth is a Fellow of the Canadian Aeronautics and Space Institute and was President of the Canadian Remote Sensing Society from 1999 to 2001. In 2002, he was Chair of the Organizing Committee for the International Geoscience and Remote Sensing Society annual symposium which was held in Toronto; an event attended by over 1,400 participants from around the world.

CERTIFICATE OF APPRECIATION PRESENTED TO TARA JENSEN

GRS-S President Al Gasiewski presents a certificate of appreciation to Tara L. Jensen for six years of service to the Society in upgrading and maintaining the GRS-S web site. The presentation was made on July 3 at a meeting of the IGARSS 2006 local organizing committee in the Chautauqua Dining Hall in Boulder, Colorado.

GRS-S MEMBERS ELEVATED TO THE GRADE OF SENIOR MEMBER FROM JANUARY 2005 TO JUNE 2005

GRS-S Members Elevated to the Grade of Senior Member from January 2005 to June 2005

January 2005: Melba M. Crawford, Edward J. Kim, Guoqing Zhou.

February 2005: Jasmeet Judge, Minglai Kao, Matthew L. Smith.

April 2005: Dirk H. Hoekman, Dennis Horwitz, George A. Kyriacou, Erzsébet Merényi, John Vesecky.

May 2005: Rajan Bhalla, Kazem F. Sabet, Steven M. Shope.

June 2005: Qian Du, Sonia Gallegos, Takashi Yahagi.

Senior membership has the following distinct benefits:

- The professional recognition of your peers for technical and professional excellence.
- An attractive fine wood and bronze engraved Senior Member plaque to proudly display.
- Up to $25.00 gift certificate toward one new Society membership.
- A letter of commendation to your employer on the achievement of Senior member grade (upon request of the newly elected Senior Member).
- Announcement of elevation in Section/Society and/or local newsletters, newspapers and notices.
- Eligibility to hold executive IEEE volunteer positions.
- Can serve as Reference for Senior Member applicants.
- Invited to be on the panel to review Senior Member applications.
- Eligible for election to be an IEEE Fellow.

Applications for senior membership can be obtained form IEEE GRS-S website: http://ewh.ieee.org/soc/grss/ (click Join Us) or IEEE Senior membership program: http://www.ieee.org/organizations/rab/md/smprogram.htm

NATIONAL SCIENCE FOUNDATION AWARDS GRANT TO CREATE NATIONAL POLAR ICE RESEARCH CENTER

The National Science Foundation (NSF) has established a Science and Technology Center (STC) to develop technologies, conduct field investigations and compile data to understand why large ice sheets are undergoing rapid changes, and develop models to explain and predict their response to climate change. The NSF awarded the University of Kansas $19M to create the Center for Remote Sensing of Ice Sheets (CReSIS) in June 05. It is one of two Centers established by NSF during 2005. The Center's long-term goals are to provide predictions of the future mass balance of the polar ice sheets under a range of possible climate conditions and to increase the number of students and professionals who are contributing to polar research. It includes Elizabeth City (N.C.) State University, Haskell Indian Nations University, the University of Maine, The Ohio State University and Pennsylvania State University as core partners. International, industrial, and government laboratory partners include: University College of London, University of Copenhagen, Denmark Technical University, University of Tasmania, Sprint Corp., Lockheed Martin Corp., Space Computer Labs, NASA Jet Propulsion Laboratory, and NASA Goddard Space Flight Center. Dr. Prasad Gogineni, Deane Ackers distinguished professor of electrical engineering and computer science at KU, will serve as the director.

http://www.cresis.ku.edu/

PACE PIECE

AVOID THE TOP FIVE RESUME MISTAKES

Deborah Walker, CCMC
Career Coach ~ Resume Writer
Find more career articles and resume samples at www.AlphaAdvantage.com
Deb@AlphaAdvantage.com

Over the years as a recruiter and career coach, I have seen the consequences of poorly written resumes. Unfortunately, most people don't seek professional career help until they experience the frustration of a long and fruitless job search. It is surprising how many of their problems can be traced to the top five resume mistakes.

#1 No resume focus.

The most effective resumes leave no doubt as to the job seeker's career objective. A one-size-fits-all resume gives the impression that the job seeker is uncertain of his career goal. An employer once told me that if a candidate is interested in two completely different positions, he must not be very good at either. If you have more than one career objective, you need more than one resume.

#2 Lack of marketing strategy.

Job seekers rarely see their search for what it is—a sales campaign. Think of your resume as marketing material designed to create a powerful first impression and win a multitude of job interviews. A professional resume writer can translate your career history into an effective marketing piece by selling toward the reader's buying motives: solving problems, saving money, or increasing profits.

#3 No accomplishment statements.

95% of all resumes lack accomplishment statements. These statements allow employers to visualize your contribution to their company. A resume writer can help you move from a job description type resume to a resume with quantifiable statements that motivate employers to call you before their competition does. These statements can dollarize your worth and increase your bargaining power.

#4 Lack of resume keywords.

These days, resumes are screened by both humans and computers. A resume lacking in keywords runs the risk of being read by neither. An average screening of a resume is 15 seconds or less, so more attention is paid to resumes using the same words found in the job description. Candidate-tracking software retrieves resumes by keywords. A keyword-focused resume will put you front and center.

#5 Incorrect resume format.

Basically, there are three resume formats: chronological, functional and hybrid.

- **Chronological:** The chronological is best known and easiest to write, a timeline style resume. This format works well if your objective is to remain in the same industry or occupation.
- **Functional:** The functional resume places transferable skills and accomplishments at the beginning of your resume. However, a poorly crafted functional resume can be confusing, causing the reader to believe the candidate has something to hide.
- **Hybrid:** The hybrid resume combines the best features of other resumes. It showcases skills and accomplishments while maintaining ease of reading. This is the best format for job seekers of all level, but it is also the most difficult to write.

A professional resume writer can build a hybrid resume that will win response. Once your resume is designed to avoid the top five resume mistakes, you will be well on your way to winning interviews and reaching your career objective.

AMENDMENT TO THE GRS-S CONSTITUTION

K. Tomiyasu
Chair, GRS-S Constitution and Bylaws Committee

L. Tsang
GRS-S Executive Vice-President

A Constitutional amendment was passed by the GRS-S Administrative Committee on July 23, 2005, and this is described below for review and acceptance by the GRS-S membership. This amendment will go into effect within 30 days of publication unless ten percent of Society members object.

Constitution, VI.13, Ex-Officio AdCom Members

~~Deletions~~ **Additions**

13. Ex-Officio AdCom Members

The AdCom may appoint ex-officio members of the Society in two categories: (i) Ex-Officio AdCom Member with voting privileges, and (ii) Ex-Officio AdCom Member without voting privileges. Ex-Officio members of the AdCom, with or without voting privileges, shall not be eligible for election as President or Executive Vice-President nor shall they vote for AdCom members **at the AdCom Election meeting**. Ex-Officio Members shall be members of IEEE. ~~An individual cannot hold an Ex-Officio position for more than three years.~~ **Terms of Ex-Officio members are three years or less. Upon expiration of the term, an Ex-Officio can be re-appointed to a new term.**

UNIVERSITY PROFILE

REMOTE SENSING AT THE DEPARTMENT OF RADIO AND SPACE SCIENCE, CHALMERS UNIVERSITY OF TECHNOLOGY

Jan Askne, Gunnar Elgered, Bo Galle, Donal Murtagh, Gary Smith-Jonforsen, and Lars M.H. Ulander
www.rss.chalmers.se

Introduction

The department of Radio and Space Science, which is associated with the national facility "Onsala Space Observatory", is doing research in remote sensing, global environmental measurements, synthetic aperture radar, space geodesy, receiver development and radio astronomy. The forerunner of the department was created in the 1940s by Professor Olof Rydbeck working in the field of ionospheric investigations and wave phenomena. Observations were performed from Råö on the Onsala peninsula south of Göteborg. Since this time the department has had a unique position in Sweden regarding observations of the Earth and cosmic clouds, interpretation of the measurements, and in associated technical developments.

The ionospheric research was followed by activities in the field of radio astronomy and the Onsala Space Observatory was equipped with large telescopes for microwaves and millimeter waves, and with sensitive receivers such as maser receivers developed within the department. In the 1970s the possibility of applying the technique for remote sensing and as part of the development of an oil spill detection system for the Swedish Coast Guard a 35 GHz radiometer for oil thickness estimates was investigated. The oil spill application was the starting point for microwave remote sensing in the department. Over the years the department has developed new earth observation techniques in collaboration with users, investigating and evaluating the applications in field campaigns. The applications have often been typical for northern latitudes, sea ice and boreal forests but the focus is today very much on atmospheric aspects, ozone interactions, climate aspects of water vapor, air pollution in cities etc.

Microwave remote sensing established

The interest for meteorological nowcasting was growing in the late 1970s, and the need for automatic equipment included not only weather radars but also techniques which could possibly replace radiosondes. Microwave radiometers can be used for profiling of atmospheric temperature and for water vapor.

At the same time the improved Mark III system was developed for geodetic Very-Long-Baseline Interferometry (VLBI) which promised to measure global distances with accuracies at the centimeter level. The goal was to estimate the contemporary tectonic plate motion and called for independent observations of the propagation delay caused by atmospheric water vapor above each site. A water vapor radiometer (21.0 and 31.4 GHz) was developed for this purpose during 1978 – 1980. The plate motion across the Atlantic Ocean was detected in the mid eighties and the microwave radiometer has continued to be operated during the VLBI experiments from 1980 to 2005. Figure 1 shows the radiometer in front of the 20 m telescope at the Onsala.

Fig. 1 The water vapor radiometer at the Onsala Space Observatory as it was installed in July 1980.

The development of a radiometer in the 60 GHz range was now initiated based on sequential measurements at eleven frequencies between 52.8 and 58.8 GHz. Simulations showed that this approach would work and together with the water vapor radiometer practical tests were carried out in 1984 when a large number of radiosondes were launched for comparison, and we also participated in field experiments, see Figure 2.

The equipment demonstrated the results from simulations, i.e. the temperature profiles had good accuracy for the lowest two kilometers decreasing higher up, while the water vapor radiometer was mainly an integrating device. Development of an industrial prototype was initiated but interrupted before a final product related to financial problems. However, in the department the atmospheric activities were continued associ-

Fig. 2. Atmospheric observations in 1984 using temperature profiling radiometer (in caravan) as part of a field experiment for investigating the atmospheric circulation in the neighborhood of a nuclear power station.

Fig. 3 In situ measurement of sea ice roughness during the Baltic campaign of 1994 by means of laser device.

ated with the water vapor radiometer while the temperature profiling was later to be the basis for activities regarding ozone profiling in the stratosphere.

Supporting ice breakers in the Baltic and investigating climatic aspects of sea ice in the Arctic

In the mid 1980s Europe was approaching the launch of its first satellite equipped with microwave instrumentation (ERS-1) and discussions were started to identify the most important applications for Sweden. A group was formed consisting of the Swedish Meteorological and Hydrological Institute, the Swedish Space Corporation, the Defence Research Organisation, and the Department of Radio and Space Science and it was decided to concentrate on investigations regarding sea ice monitoring in the Baltic. The possibility to replace NOAA imaging with high resolution radar images independent of the cloud cover was very attractive. Detection of ice ridges and rough ice conditions, see Fig. 3, were some of the concerns and SAR imaging the major tool, but also radar altimeter projects were initiated. Collaboration was set up with Finnish groups and together extensive experiments with the French Varan-S X-band SAR in 1985 and the Canadian CV-580 C-band and X-band SAR systems in 1987 were carried out as part of the International PIPOR project. Experiments followed with ERS-1 in 1992 and 1994 during the 3-day repeat cycle for which the orbit, with the support of the international ice community, had been chosen to cover the Baltic Sea optimally.

After several expeditions to the Antarctic, Sweden at this time took initiative for an expedition to the Arctic Ocean, and the Department took responsibility for a research group regarding sea ice and remote sensing. The Swedish ice breaker Oden was joined by the German research vessel Polarstern in 1991 and obtained the very first images from ERS-1 over Arctic areas in August 1991. The ships reached the North Pole as the very first surface ships without nuclear powered engines in September 1991. The coverage of ERS-1 extended up to latitude 85^{o}N, but in the next field campaign in 1996 this was extended by having the first images from Radarsat at latitudes up to 88^{o}N. The *in situ* observations were followed up by ice classification and ice concentration mapping from the radar images together with measurements of ice drift and polynya detection. Comparisons between SAR imaging and microwave radiometry showed many of the advantages of high spatial resolution and the need for SAR imaging.

SAR interferometry and biomass of forests

In contrast to other projects an activity was started up in 1991 in the Remote Sensing Group based primarily on a technical interest, with no specific application in mind. However, later this research area came to develop into one of our major methods for investigation of biomass or stem volume of boreal forests. Forest applications had been identified as a possible microwave application due to problems with the cloud cover for optical satellites. Forests cover 65% of Sweden's area and forestry is of very high economic importance for the country. Collaboration with the Swedish University of Agricultural Sciences in Umeå was started and investigations of C-, L-, and P-band observations acquired by the JPL DC-8 over Flevoland in Holland were initiated. In situ measurements of stem volume were carried out and polarimetric aspects were analyzed at the different frequencies. The sensitivity for the ground-trunk scattering at P-band was established, while C-band backscatter seemed of little use for stem volume retrieval. However, from some of the ERS-1 data obtained as part of the sea ice program it was found in 1991/92 that the interferometric phase and coherence were sensitive to the forest height. The latter was identified as the more robust measure of the forest stem volume. ERS-1 repeat pass interferometry data were used from the 3-day repeat cycle and it was found that forest information was contained in time intervals up to 12 days. As part of the investigation it was also shown how clear cuts larger than 2 ha were possible to identify. The repeat-pass interferometric coherence and phase were found quite sensitive to the influence of environmental parameters, which complicated the analysis considerably. For stable weather conditions a model of coherence versus stem volume is important. For inversion the model has to be relatively simple and an Interferometric Water Cloud Model was introduced taking into account e.g. canopy closure and volume decorrelation. Coherence observations under optimal conditions (sub-zero temperature, snow covered ground, and wind speeds larger than 5 m/s) have resulted in a relative stem volume accuracy of 13% for one investigated area where the stand size is > 2 ha. However, for another area, we have found relative accuracies twice as large and we are currently investigating more cases in order to identify the operational implications, see Figure 4.

C-band interferometry was the starting point, but today L-band interferometry is of higher interest in the Radar Group due to the planned launch of ALOS. Ongoing investigation areas include Siberia as well as sites in Sweden. However, the major effort of the Radar Group is nowadays related to forest applications using low frequency investigations.

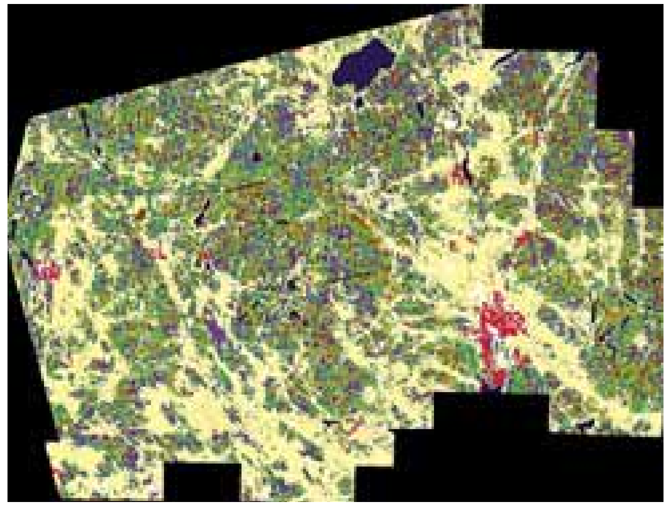


Fig. 4. Stem volume 0-350 m^3/ha in intervals of 50m^3/ha from a 4235 km^2 area at latitude 60°N in Sweden (from Rem. Sens. Env., 81, 19-35, 2002). For a smaller part of the area a relative accuracy of 13% has been achieved.

Image formation and radiometric calibration of SAR images

When we started SAR work in the mid-80, many calibration methods were based on heuristic arguments rather than theory. Our focus was mainly radiometric calibration, i.e. computing the backscattering coefficient from SAR image pixel values, since the projects required repeatability and a link to electromagnetic models. In this work, we developed the theory for reference target analysis and radiometric slope correction. The methods were applied to ERS-1 and CARABAS, including deployment of large trihedrals with side-lengths of 1.7 and 5 m, respectively. The latter are being modified for PALSAR calibration.

The work on image formation started in late 80's in support of calibration activities and the need to simulate ERS-1 images before launch. In the 90's, focus switched to algorithms for CARABAS. Most SAR algorithms at the time operated in Fourier domain by exploiting symmetries of straight flight tracks in combination with motion compensation. We found that time-domain algorithms produced superior image quality but that they were computationally inefficient. A breakthrough came when we developed a time-domain algorithm ("fast factorized back-projection") with computational performance in parity with Fourier algorithms. Recent work includes applicability to microwave SAR and SAS (synthetic-aperture sonar).

Very long wavelength SAR and forest biomass

Since 1984 the airborne VHF SAR system, CARABAS, has been under development by the Swedish Defence Research Agency (FOI), and Chalmers has been working with FOI to develop civilian applications of this unique SAR sensor. The long wavelengths (3-15m) of CARABAS have proven particularly useful for forest biomass mapping, since the waves penetrate the canopy and the backscatter comes almost exclusively from the tree trunks through the ground-trunk dihedral mechanism. Early results showed a strong correlation between backscatter and forest biomass, and to-date no sign of the signal saturation that severely limits the use of shorter wavelengths has been observed. Through the use of electromagnetic scattering models and comparison with measurements it has been shown that the ground-trunk double-bounce dominates in CARABAS images even on relatively steep slopes, and that the effect of topography on the backscatter (by disturbing the dihedral geometry) is both well understood and possible to compensate through the use of multiple flight directions (Fig. 5). Larger-scale studies in Sweden have shown that the processing can be automated to produce geocoded maps of biomass with accuracies similar to ground surveys (particularly for larger coniferous trees with diameter >15 cm) at a fraction of the cost of ground inventory. This product complements traditional optical remote sensing surveys, and the possibility of developing CARABAS for forest mapping on an operational basis is being investigated together with the Swedish University of Agricultural Sciences and FOI.

While the results of biomass mapping with CARABAS are excellent, there is little hope of transferring the system to a satellite platform for global mapping and monitoring due to the problems of ionospheric disturbance at these frequencies. Hence there is also a move towards the use of slightly higher frequencies (namely the recent P-band allocation around 435 MHz). Airborne SAR experiments have been performed to investigate in more detail methods for retrieving biomass at

Fig. 5. CARABAS image of a mixed forest in Southern Sweden, produced by combining images from multiple flight directions. Buildings and linear metallic structures (fences, overhead cables, etc.) appear very bright. Grey tones in forested areas are related to biomass, varying from unforested areas (black) to dense forest (aboveground biomass ~400 tons/ha). The image covers an area of 1.25 km by 1.5 km.

these frequencies including the corrections required for the ionospheric effects of Faraday rotation and defocusing due to scintillation. The possibilities of P-band for global forest biomass mapping and also for measuring the thickness of continental ice sheets are driving the design of proposals for future satellite missions.

Mapping Wind-Thrown Forest

Recently there has been great interest in the use of SAR for mapping the damages to forest lands caused by hurricane force winds. In January 2005 strong winds caused damages in Southern Sweden to more than 75 million cubic meters of timber (equivalent to one year's harvest for the whole of Sweden). This resulted in an urgent need for synoptic data to assess the extent of the damage, and detailed maps to aid in clean-up operations – primarily to avoid the risk for exploding insect populations and to direct the use of pesticides to avoid long-lasting damage to productive forest. Optical imaging is restricted in this case, due to the requirements for timely mapping during periods of extensive cloud-cover and short days at these latitudes. Hence the possibility of using SAR for mapping forests is of great interest, and Chalmers is involved in projects to investigate the usefulness of SAR and develop preparedness for future storms. In particular the use of long wavelengths in CARABAS has shown good results, as the major change due to the storm is in the orientation of the tree trunks and branches, which changes the polarimetric response. There is also some indication that high-resolution microwave SAR may be of use due to changes in the texture due to the patchy nature of the wind damages, although the resolution of existing satellite SAR systems is not sufficient.

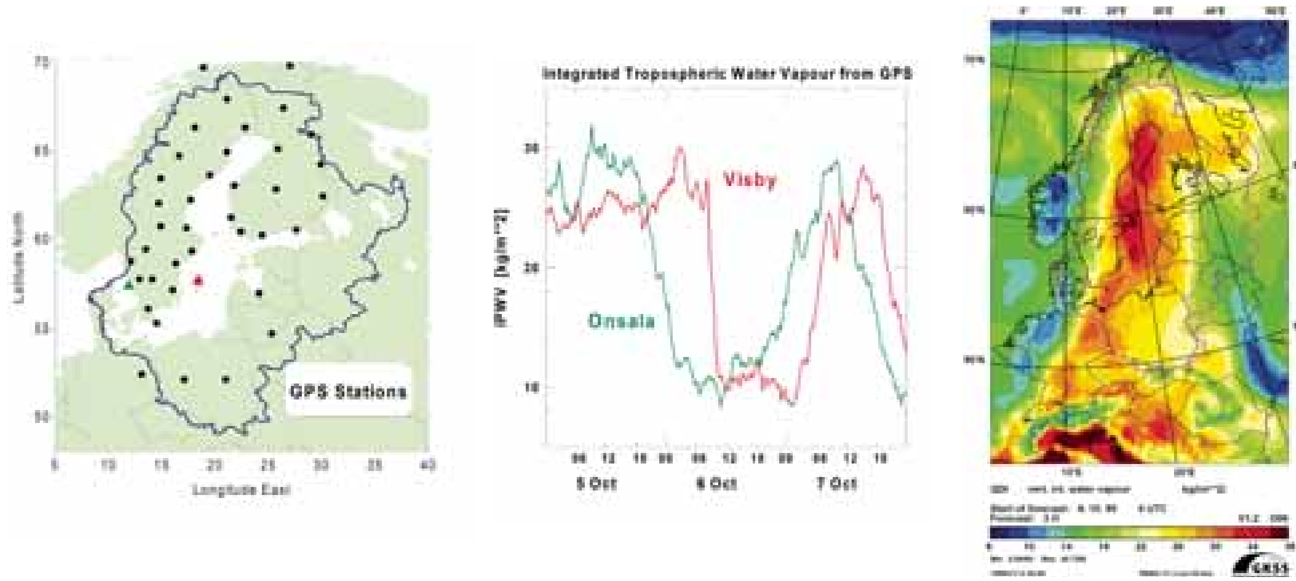
From Quasars to GPS satellites

As already described microwave radiometry was used to provide water vapor information for improvement of the accuracy of the space geodetic method of VLBI. Similarly microwave radiometry can also provide corrections for the atmospheric effects in high accuracy static positioning using ground-based GPS networks. The normal situation when using GPS for geodetic applications is, however, that no independent information is available on the variability of water vapor and the atmospheric influence must be estimated from the GPS data themselves. By spreading the observations over a large range of elevation angles the correlation between the estimates of the clock drifts in the receiver and the equivalent radio wave propagation delay in the zenith direction is reduced and both of these effects can be estimated simultaneously. Often the ground pressure can be measured or modeled with sufficient accuracy in order to infer the Integrated Precipitable Water Vapor (IPWV) at each GPS site. Since the IPWV is difficult to measure with high temporal and spatial resolution, this opened up for a new application — the use of these estimates in the area of meteorology. An example of IPWV results obtained from a ground-based GPS network is shown in Figure 6 where they can be compared to a three-hour Numerical Weather Prediction (NWP) forecast.

We have used ground-based GPS for IPWV measurements where three different applications can be identified:

- weather forecasting, including nowcasting, when the results must be available in near real time,
- validation of NWP as well as long term climate models,
- climate monitoring.

For weather forecasting near real time data analysis and coordinated efforts at the European level has been accomplished through "COST Action 716: Exploitation of Ground-Based GPS for Climate and Numerical Weather Prediction Applications" where the space geodesy group in our department played a leading role. Today more than 400 sites are providing water vapor data to the hub at the MetOffice in the UK within 1 hour and 45 minutes of the data acquisition. European weather services can, thereafter, download data for their specific needs.



(a) (b) (c)

Fig. 6. Measurements of the IPWV using GPS receiver sites in the catchment area of the Baltic Sea. (a) The GPS network where the Onsala and the Visby sites are marked by a green and a red triangle, respectively. (b) Time series of the IPWV at Onsala and Visby. (c) A three hour forecast for the time epoch 3 UT on the 6th of October 1995 made at the GKSS in Germany. Note the overall consistent results between the temporal information in (b) and the spatial information in (c).

The continuously operating and rather dense networks of GPS receivers provide consistent time series of the water vapor content over both short and long time periods. So far such data sets have been used for validation of NWP models within the above mentioned COST project and of climate models, e.g., within the BALTEX experiment.

The application of climate monitoring is still in the future. Parameter averages taken over 30 years or more are often needed in order to define a certain climate. Although the history of continuously operating GPS networks is now of the order of ten years, as the time series grow longer we expect the GPS data to be able to provide independent information with a good spatial resolution. The strength in the IPWV estimates from GPS data is that they are based on observations of time delays, thereby avoiding the difficult calibration of intensities over many decades. As an example Figure 7 shows linear trends in IPWV time series measured by the Swedish GPS network SWEPOS. Although the trends are small we can clearly see systematic differences over the region as well as different behavior for the winter (Figure 7a) and summer (Figure 7b) periods.

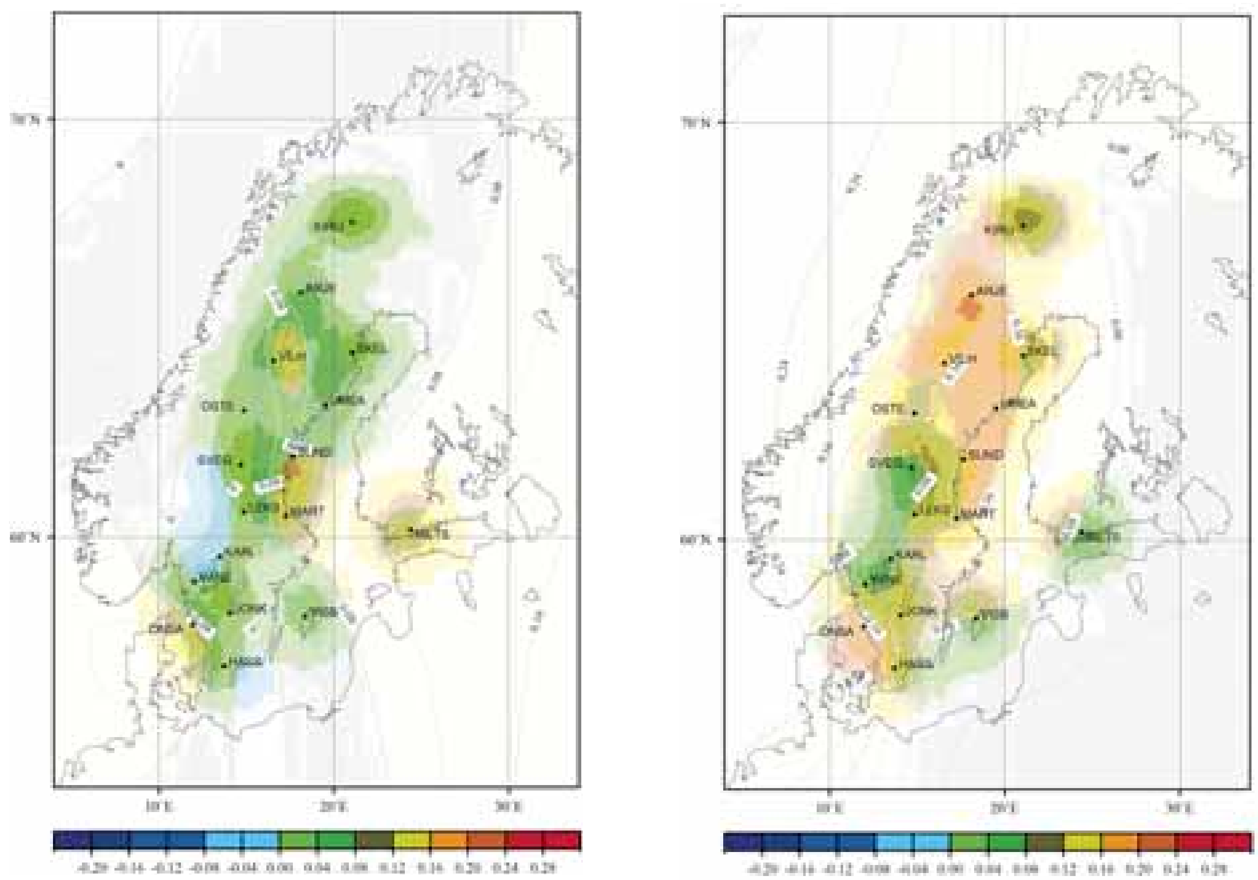
Today IPWV results from GPS are routinely compared to those from independent techniques, such as microwave radiometry, radiosondes, and VLBI. We are also assessing the possibility to infer 3D information on the atmospheric water vapor using very dense GPS networks where the data are analyzed using tomographic methods.

Chalmers' Environmental Initiative

Chalmers University of Technology has a unique role in the Swedish University organization as a foundation university since 1994. This means that it is owned by a foundation and the relationship with the state is based on agreements instead of public law regulations. The university can by itself decide on strategic investments, organization, and recruitment of academic staff. When Chalmers in 1999 decided to profile environmental sciences at the university and introduced seven new professorships one of them was in Global Environmental Measurements associated with the developments in remote sensing. As part of the university effort a research group using optical remote sensing was also formed and this has now joined the department.

Global measurements and the upper atmosphere

The global environmental measurements group was formed in November 2000 when the new professorship was established. Part of the previous remote sensing group moved to the new group. The group's expertise lies in remote sensing of the atmosphere from space using passive techniques from the UV to the microwave region. Central to our research at the moment is the Odin satellite mission (see cover figure). Odin is a joint effort between Sweden, France, Canada and Finland aimed at both astronomical and atmospheric research. It was launched in February 2001 and carries two instruments, a



(a) (b)

Fig. 7. Estimated linear trends in IPWV for the time period August 1993 – July 2003 for (a) winter data, and (b) summer data. The scale is in kg/m2/yr.

Sub-Mm Radiometer (SMR) built at the department and an Optical Spectrograph and Infra-Red Imaging System (OSIRIS) built in Canada.

Approximately 50 % of the observing time with Odin is dedicated to atmospheric research covering topics such as ozone depletion, atmospheric transport and the distribution of minor species in the upper atmosphere. Odin was in the fortunate position to give a bird's eye view of the unique Antarctic ozone-hole break up event in September 2002.

In the group we have developed tools for analyzing both the sub-mm and the optical spectra to obtain the vertical distributions of many atmospheric species. Currently much effort is being put on extracting ice water content in clouds from scattering in the sub-mm bands. In addition to producing operational products we analyze these using a variety of tools such as photochemical modeling and data assimilation. Odin contributes to various EU projects such as VINTERSOL and SCOUT

The group also runs two ground based radiometers measuring ozone, carbon monoxide and water vapor in the middle atmosphere helping to quantify the ascent and decent rates in the global mesospheric circulation pattern. Work is also proceeding on projects, in particular work for future atmospheric chemistry and climate missions.

Optical remote sensing

The Optical Remote Sensing group started its work 1980 at Swedish Environmental Research Institute (IVL). In 1999 the research group moved to Chalmers as part of Chalmers Environmental Initiative. The research field of the optical remote sensing group is development and application of ground-based optical remote sensing methods for atmospheric studies. In specific we are focusing on tailoring instruments and measurement strategies to address specific measurement problems related to environmental research and monitoring needs. The work is very international and field oriented, and spans a large variety of disciplines covering: volcanic gas measurements, industrial hydrocarbon emissions, atmospheric chemistry in Mega cities in developing countries, emissions of climate gases from different ecosystems, emission from ships and aircraft, methane emissions from landfills, stratospheric ozone depletion and satellite validation.

Since 1994 the team operates a high resolution FTIR for Solar spectroscopy at Harestua in southern Norway. The instrument is part of NDSC (Network for the Detection of Stratospheric Change), and its main purpose has been to study the composition of the stratosphere in relation to chemically induced stratospheric ozone loss, as well as satellite validation and validation of global chemical transport models. During recent years an increasing part of the work has been devoted to studies of tropospheric molecules, exploiting the spectral archives collected during 10 years operation. We have actively participated in the EU projects SESAME, THESEO, COSE and UFTIR.

Based on our expertise in Solar FTIR spectroscopy a ground-based Solar Occultation FTIR (SOF) instrument has been developed. With this instrument vertical columns of numerous molecules may be determined over local and regional scales, providing unique opportunities for quantification of emissions from industries, cities and regions. The SOF instrument also provides a possibility to validate satellites and models over spatial dimensions corresponding to the pixel size of the satellites and models.

The rapid development of CCD-cameras, computers and radiative transfer models has opened up the possibilities of developing new compact, cheap instrumentation, based on optical remote sensing. Examples of this are instruments for volcanic gas monitoring and novel measurement strategies for urban air monitoring in developing countries. A new instrument for real time monitoring of gas emissions from active volcanoes has been developed and a network based on this technique, NOVAC (Network for Observation of Volcanic and Atmospheric Change) is presently under development. The work on volcanoes have been funded by EU via the projects DORSIVA and NOVAC, coordinated by Chalmers, as well as UN, SIDA and AGS.

AGS, Alliance for Global Sustainability, is an organization comprising the 4 universities MIT (Boston USA), ETH (Zürich), Tokyo University and Chalmers. The purpose of this organization is to support research related to environmental problems in developing countries, with strong emphasis on impact. AGS have supported projects where we have applied optical remote sensing to air pollution studies in Beijing, Shanghai, Kathmandu and Mexico City.

Courses

Related to remote sensing the department offers courses in “Space techniques”, “Space environment”, “Satellite positioning”, “Remote sensing in environmental science”, and “Radar and remote sensing”. These courses are also part of an international M.Sc. program in “Radio Astronomy and Space Science” consisting of one year of full time study plus a six month project. In the near-future education at Chalmers will be reorganized according to the so called Bologna model. The present international M.Sc. programs will be replaced by new, two year, programs from 2007/08. The department has proposed a new M.Sc. program combining the fields of remote sensing and astronomy.

Website www.rss.chalmers.se

On the website you find information about our research and education, some course material (e.g. Remote Sensing using Microwaves) and programs for atmospheric inversions.

and the future...

From looking back we see that many of the first applications of interest for us are still under development and that endurance in the developments is very important. Today the fast technical developments of remote sensing, of sensors and platforms, are still more important to convey to new generations of students in order to make use of the large investments made in the society and the implications for climate change etc. Our long history and tradition within the fields of observational techniques of the earth and its surroundings is important for the new educational program as well as our ongoing scientific projects in the fields of remote sensing and radio astronomy spanning electromagnetic waves from the optical to low frequency regime. Developments of new sensors and routines for their applications in collaboration with potential users will continue.

Fig. 9. Harestua Solar Observatory.

Publications

Mainly some few recent publications are listed. For further details; see our website www.rss.chalmers.se and search scholar.google.com for the names of the authors.

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INDUSTRIAL PROFILE

ZAX MILLIMETER WAVE CORPORATION: MANUFACTURER OF ACTIVE AND PASSIVE MILLIMETER WAVE COMPONENTS AND SUBSYSTEMS

David Zacharias
ZAX Millimeter Wave Corporation
555 West Allen Ave. Unit 3
San Dimas, CA 91773
Email: zax@millimeterwave.com
http://www.millimeterwave.com/index.html

Introduction

Many of you are familiar with ZAX Millimeter Wave Corporation, particularly if you have been involved with building or calibrating microwave radiometers. ZAX was founded in 1984 by David Zacharias in San Dimas, California. David brought experience from his work at the Georgia Research Station in Atlanta, which is now the Georgia Tech Research Institute (GTRI) and also at Aerojet ElectroSystems Company (now Northrop Grumman Electronic Systems) in Azusa California, to his newly formed business. Expanding their capabilities over the years since, ZAX currently has the ability to deliver a wide variety of custom-built millimeter-wave components, perhaps most notably for applications in airborne and spaceborne remote sensing.

Above 40 GHz, suppliers of RF hardware are few; almost no markets demand manufacturing of commercial quantities of components. Suppliers of hardware for this frequency range are generally highly specialized, delivering components to specific applications. To this end ZAX has been particularly responsive to needs of the experimental and operational microwave radiometry community by providing a variety of highly specialized components to customers with often stressing requirements of quality, budget, timeliness or just plain new capabilities. ZAX has made possible many activities for the microwave radiometry community.

RF Sources and Mixers

Although perhaps best known in remote sensing field for their

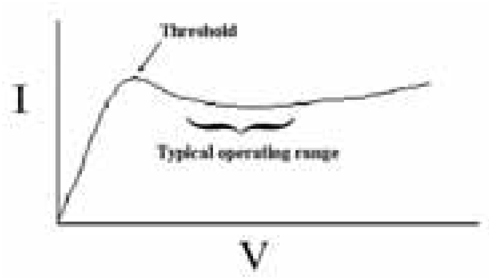

Figure 1. GaAs Gunn diode DC characteristics showing the relative current at threshold of oscillation and the operating current as a function of voltage.

Figure 2. ZAX fixed frequency Gunn diode oscillator operating near 89 GHz with WR-10 waveguide output (left) and sub-millimeter-wave mixer with WR-5 RF input, WR-10 LO input and SMA IF output.

specialized microwave and millimeter wave blackbody calibration loads, ZAX originally developed their business and capabilities building millimeter wave mixers and RF sources. ZAX developed Local Oscillator (LO) sources and mixers operating at millimeter wave frequencies and then extended those techniques into the sub-millimeter wave range by building components for several applications including airborne radiometers in NASA's Microwave Imaging Radiometer (MIR) operating at 89, 150, 183, 220 and 325 GHz [1]. In September 1993, the MIR provided airborne images comparing tropospheric emissions centered at 183.310 GHz and 325.153 GHz water vapor lines [2].

The most commonly used RF LO sources at millimeter wave frequencies for microwave radiometry have been Gunn Diode Oscillators (GDO). The Gunn effect provides an efficient way to directly convert DC into RF energy near the desired operating frequency in the millimeter wave region. Gunn Oscillator designs utilize the bulk negative conductance properties of Gallium Arsenide (GaAs) and Indium Phosphide (InP). Gunn diodes achieve the necessary RF power at millimeter wave frequencies to drive sub-harmonically pumped mixer stages operating up to 300+ GHz without the need for relatively inefficient frequency multiplier stages before the mixer.

ZAX circuits incorporating the Gunn diodes to provide state-of-the-art performance at frequencies from 18 GHz to above 140 GHz. InP Gunn Oscillators yield higher output power, higher efficiency, and lower AM noise than their GaAs counterparts. Tunable models feature high power-bandwidth products. Custom units are also made by ZAX to meet special requirements.

Each Gunn diode requires a specific DC voltage for optimal operation. The current required to turn-on a GaAs Gunn oscillator (the threshold current) normally exceeds the operating current as illustrated in Figure 1. The power supply should have low ripple to minimize AM and FM noise.

ZAX manufactures Gunn oscillators in variety of configurations depending on the need for output power, frequency and phase stability, tuning range and bandwidth. High output power and excellent frequency and power stability can be achieved from fixed frequency oscillator designs up 170 GHz. The precise frequency may often be adjusted by bias tuning (bias pushing) over a small frequency range. High temperature stability and low phase noise can also be achieved in high-Q cavity-stabilized designs. ZAX also offers mechanically tuned Gunn oscillators to allow operation at a single frequency selectable through adjustment of the output cavity with a micrometer. This design allows precise control of the frequency of oscillation with high output power and monotonic operation up to ~116 GHz. The Gunn oscillator can also be varactor tuned to permit voltage control of the frequency of oscillation. These Voltage Controlled Oscillators (VCO's) can be made for narrowband or wideband use and thus are ideally suited for phase locked and swept frequency applications. ZAX has also manufactured injection-locked configurations to achieve greater output power often utilized to drive frequency multipliers. Gunn multiplier configurations have been utilized to yield outputs in the hundreds of microwatts at over 400 GHz.

To accompany the Gunn LO sources, ZAX has developed balanced, harmonic and sub-harmonic mixer designs for 40 to 220 GHz and designed and built special units that operate up to over 400 GHz. Mixer performance is the key to achieving low system noise at frequencies where no suitable LNAs exist and ZAX has provided many specialized mixer components with state-of-the-art performance.

Antenna Manufacturing

ZAX manufacturing capability and experience cover a variety of millimeter wave antennas. In particular, ZAX has produced many corrugated conical horn antenna designs ranging from low to large flare angles. Each design can be tailored to applications including a stand alone horn, feedhorn-lens, horn-lens and feedhorn-reflector combinations. In addition, the horns are designed for a specified operating bandwidth. Large flare angle (scalar) feedhorns can provide nearly constant E- and H-pattern performance over an octave frequency bandwidth. This design produces a large beamwidth and is normally used in reflector-feedhorn or lens-feedhorn systems. Low flare angle feedhorns are physically longer than scalar feedhorns, yield narrow beamwidths and are typically utilized for narrow bandwidth

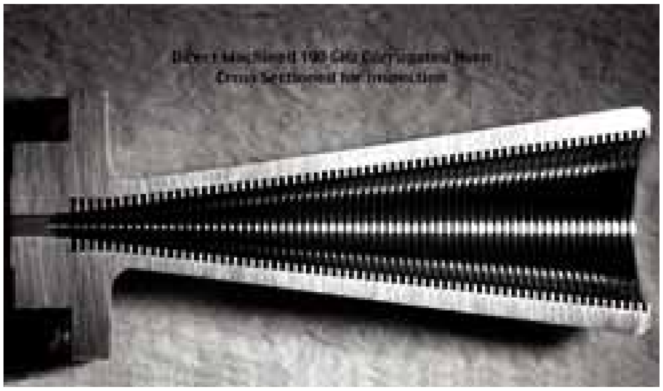

Figure 3. Cross-section of a 190-GHz corrugated horn antenna manufactured by using direct machining. Note the ratio of the largest to smallest radius at the throat of the horn must allow clearance for removal of cutting tools.

Figure 4. Model of the internal geometry of the corrugated feedhorn representing the first step of the electroforming process. Creating the geometry 'inside-out' allows designs to be creating by the electroforming process that can not be manufactured by direct machining.

Figure 5. Blackbody calibration targets manufactured by ZAX millimeter wave.

applications. Fabrication processes for these and other components are selected based upon electrical performance, size, and cost requirements. Direct machining, or a three step electroforming process can generally fulfill fabrication requirements.

Direct Machining

Large diameter, low frequency, large flare angle, and short length corrugated feedhorns are normally candidates for direct machining on a precision lathe. The throat of such antennas is sufficiently large to provide clearance for cutting tools. Direct machining is an economical, single step fabrication process.

Electroforming

The length of low flare angle feedhorns, the diameter and depth of matching grooves near the intersection of the circular waveguide and the corrugated conical flared sections can restrict the tool clearance available for direct machining operations. Such designs dictate a higher cost multiple step electroforming process. Electroforming involves a three step process consisting of: (1) Precision external machining of the internal geometry of the circular waveguide and the conical corrugated grooved wall envelope into the surface of an aluminum mandrel, (2) Electroforming the final feedhorn configuration by electrochemically depositing copper and nickel onto the mandrel surface until the desired feedhorn wall thickness is achieved, (3) Removal of the mandrel by a chemical etching process which selectively etches the mandrel material.

Blackbody Calibration Targets

ZAX is perhaps best known for manufacture of high performance blackbody calibration targets in microwave radiometry for space, airborne, and ground applications. The programs that utilize ZAX calibration loads are extensive. The list includes AMSU, ATMS, SSM/T2, SSMIS, MHS, MIR, CoSMIR, AMPR, MWR, WindSat, MLS, HAMSR, MIRO and other programs, as well as the MET office, Northrop Grumman and NASA ground calibration facilities. Calibration target design has evolved considerably over the past two decades. One of the first blackbody loads that ZAX manufactured for space application was for the Special Sensor Microwave/ Temperature-2 (SSM/T2); its size covered only a 2.6" diameter footprint. The unmistakable trend in calibration targets is their steady increase in size. Consider the recent WindSat calibration target measuring over 12" [3], and the unique calibration load design for the Polarimetric Scanning Radiometer (PSR) [4] with its special slanted pyramids, multi-segmented design and large overall footprint. Multi-layer blended coatings, physical profile modifications and detailed electromagnetic and thermal analyses continue to drive improvements in the area of blackbody design.

Manufacturing and Testing Services

ZAX has full in house CNC machining capability and will provide machining services for precision machining requirements. ZAX design and manufacturing facilities include CAD, 3D rendering and CNC programming software, multiple CNC vertical machining centers, NC EDM machines, CNC Lathe, and precision assembly capability. Since its beginnings in the mid 1980's, ZAX has fabricated corrugated feedhorns, mixer housings calibration targets and precision custom components to customer prints as well as to our own designs. ZAX has also worked to optimize performance and manufacturability of precision components and assemblies designed by others.

With an HP 8510B Vector Network Analyzer system with frequency extensions currently up to 110 GHz, as well as test components to facilitate measurements up to 425 GHz, ZAX offers testing services to microwave and millimeter wave customers. One of the recent testing activities at ZAX was verification of temperature data from sensors attached to the blackbody calibration standard manufactured by ZAX for the Advanced Technology Microwave Sounder (ATMS). This detailed work required a small thermal vacuum chamber to house the calibration target cooled to liquid Nitrogen (LN2) temperatures. The goal of the experiment was to assess the temperature measurement to within 15 mK and demonstrate traceability to a National Institute of Standards and Technology (NIST) calibrated standard measurement.

WAVEGUIDE CHART

DESIGNATION		FREQUENCY (GHz)		INSIDE DIMENSIONS		FLANGE INFORMATION				
BAND	EIA	TE10 MODE	CUT OFF	A	B	TYPE	SIZE	HOLES	UG-	MIL-
X	WR-90	8.2 - 12.4	6.56	0.900	0.400					
Ku	WR-62	12.4 - 18	9.49	0.622	0.311					
K	WR-42	18 - 26.5	14.05	0.420	0.170	Square Square Round	0.875 0.875 1.125	Clearance Threaded Threaded	595 / U	3922 / [illegible] 3922 / [illegible] 3922 / [illegible]
Ka	WR-28	26.5 - 40	21.07	0.280	0.140	Square Square Round	0.750 0.750 1.125	Clearance Threaded Threaded	599 / U 381 / U	3922 / [illegible] 3922 / [illegible] 3922 / [illegible]
Q	WR-22	33 - 50	26.34	0.224	0.112	Square Square Round	0.750 0.750 1.125	Clearance Threaded Threaded	383 / U	3922 / [illegible] 3922 / [illegible] 3922 / [illegible]
U	WR-19	40 - 60	31.39	0.188	0.094	Square Square Round	0.750 0.750 1.125	Clearance Threaded Threaded	383 / Um	3922 / [illegible] 3922 / [illegible] 3922 / [illegible]
V	WR-15	50 - 75	39.87	0.148	0.074	Round	0.750	Threaded	385 / U	3922 / [illegible]
E	WR-12	60 - 90	48.37	0.122	0.061	Round	0.750	Threaded	387 / U	3922 / [illegible]
W	WR-10	75 - 110	59.05	0.100	0.050	Round	0.750	Threaded	387 / Um	3922 / [illegible]
F	WR-8	90 - 140	73.76	0.080	0.040	Round	0.750	Threaded	387 / Um	3922 / [illegible]
D	WR-6.5	110 - 170	90.79	0.0650	0.0325	Round	0.750	Threaded	387 / Um	3922 / [illegible]
G	WR-5	140 - 220	115.75	0.0510	0.0255	Round	0.750	Threaded	387 / Um	3922 / [illegible]
-	WR-4	170 - 260	137.22	0.0430	0.0215	Round	0.750	Threaded	387 / Um	3922 / [illegible]
Y	WR-3	220 - 325	173.55	0.0340	0.0170	Round	0.750	Threaded	387 / Um	3922 / [illegible]
--	WR-2*	325 - 500	295.03	0.0200	0.0100	Round	0.750	Threaded	387 / Um	3922 / [illegible]
-	WR-1.5*	500 - 750	393.36	0.0150	0.0075	Round	0.750	Threaded	387 / Um	3922 / [illegible]
-	WR-1*	750 - 1100	590.08	0.0100	0.0050	Round	0.750	Threaded	387 / Um	3922 / [illegible]

(* ZAX DESIGNATIONS)

Figure 6. Waveguide Chart

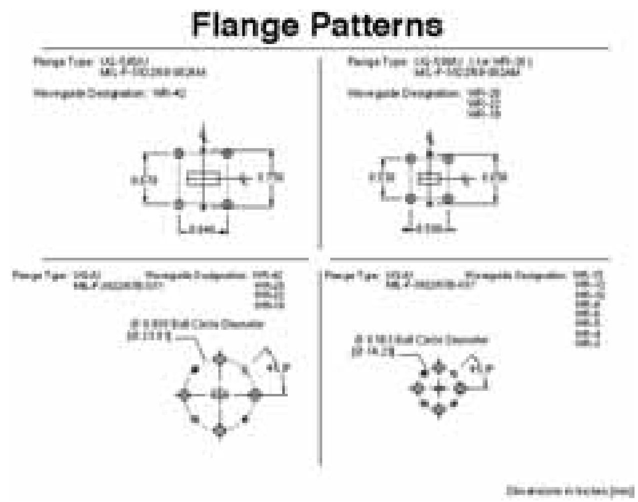

Figure 7. Flange Patterns

Conclusion

The state-of-the art in microwave radiometer calibration and performance continues to improve and ZAX continues to play an important role in this trend by providing improved blackbody calibration standards and high performance millimeter-wave components for application in experimental and operational remote sensing. Calibration standards for passive radiometry continue a trend of becoming larger and more specialized to support a variety of space, airborne and ground-based applications. ZAX continues to accept performance and manufacturing challenges in support of specialized needs for millimeter wave remote sensing.

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DUAL SENSOR ALIS EVALUATION TEST IN AFGHANISTAN

Motoyuki Sato[a], Jun Fujiwara[b], Xuan Feng[a], Takao Kobayashi [a c]

[a]*Center for Northeast Asian Studies, Tohoku University, 41 Kawauchi, Sendai, Japan 980-8576;*
[b]*Tokyo Gas Co. Ltd., 3-13-1 Minami-Senjyu, Arakawa, Tokyo, Japan 116-0003;*
[c]*Japan Science and Technology Agency, 1-32-12 Higashi, Shibuya, Tokyo, Japan 150-0011*
sato@cneas.tohoku.ac.jp

Figure 1. Manual prodding by a deminer. Bibi Mahro Hill in Kabul, Afghanistan.

Figure 2. A PMN-2 AP landmine used during Soviet occupation in Bibi Mahro Hill in Kabul, Afghanistan.

Introduction

It is widely known that many countries in the world are suffering from remaining landmines, the byproduct of various wars and conflicts. In order to protect the people living in these countries, technical contributions of scientists and engineers are required. Because of this, Humanitarian Demining has gathered interest in the Geoscience and Remote Sensing community.

We have found many publications on new demining sensors. Most of them discuss ground penetrating radar (GPR) and/or metal detectors (MD). These development efforts are significant because they can be implemented in real demining operations. Before they can be widely deployed, however, these new demining technologies have to be evaluated by the local deminers who will use the tools. This article describes our experience in development and field evaluation of a dual sensor for humanitarian demining which we carried out in Afghanistan.

Humanitarian Demining [1]

Landmines are explosive ordnance that are usually laid in order to stop or make more difficult access to certain terrain. There are approximately 300 different landmines divided into two main types; anti-personnel mines (AP) and anti-tank mines (AT). Both types of landmines are used either separately or together, depending on the military tactics and tasks.

For buried landmines, there are two types of mine clearance: military and humanitarian. Military mine clearance is the process undertaken by soldiers to clear a safe path so they can advance during conflict or clear an area where mine protection is no longer needed. The military process of mine clearance often only clears mines that block strategic pathways required for the advance or retreat of soldiers at war. This process accepts that limited casualties may occur.

Humanitarian mine clearance, on the other hand, aims to clear land so that civilians can return to their homes and their everyday routines without the threat of landmines and unexploded ordnance UXO. This means that all the mines in the places where people ordinarily live must be cleared.

In many mine-affected countries, humanitarian demining is carried out under the control of the United Nations Mine Action Service (UNMAS) [1]. In most countries the UN bodies advise and assist the national authorities, or a UN peacekeeping mission to carry out mine clearance. The UN typically establishes a Mine Action Authority or Coordination Centre responsible for overseeing clearance activities. The actual clearance operations may then be carried out by national civilian agencies, military units that agree to take part in humanitarian operations, national or international NGOs or commercial organizations.

The procedure for landmine clearance has been developed and the process is now established as the International Mine Action Standards (IMAS). Figure 1 shows one of the demining sites in Afghanistan, where a deminer with an NGO is prodding by hand after detection of an anomaly by a metal detec-

Figure 3. A plastic tray used to carry landmines. Excavated landmines and metal fragments are stored in pits on the ground, Bibi Mahro Hill in Kabul, Afghanistan.

tor. This is slow and labor intensive, but it is quite adaptable in any geographical conditions. The important fact is that it is the most reliable method of landmine clearance. Although mine clearance operations carried out to international humanitarian standards are expensive, recent studies have shown that they not only allow for the social recovery of affected communities, but can also be justified on the basis of purely economic cost-benefit analysis. In order to solve this remaining mines and UXO problem, there has been intensive research and development programs conducted in Europe, Canada, United States and Japan that have introduced many new demining technologies since the 1990's. At the same time, international organizations such as ITEP [2] and GICHD [3] have been established, and they have gathered information, evaluated the technologies, and distributed information. Web sites of these organizations and data bases are listed in the reference.

Scope of the landmine problem in Afghanistan [4]

Landmines and unexploded ordnance (UXO) affect some 6.4 million Afghans living in, or planning to return to, one of 2,400 landmine-contaminated communities. Despite progress

Figure 4. ALIS under test at CDS test site, Afghanistan.

by the mine action community over the past 15 years, Afghanistan remains heavily contaminated by mines. This contamination has a devastating effect on human lives and livelihoods as mines and unexploded ordnance continue to kill and injure as many as three Afghans per day. It is reported that more than 100,000 were killed or injured over the past 25 years in this country. This contamination also constitutes a structural impediment to the development of the country and its elimination is a precondition for the emergence of an economically sound Afghanistan.

Landmines were first used in Afghanistan during the Soviet occupation (1979-1989). Figure 2 shows a PMN-2 AP landmine, which was laid during this period. Many of this type of landmine still remain in Kabul city and the picture shows one of them, which was destroyed by humanitarian demining. In Fig. 3 a deminer is showing a plastic tray used to carry PMN-2 landmines. Landmine and UXO contamination continued to occur during the period of the pro-Soviet ruling government (1989-1992), during fighting between various factions from 1992-1995, and during the Taliban era and in the fighting with resistance forces from 1996 to September 2001. Some very limited contamination also continues to occur as a result of military operations by and against the American-led coalition since October 2001 and also as a result of ongoing factional fighting.

The United Nations Mine Action Centre for Afghanistan (UNMACA), a project of the United Nations Mine Action Service (UNMAS) currently has de facto responsibility for planning, management, and oversight of all mine-action activities in Afghanistan on behalf of the Government of Afghanistan. UNMACA coordinates 8,000 Afghans, who work for implementing partners accredited by the Mine Action Programme for Afghanistan (MAPA); a period of five years (2003-2007) will be required to address all mine- and UXO-contaminated areas that have a high impact on Afghan communities, in addition to marking medium and low impact areas. In the following five years (2008-2012), medium and low impact areas will be addressed.

Approach to Landmine Problems in Afghanistan by Japanese Government

The Japanese government has carried out various efforts aimed at rehabilitation of Afghanistan. Removal of landmines from Afghan land is an essential factor for every phase of development in Afghanistan. The government of Japan has also been supporting the effort to deal with anti-personnel landmines through multilateral cooperation and the dispatching of experts. Some of this works is carried out through UNMACA. In addition, the government of Japan plans to support the anti-personnel mine-clearance activities in Afghanistan through a Japanese grant aid for research, while the transitional administration of Afghanistan makes a request for the research project for developing mine clearance related equipment in Afghanistan. This project supports research activities and development of mine detectors which suit the local conditions of Afghanistan. For the purpose of contributing to the execution of the project by the transitional administration of Afghanistan, the government of Japan extended a grant to the transitional administration of Afghanistan. On behalf of the department of mine clearance, department of disaster preparedness of the transitional administration of Afghanistan, Japan International Cooperation System (JICS), supported the field evaluation test of the Advanced Landmine Imaging System (ALIS) in Afghanistan.

Figure 5. GPR antennas and metal detector sensor of ALIS.

Four organizations oriented to mechanical demining and three organizations oriented to sensors for landmines were selected and carried out field testing in Afghanistan in 2004 and 2005. Most of the demining machines and sensors were developed in the project for development of anti-personnel mine detection and clearance equipment supported by New Energy and Industrial Technology Development Organization (NEDO) which is under the Ministry of Economy, Trade and Industry (METI), and research and development for supporting humanitarian demining of Antipersonnel mines, which is supported by Japan Science and Technology Agency (JST) under the Ministry of Education Culture, Sports, Science and Technology (MEXT)[5].

Dual Sensor for landmine detection

Detection of antipersonnel (AP) landmines, whose casing is made of plastic, is the principle task of humanitarian demining. Even in a plastic AP-landmine, normally a very small metallic part is included, and it can be detected by a metal detector (MD). Therefore, MD is widely used for humanitarian demining operation. A metal detector is an electromagnetic induction (EMI) sensor, which is widely used in non-destructive inspection in industries. It can detect almost all the conductor materials, in most soil conditions. This is an established technology, and specialized MD sensors for landmine detection are available commercially. The commercial sensors have two different operation principles, namely time-domain and multiple frequencies. They are normally equipped with sophisticated automatic detection software.

These highly developed MD sensors can detect very small metal parts contained in plastic landmines. Even most plastic landmines contain a small metal pin several mm in length and less than one mm in diameter. Detection of 10 mg of steel is about at the detection limit for commercial MD sensors, and even then at very short range. Fortunately, most mines have more than 10 mg of metal. Therefore, current MD sensors can detect nearly 100% of the buried landmines at shallow depths, and

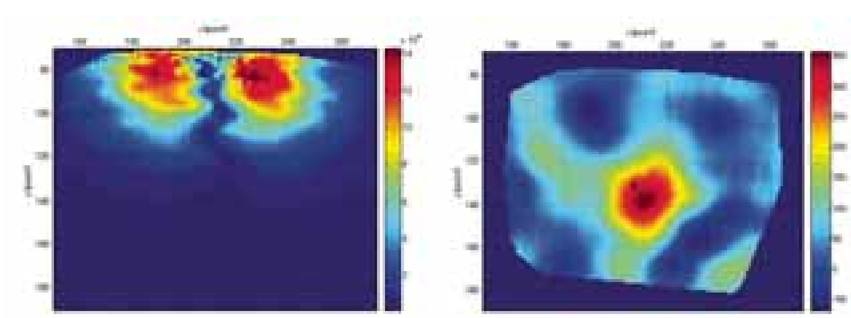

Figure 6. Typical ALIS output image of buried AP landmine. CDS test site, Afghanistan. (left) Metal detector image (right) GPR image

they can also detect all the metal fragments remaining in the survey area. Metal fragments recovered during the humanitarian demining operation in Bibi Mahro Hill are shown in Fig. 3. Most of them at this site are bullet shells, and they are shown stored in a pit. Humanitarian demining in Bibi Bahro Hill started in October 2002. A total of 277 landmines were found along with 2135 UXO and 218320 metal fragments. The technical problem of MD is not its detectability, but its very high false alarm rate. On the other hand, Ground Penetrating Radar (GPR) is a useful sensor for detecting buried objects. GPR is based on another principle, reflection of electromagnetic waves caused by differences in conductivity and permittivity. Therefore, GPR is sensitive to the plastic body of the AP mines. We think that GPR is useful for identification of AP-landmines, if it is used in combination with MD. Of course, the idea of combining GPR and MD is not new, and this type of sensing is normally referred as "Dual Sensor". A few dual sensor systems are in the preproduction stage and are now beginning to be field tested, and one of them is now in service [6][7][8].

However, we think the method of combining the two sensors must still be developed. We report here development of a novel technique of tracking sensor position with combined MD and GPR sensors, all in a hand-held system. It is camera-based; using markers to help with coregistration of the MD and GPR images and then can use signal processing for landmine detection. This is the Advanced Landmine Imaging System (ALIS) [9]-[12].

Advanced Landmine Imaging System (ALIS)

ALIS is a hand-held landmine detection sensor that is equipped with a metal detector and GPR. In addition to detection, it can track the sensor position in real time while scanning. The sensor signals from the metal detector and GPR are stored in a PC providing both detection and sensor position information. The entire system is controlled by the PC which is carried inside a daypack worn by the deminer. Software controls the system and the operations can be done directly by the PC, but usually we use a handheld PC display which is connected to the PC via wireless LAN. The deminer usually monitors the metal detector signal displayed on a heads-up display.

Figure 4 shows the ALIS system in operation. A deminer is scanning the handheld ALIS sensor, and wearing a daypack that contains the operating PC. The deminer is also wearing a heads-up display. The same display that the deminer is monitoring is transmitted to a handheld PC display allowing several operators to monitor the operation. For the normal operation of ALIS, we need one operator who scans the sensor, and another operator who controls and monitors the sensor signal.

The scanning by ALIS follows exactly the same procedure as for the normal hand-held metal detector. A deminer stands at

Figure 7. ALIS under test in Bibi Mahro Hill in Kabul, Afghanistan.

the front of the boundary of a safe zone, and scans an area about 1 m by 1 m using the hand-held sensor. We recommend scanning continuously, even if the deminer detects an anomalous signal from the metal detector. After scanning the area, we process the acquired data sets using the same PC. Normally, the processing requires one to a few minutes until all the data sets are displayed. Subsequently, ALIS provides a horizontal visual image of the metal detector signal, and 3-D GPR information. The information on 3-D GPR is usually too much for interpretation on the site, so ALIS displays horizontal slices (C-scan) of the GPR signal. An operator can select the depth of the GPR time-slice images displayed, and can subsequently detect the buried landmine image by visual inspection. After processing and generating the signal images, one can locate/designate the suspect position on the camera image.

Another unique feature of ALIS is its compatibility with conventional landmine detection operation. Landmine detection with metal detectors is quite a common demining procedure in many countries. The procedure for demining is well established, and many deminers have been trained to follow the procedure exactly to avoid any accident. Any new sensor for landmine detection requires a change in the operation procedure. However, ALIS requires minimum modification of the procedure, as we have described. The ALIS is an add-on system that can be attached to an existing commercial metal detector. The performance of the metal detector is not altered by adding the ALIS system. The operator still hears the audio tone signal from the metal detector, and can detect anomalies using their own experience. ALIS adds a visual image to the metal detector sensor, and GPR images. Therefore, the operator can obtain additional valuable information, although the operation of the sensor does not have to be changed much.

ALIS uses an impulse GPR system that operates in the 1-3 GHz frequency range. Two orthogonally polarized cavity back spiral antennas are used and they are mounted in front of the MD coil as shown in Fig. 5. ALS is based on a commercial metal detector. More than 2000 sets of this type of metal detector have been operated, and we believe it is one of the most reliable sensors for landmine detection in the Afghan soil. The interference of the two sensors, namely GPR and metal detector has been studied. This MD has a calibration function, and even when metal objects are located near the metal detector sensor, the output signal can be compensated by this calibration procedure. We found that, if the antenna is firmly fixed against the metal detector sensor position, the influence of the presence of the GPR antennas can be completely canceled and the sensitivity of the metal detector to buried objects does not change. However, the influence of the metal detector sensor on the GPR signal is hard to compensate. Therefore, the GPR antennas are mounted in front of the metal detector sensor.

The GPR data acquired along with the sensor position information is processed after scanning the ALIS sensor over an area of about 1 m by 1 m. First, all the acquired data set is transformed to a regular grid of points. An interpolation algorithm is used for this process. After the transformation of the data sets, the metal detector signal can be displayed directly in a horizontal (plan) image as shown in Fig. 6(left). A 3-D GPR image is reconstructed using the Kirchhoff migration algorithm. However, we normally use only the horizontal time-slice image (C-scan) display as shown in Fig. 6(right) for data interpretation. This is due to too much clutter in the 3-D image. We found through many trials that detection of buried landmines with the horizontal time-slice image is most reliable.

After all the data processing was finished, we use the metal detector and GPR signals for detection of buried landmines. Currently, we are interpreting the data manually. First, we detect anomalies appearing in the metal detector image. Normally this is quite easy, but it includes many signals due to metal fragments and other objects (i.e., false alarms). After marking the location of these anomalous points on the GPR horizontal slice image, we move the depth of the horizontal slice images and try to find a continuous image that can be a GPR image of buried landmines.

One set of data acquisition by ALIS takes several minutes, which is almost equivalent to the time required for normal scanning operation of a conventional MD, and the signal processing needs about two minutes after the data acquisition. Wireless LAN sends sensor data to a handheld PC display for judging the image by multiple operators.

Evaluation test of ALIS in Afghanistan

After the laboratory tests, we conducted field evaluation tests of ALIS in Kabul city, Afghanistan in December 2004. The field tests were conducted at two locations. The first site (CDS: Central Demolition Site) was a controlled flat test site, prepared for the evaluation of landmine sensors. The second site (Bibi Mahro Hill) is a small hill inside Kabul city, which is a real landmine field, where a demining operation was being carried out.

At the CDS site, we could validate the operation of the ALIS for known targets under various conditions. The soil in the CDS site was relatively homogeneous, although we found much clutter in the raw GPR profile. Metal fragments were basically removed from the soil, before the evaluation was carried out. After migration (SAR) processing, in most cases, we could find clear images of buried landmines. The climatic conditions when we conducted the field tests were partly rainy, and water content of the soil at CDS site was about 10%, corresponding to a dielectric constant of 5.3. Real PMN-2 and Type 72 landmines without booster were buried at the CDS site at different depths between 0 and 20 cm. We found that the metal detector could only detect landmines buried shallower than 15 cm, and GPR could show clear images of landmines, which were buried up to a depth of 20 cm. We also found that the metal fragments, which are included in the soil, do not show clear GPR images, therefore we could discriminate metal fragments from landmines with ALIS. Figure 6 shows an example of the ALIS output for an inert PMN-2 mine, which was buried at 10 cm. Both MD and GPR images are clear in this case.

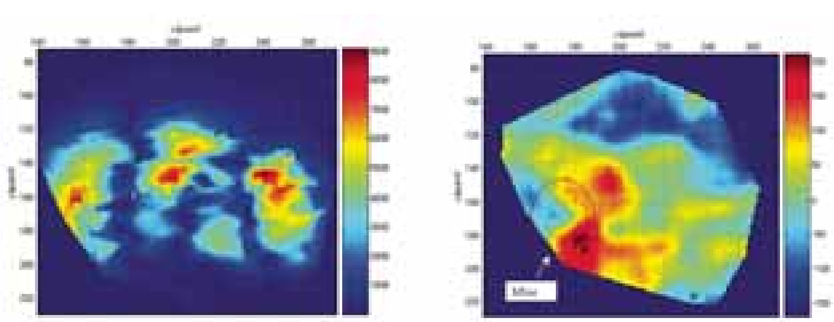

Figure 8. ALIS output at Bibi Mahro Hill in Kabul, Afghanistan (left) Metal detector image (right) GPR image

Bibi Mahro Hill is a small hill near the Kabul airport, where missile stations were sited in the 1980's. Afghan NGO, OMAR is currently demining in this site. The soil in this site is very non-homogeneous. It is covered by vegetation, and at the same time, it contains many small objects such as gravel, pieces of wood and metal fragments. Most of the area to be cleared is sloped as shown in Fig. 1. Landmines were originally buried along a line to create a mine belt; therefore, it used to be relatively easy to find the locations of the buried landmines. But after

20 years most of them have moved, and we found many of them even on the ground surface. We fully expect that the location of the landmines now is quite random. A local residential area is very close to the area of the demining operation. The cleared and un-cleared areas are indicated by white and red stones, and deminers can identify the safe areas. However, while we visited there, a local boy chasing a dog entered the area, and although he went out with no problems, it seems that keeping an area safe is quite difficult in an urban area.

At the calibration site in Bibi Mahro Hill, we buried a PMN-2 plastic shell model filled with TNT explosive and put a small metal pin in it imitating the metallic part of a booster in a real landmine. In addition, we buried a small metal fragment about 15 cm distance from the landmine model. Figure 8 shows the ALIS visualization output at Bibi Mahro Hill. Figure 8(left) is the MD image, and we can see two separated metal objects in the figure. CEIA MIL-D1 has a differential signal output. A single metal object shows a symmetric response with a null point at the center. Figure 8(right) shows the GPR image, and we can find only one clear image here that corresponds to the landmine model. Note that the center of the two sensors differs by 20 cm, so the images in Fig. 8 have a 20 cm offset.

Conclusion

Dual sensors for humanitarian demining are proving to be quite useful. We developed ALIS which has high efficiency with better reliability for landmine detection with MD-GPR sensor fusion. The developed ALIS can visualize the signal, even though it is a hand-held sensor. In this article we described our evaluation tests of ALIS in a real mine field in Afghanistan, and found it highly reliable. In 2005, we tested ALIS in mine-affected countries including Croatia and Egypt. We have learned quite a lot from these tests, and what we have found out will improve the sensor system. We hope that many new techniques developed in humanitarian demining projects will be of practical use in the near future.

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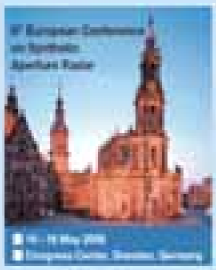

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