

# **A Survey of the Active Scientific Use of the Radio Spectrum**

## **Committee**

### **Fawwaz Ulaby**

#### **Chair**

FAWWAZ T. ULABY is the Emmett Leith Distinguished Professor of Electrical Engineering and Computer Science and Arthur Thurnau Professor of Engineering at the University of Michigan. He attended the American University of Beirut, from which he received the B.S. degree in physics. He later received the Ph.D. in Electrical Engineering from the University of Texas at Austin. Dr. Ulaby's research is focused on the science and technology of radar remote sensing and its applications. He is a member of the National Academy of Engineering, a Fellow of AAAS, and a member of several scientific boards and commissions. Between 1999-2005 Dr. Ulaby was the R. Jamison and Betty Williams Professor of Electrical Engineering and Computer Science at the University of Michigan, where he had also served as Vice President for Research (1999–2005). Between 2000 and 2006 he also served as Editor-in-Chief of IEEE Proceedings, Dr. Ulaby then became the founding Provost and Executive Vice President for Academic Affairs of the King Abdullah University of Science and Technology (KAUST), a graduate research university under development in Saudi Arabia. Prior to assuming this position, In April of 2009, he returned to the University of Michigan as the Arthur Thurnau Professor of EECS. Since joining the University of Michigan faculty in 1984, Professor Ulaby has directed large, interdisciplinary NASA projects aimed at the development of high-resolution satellite radar sensors for mapping earth's terrestrial environment. He also served as the founding Director of a NASA-funded Center for Space Terahertz Technology. His involvement with the IEEE Geoscience and Remote Sensing Society extends over a period exceeding three decades, including service as the first President of the Society (1979-1981), Editor of its Transactions, General Chairman of its first and seventh IGARSS (1981 and 1987), and in other capacities. He also served on several IEEE-wide boards and committees. Professor Ulaby has authored 14 books and published some 700 scientific papers and reports. His undergraduate textbook on Applied Electromagnetics has been adopted by some 150 universities across the United States and by a comparable number of universities in other countries. Several of his books have been translated into Chinese, Korean, Portuguese and other languages. He is the recipient of numerous awards including the NASA Group Achievement Award (1990), the University of Michigan Regents Medal for Meritorious Service (1996), and the IEEE Millennium Medal (2000). Over his 30-year academic career, he has supervised 115 M.S. and Ph.D. graduate students. In 2002 he received the William Pecora Award, a joint recognition by NASA and the Department of the Interior, and in 2006 he received the IEEE Thomas Edison Medal, the Distinguished Alumni Award from the American University of Beirut, the Distinguished Educator Award from the IEEE Geoscience and Remote Sensing Society, and the EECS Professor of the Year Award from EKN.

## **Susan K. Avery**

### **Member**

SUSAN K. AVERY is the President and Director of the Woods Hole Oceanographic Institute. Dr. Avery earned a doctorate in atmospheric science from the University of Illinois in 1978. Her research interests include studies of atmospheric circulation and precipitation, climate variability and water resources, and the development of new radar techniques and instruments for remote sensing. She is the author or co-author of more than 80 peer-reviewed articles and has directed the University of Colorado's Center for Limb Atmospheric Sounding. She also has an interest in scientific literacy and the role of science in public policy. Dr. Avery also holds an appointment at the Cooperative Institute for Research in Environmental Sciences (CIRES), of which she has been a fellow since 1982. From 1994-2004, she served as director of CIRES, the first woman and first engineer to hold that position. As director of CIRES, she facilitated new interdisciplinary research efforts spanning the geosciences while bringing them together with social and biological sciences. She also spearheaded a reorganization of the institute and helped establish a successful K-12 outreach program and a Center for Science and Technology Policy Research—efforts to make CIRES research more applicable, understandable, and accessible to the public. Since August 2004, she has served in interim positions as vice chancellor for research and dean of the graduate school, as well as provost and executive vice chancellor for academic affairs at the University of Colorado at Boulder. She has been a member of its university faculty since 1982, most recently holding the academic rank of professor of electrical and computer engineering. Dr. Avery helped form an integrated science and assessment program that examines the impacts of climate variability on water in the American West. She also worked with the National Oceanic and Atmospheric Administration and the Climate Change Science Program to help formulate a national strategic science plan for climate research. Dr. Avery has served on a number of NRC committees. She is a fellow of both the Institute of Electrical and Electronics Engineers and of the American Meteorological Society, for which she also served as president. She is chair of the Climate and Weather of the Sun-Earth System program; chair-elect for the Council on Research Policy and Graduate Education; chair of the science policy board for the Center for Sustainability of Semi-Arid Hydrology and Riparian Areas; and a member of the advisory board for the Jet Propulsion Laboratory. She is a past chair of the board of trustees of the University Corporation for Atmospheric Research.

## **Coleman D. Bazelon**

### **Member**

COLEMAN D. BAZELON is a Principal at The Brattle Group in Washington, DC. He received his PhD in Agricultural and Resource Economics from University of California at Berkeley in 1995. Dr. Bazelon is an expert in regulation and strategy in the wireless, wireline, and video sectors. He has consulted and testified on behalf of clients in numerous telecommunications matters, ranging from wireless license auctions, spectrum management, and competition policy, to patent infringement, wireless reselling, and broadband deployment. He frequently advises regulatory and legislative bodies, including the U.S. Federal Communications Commission and the U.S. Congress. He also has expertise in the federal government's use of discount rates for policy and regulatory analysis, intellectual property valuation, and antitrust and damages analysis. Prior to joining Brattle, Dr. Bazelon was a vice president with Analysis Group, an economic and strategy consulting firm. During that time, he expanded the firm's telecommunications practice area. He also served as a principal analyst in the Microeconomic and Financial Studies Division of the Congressional Budget Office where he researched reforms of radio spectrum management; estimated the budgetary and private sector impacts of spectrum-related legislative proposals; and advised on auction design and privatization issues for all research at the CBO.

## **William A. Bristow**

### **Member**

WILLIAM A. BRISTOW is a Professor of Electrical Engineering in the Geophysical Institute at the University of Alaska, Fairbanks (UAF). He earned his Ph.D. in Space Physics from the University of Alaska Fairbanks in 1992. Dr. William Bristow's current research interests include radar systems, studies of winds in the upper atmosphere, studies of the magnetosphere-ionosphere coupling, and space-weather effects on radio propagation, which directly impacts radio communications in high-latitude regions. Dr. Bristow is the principle investigator for the SuperDARN network which consists of two radar systems in Alaska. He also studies high latitude ionospheric plasma processes using the Goose Bay HF Coherent Radar. He spent 1992-1998 at the Johns Hopkins Applied Physics Laboratory as a Post-Doctoral Fellow and then a Senior Professional Staff Physicist before returning to UAF in 1998.

## **Donald B. Campbell**

### **Member**

DONALD B. CAMPBELL is a Professor of Astronomy at Cornell University. Dr. Campbell received his PhD from Cornell. His research work is in the general area of planetary studies with a concentration on the radio- wavelength-scattering properties of planets, planetary satellites and small bodies. He makes extensive use of the high powered radar systems on the Arecibo telescope. Recently, working with past and present Cornell graduate students, he has explored remotely the polar regions of the Moon looking for evidence of ice deposits, studied the radar scattering properties of the icy satellites of Jupiter and Saturn, Europa, Ganymede, Callisto, Titan, and Iapetus, and used the polarization properties of the reflected radar signals to investigate surficial deposits on the surface of Venus and to look for regoliths on near earth asteroids. He was previously Director of Cornell's National Astronomy and Ionosphere Center (NAIC). The NAIC manages the Arecibo Observatory, in Arecibo, Puerto Rico, on behalf of the National Science Foundation. Dr. Campbell has been Professor of Astronomy at Cornell since 1987. Prior to coming to the Cornell campus he was Director of the Arecibo Observatory in Puerto Rico for seven years. He served on the NRC Panel on Radio and Submillimeter-wave Astronomy for the 2000 Astronomy and Astrophysics Decadal Survey and was a member of the U.S. National Committee for the International Astronomical Union in 1995-1997.

## **Marie Colton**

### **Member**

MARIE COLTON is the Director of the NOAA Great Lakes Environmental Research Laboratory (GLERL). She earned her Ph.D. in Physical Oceanography from the Naval Postgraduate School in 1989. Her research interests are in active remote sensing of water bodies. During her career she has been an aerospace engineer at NASA, a physicist at the Naval Research Laboratory, an oceanographer at the Fleet Numerical Meteorology and Oceanography Center, and center director of NOAA's satellite service. While serving as acting director of GLERL, Colton also worked as technical director for NOAA's Ocean Service, where she oversaw all of the science and technology enterprise from hydrographic mapping to ecology.

## **Sandra L. Cruz-Pol**

### **Member**

SANDRA CRUZ-POL is a Professor in the Department of Electrical and Computer Engineering at the University of Puerto Rico at Mayagüez. She obtained her Ph.D. in Electrical Engineering from Pennsylvania State University. Her research interests include microwave remote sensing of natural phenomena, modeling of the microwave atmospheric absorption and microwave sea surface emissivity, and stratus cloud studies using W and Ka-Bands. She is currently working on several microwave remote sensing projects sponsored by NSF (Engineering Research Center for Subsurface Sensing and Image Systems in collaboration with Northeastern University), NASA (Tropical Center for Earth and Space Sciences), IBM and IAP. She is also working in the retrieval of multidimensional cloud liquid water content images using a dual-frequency millimeter-wave Cloud Profiling Radar System in a joint project with the University of Massachusetts' Microwave Remote Sensing Laboratory. Dr. Cruz-Pol is a member of the Institute of Electrical and Electronic Engineers, the IEEE Geoscience and Remote Sensing Society (GRSS), and the Tau Beta Pi and Phi Kappa Phi Honor Societies. She is currently the Associate Editor for University Affairs for the IEEE GRSS Newsletter. She was the counselor for the student chapter of the IEEE in UPRM, the largest in IEEE Region 9. She has been a recipient of NASA, GEM, NSF-GEE and GTE Fellowships. She has also spent time as a researcher at AT&T Laboratories, Lincroft, NJ, and Middletown, NJ. She is a member of the NRC Committee on Radio Frequencies.

## **Lennard A. Fisk**

### **Member**

LENNARD A. FISK is the Thomas M. Donahue Distinguished University Professor of Space Science in the Department of Atmospheric, Oceanic, and Space Sciences at the University of Michigan. Dr. Fisk was previously the associate administrator for space science and applications (the predecessor to the current Heliophysics and Earth Science divisions) and chief scientist at NASA. He has served as a professor of physics and as vice president for research and financial affairs at the University of New Hampshire. He is a member of the board of directors of the Orbital Sciences Corporation and co-founder of the Michigan Aerospace Corporation. He is an active researcher in both theoretical and experimental studies of the solar atmosphere and its expansion into space to form the heliosphere. Dr. Fisk received his Ph.D. in applied physics from the University of California, San Diego. He was a member of the 2012 NRC Committee on a Decadal Strategy for Solar and Space Physics (Heliophysics). Other relevant NRC service includes chair of the Committee on the Role and Scope of Mission-Enabling Activities in NASA's Space and Earth Science Missions, co-vice chair of the Committee on the Rationale and Goals of the U.S. Civil Space Program, chair of the Space Studies Board, chair of the Planning Committee for Workshop on U.S. Civil Space Policy, chair of the Planning Committee for Decadal Science Strategy Surveys: A Workshop, chair of the Committee on an Assessment of Balance in NASA's Science Programs, and current member of the Committee on Earth Science and Applications from Space.

## **Albin J. Gasiewski**

### **Member**

ALBIN GASIEWSKI is a Professor in the Department of Electrical and Computer Engineering at University of Colorado at Boulder (CU) and is the Director of the NOAA-CU Center for Environmental Technology (CET). He received his Ph.D. degree in electrical engineering and computer science from the Massachusetts Institute of Technology in 1989. His technical interests include passive and active remote sensing, radiative transfer theory and applications, electromagnetics, antennas and microwave circuits, electronic instrumentation, airborne sensors, meteorology, and oceanography. From 1989 to 1997 he was faculty member within the School of Electrical and Computer Engineering at the Georgia Institute of Technology. As an associate professor at Georgia Tech, he developed and taught courses on electromagnetics, remote sensing, instrumentation, and wave propagation theory. From 1997 through 2005 he worked at the U.S. National Oceanic and Atmospheric Administration's (NOAA) Earth System Research Laboratory (ESRL), in Boulder, Colorado, where he was Chief of the Microwave Systems Development Branch of the ESRL Physical Science Division. In 2006 he joined the Department of Electrical and Computer Engineering at CU. Dr. Gasiewski was the 2005-2006 President of the IEEE Geoscience and Remote Sensing Society and is also a member of the International Union of Radio Scientists (URSI), where he served as Vice Chair of the United States National Committee of URSI (USNC/URSI) Commission F. He served on the U.S. National Research Council's Committee on Radio Frequencies (CORF) from 1989-1995 and on the USNC/ URSI from 1996-1997 and again from 2009-2011. He co-chaired the previous NRC spectrum study on passive science.

## **Jeffrey Herd**

### **Member**

JEFFREY HERD is the Associate Group Leader of the Radiofrequency and Quantum Systems Technologies Group at MIT Lincoln Laboratory. In this role, he is responsible for the leadership of Advanced RF Technology efforts. The Laboratory's activities in this area include significant programs in developing future radars for air traffic control, weather surveillance, and airborne collision avoidance. Before joining Lincoln Laboratory in 1999, Dr. Herd worked in the Sensors Directorate of the U.S. Air Force Research Laboratory. From 1992-1994, he was a visiting scientist at the Institute for High Frequency Physics at the German Aerospace Research Establishment (DLR) in Munich, Germany. He received his B.S., M.S., and Ph.D. degrees, all in Electrical Engineering, from the University of Massachusetts, Amherst; he received his Ph.D. in 1989.

## **Linwood Jones**

### **Member**

LINWOOD JONES is a Professor of Electrical Engineering and Computer Science and Director of the Central Florida Remote Sensing Laboratory at the University of Central Florida. He received his PhD in Electrical Engineering from Virginia Polytechnic Institute in 1971, his MEE from University of Virginia in 1965, and his BSEE from Virginia Polytechnic Institute in 1962. Dr. Jones is an internationally recognized expert on microwave remote sensing for Earth Science applications. He has played an active role in every NASA scatterometer mission flown in space from SkyLab S-193 to the present QuikSCAT. Also, he has extensive experience in space technologies with over forty years experience in NASA, DOD and commercial space programs with strong background in satellite systems engineering, and microwave remote sensing physics and instrument design and development. He has been a developer of geophysical algorithms for passive (radiometry) and active (scatterometry) microwave remote sensors for earth observations. In 1999 he was elected Fellow of IEEE for contributions to the development and application of active microwave remote sensing technology for satellite oceanography.

## **Paul Kolodzy**

### **Member**

PAUL KOLODZY is a private consultant with Kolodzy Consulting. He provides wireless communications consultation services to Government (DoD and Civilian) and commercial customers. He received his PhD and MS in Chemical Engineering from Case Western Reserve University and his BS in Chemical Engineering from Purdue University. Prior to his work as a private consultant, he was the senior technology advisor and consultant to M2Z Networks. Before M2Z Networks he was the Director of the Center for Wireless Network Security (WiNSeC) at Stevens Institute of Technology. Prior to that, he was the Senior Spectrum Policy Advisor at the Federal Communications Commission (FCC) and Director of the Spectrum Policy Task Force charged with developing the next generation spectrum policy. Dr. Kolodzy has also been a Program Manager at the Defense Advanced Projects Agency (DARPA) in the Advanced Technology Office managing R&D for communications programs developing generation-after-next capabilities. Before DARPA, he was the Director of Signal Processing and Strategic Initiatives at Sanders (now BAE Systems), a premier electronic warfare company. Dr. Kolodzy got his start as the Group Leader and Staff Member at MIT Lincoln Laboratory working on Optical Systems for Laser Radars, Signal Processing, and Target Recognition for Acoustics, RF (SAR), and Optical signatures. Dr. Kolodzy has 20 years of experience in technology development for advanced communications, networking, electronic warfare, and spectrum policy for government, private sector and academic groups. He participated in the NRC Computer Science and Telecommunications Board's Forum on Spectrum Management Policy Reform and the 2010 spectrum study which focused on passive uses.

## **Robert Palmer**

### **Member**

ROBERT PALMER is the Tommy C. Craighead Chair in the School of Meteorology at the University of Oklahoma (OU). He is also an Adjunct Professor in the School of Electrical and Computer Engineering at OU. Dr. Palmer has a PhD in electrical engineering from the University of Oklahoma (1989). Dr. Palmer began his career as a postdoctoral fellow at the Radio Atmospheric Science Center of Kyoto University, Japan, from 1989 to 1991. His major accomplishments were the development of novel interferometric radar techniques for studies of the lower and middle atmosphere. After his time in Japan, Dr. Palmer held the position of research associate in the Physics and Astronomy Department of Clemson University where he continued his work with atmospheric radar. From 1993 to 2004, he was a member of the faculty of the Department of Electrical Engineering at the University of Nebraska-Lincoln, where his interests broadened into areas including wireless communications, remote sensing, and pedagogy. While in Nebraska, he received several awards for both his teaching and research accomplishments. Currently, Dr. Palmer serves as Associate Vice President for Research and Director of OU's interdisciplinary Advanced Radar Research Center (ARRC), which is the focal point for radar research and educational activities on the Norman campus. Since coming to OU, his research interests have been focused primarily on the application of advanced radar signal processing techniques to observations of severe weather, especially related to phased array radars and other innovative system designs. Dr. Palmer has published widely in the area of radar remote sensing of the atmosphere with over 80 peer-reviewed journal publications and 200 conference presentations. Common themes throughout this body of work include an emphasis on generalized imaging problems, spatial filter design, and clutter mitigation using advanced array/signal processing techniques. Dr. Palmer served on the NRC Committee on Evaluation of the Multifunction Phased Array Radar Planning Process.

## **Dean Paschen**

### **Member**

DEAN PASCHEN is the Director of Advanced Programs for FIRST RF Corporation. Mr. Paschen received a BSEE and MSEE from the University of Illinois in 1981 and 1982, respectively. At FIRST RF, Mr. Paschen is responsible for engineering development tasks on government R&D contracts relating to aerospace and defense applications and development of advanced radio frequency (RF) and antenna technologies. These areas include: broadband antennas, conformal antennas, and phased array antenna systems. The systems engineering supports radar, communications, electronic warfare (EW), threat neutralization, algorithms, navigation, identification, guidance, antenna pointing, seekers and fuzing, telemetry, and remote sensing. His first employment following graduate school was an antenna engineering position at Ball Aerospace & Technologies Corporation. After nearly 26 years leading to the Chief Technologist position in the antenna group at Ball, Mr. Paschen moved to FIRST RF Corporation in Boulder, Colorado. He has 15 issued patents and 11 published papers.

# **Michael W. Spencer**

## **Member**

MICHAEL W. SPENCER is the Deputy Manager for Radar Science and Engineering Section at the Jet Propulsion Laboratory (JPL). He received his PhD in Electrical Engineering from Brigham Young University. His research interests are in radar systems engineering, modeling and simulation of advanced remote sensing systems, and stochastic signal processing. Dr. Spencer came to JPL in 1990 and initially worked on modeling and simulation for the NASA scatterometer (NSCAT) instrument, a Ku-band radar launched in 1996 to measure sea-surface winds from space. He was involved as a lead systems engineer for the SeaWinds instrument (a follow-on to NSCAT) from the early conceptual design phase through launch, calibration, and operations on the QuikSCAT satellite in 1999 and again on the ADEOS-2 satellite in 2002. He continues to be interested in wind sensing from space, and has developed concepts for future high-resolution systems. More recently, Dr. Spencer has been lead payload system engineer for the development of an advanced radar for the measurement of soil moisture. For the Soil Moisture Active/Passive (SMAP) mission, he has been responsible for the design of a unique L-band synthetic aperture radar (SAR), which utilizes a large rotating mesh reflector antenna to achieve a very wide measurement swath. In addition to the above activities, Dr. Spencer has held system engineering and management roles on the Aquarius and GeoSAR projects. Previous to coming to JPL, Dr. Spencer was with the Aerospace Corporation, where he was involved with the modeling and simulation of advanced sensor systems.