Results of the U.S. National Research Council Survey of the Scientific Uses of the Radio Spectrum

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1 Abstract

The U.S. National Research Council convened a committee that was charged to develop a report which identifies scientific research areas requiring quiet spectrum, namely radio astronomy and Earth remote sensing. To do so, the report highlights the important science being conducted today which is enabled by the allocation of radio bands for scientific use. The report looks ahead 10-20 years to envision how these two scientific communities will be using the spectrum, and what changes to the spectrum regulations we should begin working on now in order to enable the science to continue to move forward.

2 Context of the Study

The current system of allocating bands in the radio spectrum was developed over fifty years ago, and a review of the needs of scientific users is in order. In recent years, the explosion of new wireless technologies has significantly increased the demand for access to the radio spectrum. The increased demand has led to discussions in both government and industry about new ways of thinking about spectrum allocation and use. Scientific users of the radio spectrum (such as radio astronomers and earth scientists using remotely sensed data) have an important stake in the policies which will result from this activity.

The scientific uses of the spectrum have changed from the early days of radio astronomy following World War II. At that time radio astronomers sought access mainly to specific narrow bands in order to conduct their research. Today radio astronomers require broader access to the spectrum in order to study new objects and phenomena. Observations of quasars, galaxies at high redshifts, and other exotic objects discovered over the past fifty years do not necessarily fall into the bands allocated for studying the hydrogen line, ammonia line, or other interesting molecules in nearby galaxies.

As the space age has progressed, a number of fields have come to rely on the ability to remotely sense terrestrial phenomena such as ocean currents or atmospheric conditions from aircraft or orbiting satellites. Thus the requirements of scientists to access to the radio spectrum have grown substantially.

Oceanographers and climatologists use the broad field of view offered by satellites in Earth orbit to analyze the ocean's temperature, salinity, and other key characteristics. These studies led to the discovery of the 'El Nino' effect, for example. Interference in the bands allocated for these activities would have a negative impact on these studies. Other fields make similar measurements from space of weather patterns, soil conditions, levels of various gases in the atmosphere, the ozone hole, etc.

Demand for spectrum from commercial and other users has also grown. The current generation of wireless electronics and communications applications has placed pressure on spectrum managers to open new areas of the spectrum for commercial use. Other technologies such as UWB devices, e.g. vehicular radars, are also threatening access to bands which are needed to conduct scientific research.

3 Task of the Study Committee

The committee was tasked to prepare a report exploring the scientific uses of the radio spectrum which:

- Portrays the science that is currently being conducted using the radio spectrum;
- Identifies the spectrum requirements necessary to conduct research;
- Identifies the anticipated future spectrum requirements for at least the next 10 years; and
- Advise spectrum policy-makers on the value to the nation of accommodating scientific uses of the spectrum, recognizing the need to balance multiple communities.

The committee will comment on the spectrum use by the relevant scientific communities but will not make recommendations on the allocation of specific frequencies.

In general, the goal of this study is to highlight the scientific research that is being conducted using the radio spectrum, and show how the spectrum is used by researchers. A further is to examine ways in which scientific users have partnered with other services in the past, and identify areas of potential collaboration.

The study surveys the methods by which the scientific community uses the radio spectrum to gather and transmit data and identify important advances in scientific knowledge that result from these activities. By gathering all of these uses in one report, the study provides a comprehensive picture of today's scientific uses of the spectrum. This report is a reference of lasting value to scientists, engineers, and government officials who work on spectrum management and allocation issues.

An additional goal of the study process is to facilitate increased communication across the various fields of scientific inquiry. Better communication will enable scientists to identify common problems that they face and share ideas for mitigating or solving these problems. Further, the study enables the diverse communities to identify common goals for future spectrum management issues and ways in which scientific users can more efficiently use the spectrum that is allocated to them.

Furthermore, the study highlights ways in which scientific users may share the spectrum with other users in order to share spectrum efficiently. Such discussions will stimulate the consideration of other areas where different spectrum users can work together.

4 Scientific Background

4.1 Radio Astronomy

Radio astronomy is a vitally important tool used by scientists to study our universe. It was through the use of radio astronomy that scientists discovered the first planets outside the solar system, circling a distant pulsar. Measurements of radio spectral line emission have identified and characterized the birth sites of stars in our own galaxy, and the complex distribution and evolution of galaxies in the universe. Radio astronomy measurements have discovered ripples in the cosmic microwave background, generated in the early universe, which later formed the stars and galaxies we know today. Observations of supernovas have allowed us to witness the creation and distribution of heavy elements essential to the formation of planets like Earth, and of life itself. Radioastronomical spectral line observations have enabled the study of interstellar chemistry and organic molecules in space that are likely pre-biotic in origin.

As passive users of the spectrum, radio astronomers have no control over the frequencies at which atoms and molecules radiate or over the character of the "transmitted" signal. These frequencies are set by the laws of nature. The emissions that radio astronomers measure are extremely weak--a typical radio telescope receives less than one-trillionth of a watt from even the strongest cosmic source, and as many as 7 orders of magnitude less (one tenth of one billionth of one billionth of a watt) from the weakest. Because radio astronomy receivers are designed to pick up such remarkably weak signals, such facilities are therefore particularly vulnerable to interference from in-band emissions, spurious and out-of-band emissions from licensed and unlicensed users of neighboring bands, and those that produce harmonic emissions that fall into the radio astronomy bands.

In addition to the gains in scientific knowledge that result from radio astronomy, such research spawns technological developments that are of direct and tangible benefit to the public. For example, radio astronomy techniques have contributed to advances in medical imaging, the understanding of plate tectonics and earthquakes, and wireless telephone geographic location technologies such as those used in connection with the U.S. Federal Communication Commission's (FCC) Emergency-911 requirements.

Continued development of new critical technologies from passive scientific observation of the spectrum depends on scientists having continued access to interference-free spectrum. More directly, the underlying science undertaken by the observers cannot be performed without access to interference-free spectrum. Loss of such access constitutes a loss for the scientific and cultural heritage of all people, and humanity, as well as for the practical applications from the information learned and the technologies developed.

4.2 Earth Remote Sensing

Earth remote sensing is a critical and unique resource for monitoring and measuring weather and climate information on both a research and an operational basis. Satellite-based microwave remote sensing represents the only practical method of obtaining uniform-quality atmospheric and surface data encompassing the most remote oceans as well as densely populated areas of Earth. Remotely-sensed data have contributed substantially to the study of meteorology, atmospheric chemistry, oceanography, and global climate change. Currently, instruments operating in the remote sensing bands provide regular and reliable quantitative atmospheric, oceanic, and land measurements to support an extensive variety of scientific, commercial, and government (civil and military) data users. Major governmental users of remotely-sensed data include the National Oceanic and Atmospheric Administration (NOAA), the National Science Foundation (NSF), the National Aeronautics and Space Administration (NASA), and the Department of Defense (DOD, especially the U.S. Navy). Applications of the data include weather forecasts for use in the energy industry; military and civilian aviation and sailing; hurricane and severe storm warning and tracking; tsunami prediction; flood monitoring; seasonal and inter-annual climate forecasts and monitoring; observation and prediction of El Niño effects on agricultural production; studies of the ocean surface and internal structure; and monitoring of changes in vegetation cover, snow cover, water resources, and ozone holes, as well as many other critical areas. These measurements are extremely important, yet extremely vulnerable to in-band and out-of-band interference due to the extreme sensitivity needed to extract the needed information.

5 Conclusion and Final Justification

The NRC Spectrum Study Committee requests a session at the August 2008 URSI General Assembly for the co-chairs to report the committee's findings and recommendations directly to the radio science and spectrum policy communities. Communicating to a broad audience is critical to the report's impact and its recommendations that bear directly upon radio astronomy, Earth remote sensing, and spectrum policy in general. Marshall C. Cohen, Caltech, and Albin J. Gasiewski, University of Colorado at Boulder (committee co-chairs) will conduct the session.

Appendixes

A.1 Roster of the Committee to Survey the Scientific Uses of the Radio Spectrum and Web Site Information

Committee Membership

Marshall H. Cohen, California Institute of Technology, Co-Chair
Albin J. Gasiewski, University of Colorado at Boulder, Co-Chair
Donald Backer, University of California, Berkeley
Roberta Balstad, Columbia University
Steven W. Ellingson, Virginia Polytechnic Institute and State University
Darrel Emerson, National Radio Astronomy Observatory
Aaron S. Evans, Stony Brook University
Joel Johnson, The Ohio State University
Paul Kolodzy, Kolodzy Consulting, LLC

David Kunkee, The Aerospace Corporation
Molly K. Macauley, Resources for the Future, Inc.
James M. Moran, Harvard-Smithsonian Center for Astrophysics
Lee G. Mundy, University of Maryland at College Park
Timothy J. Pearson, California Institute of Technology
Christopher Ruf, University of Michigan
Frederick S. Solheim, Radiometrics Corporation
David H. Staelin, Massachusetts Institute of Technology
Alan B. Tanner, Jet Propulsion Laboratory

NRC Staff
Don Shapero, Director, Board on Physics and Astronomy
Brian Dewhurst, Program Officer, Aeronautics and Space Engineering Board
David Lang, Associate Program Officer, Board on Physics and Astronomy

The committee keeps a web page at http://www7.nationalacademies.org/bpa/Spectrum_Study_Home.html.