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

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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 Earth remote sensing and radio astronomy. The committee's final report, *Spectrum Management for Science in the 21st Century,* [4] released November 2009, highlights the important science being conducted today that is enabled by the allocation of radio bands for scientific use. The report also looks ahead 10-20 years to envision how these two scientific communities will be using the spectrum, and what changes to spectrum regulations we should begin working on now in order to enable the science to continue to move forward.

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

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[4] The committee's final report, *Spectrum Management for Science in the 21st Century,* is available for free download at http://www.nap.edu/catalog.php?record_id=12800.

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

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 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.

4.2 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.

4.3 Technology Development and Mitigation Strategies

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. Spinoffs from Earth remote sensing techniques include instrument calibration, image processing, radio detection methods, and radio imaging techniques.

The EESS and RAS services have classically limited the impact of interference by using mitigation techniques. However, there are physical limits to the capacity of the "unilateral" techniques that typically have been used, and they often do not provide adequate protection from interference. Recently, new techniques have been suggested, in which the active and passive users of the RF spectrum collaborate in order to share the spectrum. These "cooperative" mitigation techniques may provide a potential for meeting the expanding spectral needs of the passive sensing community.

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 The committee's final report, *Spectrum Management for Science in the 21st Century*:
Available for free download at http://www.nap.edu/catalog.php?record_id=12800.

A.2 Roster of the Committee to Survey the Scientific Uses of the Radio Spectrum:
Available at: http://sites.nationalacademies.org/BPA/BPA_048593