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Spectrum Management for Science in the 21st Century

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The U.S. National Research Council's Committee on Radio Frequencies (CORF) has just finished overseeing the completion of "Spectrum Management for Science in the 21st Century," a report aimed at protecting the scientific use of the radio and microwave spectrum. The report attempts to lay the foundation of an effort to identify the needs of radio astronomy and Earth remote sensing, to identify the benefits of these two activities, and to develop the practical, forward-looking approaches to spectrum access that are needed to ensure the necessary conditions for their important observations. The committee focused on three major topics: Earth remote sensing (Chapter 2), radio astronomy (Chapter 3), and interference mitigation and technology (Chapter 4). The committee process included an in-depth study of each of the topics of these chapters, including the current and expected future status of Earth remote sensing and radio astronomy and applicable radio frequency interference mitigation technologies. A series of findings were developed from these chapters, and an associated series of recommendations to help ensure the viability of these scientific endeavors were made. The findings and recommendations are detailed in Chapter 5. The Spectrum Study is available (free of charge for personal use) as a pdf download at http://www.nap.edu/catalog.php?record_id=12800 The Executive Summary of the Report is reprinted here, by permission of the US National Academy of Sciences.

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[1] Speaker

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Executive Summary

Natural radio emissions from objects as diverse as hurricanes and distant galaxies yield vital information about the planet Earth and its place in the Universe. Observations of Earth are central to weather forecasting and climate studies, and radio observations of the cosmos are similarly critical for increasing our understanding of the Universe and answering grand questions such as that on the origin of planets. Such information is gathered by geoscientists using complex Earth-orbiting satellites and ground-based equipment and by radio astronomers using large, ground-based radio telescopes. Signals from natural radio emissions are extremely weak, and the equipment used to measure them is becoming more and more sophisticated and sensitive.

The radio spectrum is also being used by radiating, or "active," services, ranging from aircraft radar to rapidly expanding consumer services such as cellular telephony and wireless Internet. These valuable active services transmit radio waves and thereby potentially interfere with the receive-only, or "passive" scientific services, which do not radiate. Transmitters for the active services create an artificial "electronic fog," which can cause confusion and, in severe cases, totally blind the Earth Exploration Satellite Service (EESS) and Radio Astronomy Service (RAS) receivers.

Both the active and the passive services are increasing their use of the spectrum, and so the potential for interference, already strong, is also increasing. This tension between the active services' demand for greater spectrum use and the passive users' need for quiet spectrum is at the heart of this report's discussion and motivates the findings and recommendations of the study committee—the National Research Council's Committee on Scientific Use of the Radio Spectrum.

Many billions of dollars have been invested in the nation's radio astronomy and Earth remote sensing facilities. The public marvels at new discoveries made at radio astronomy observatories, and the nation remains ever more reliant on accurate and up-to-date weather and climate information retrieved from Earth remote sensing satellites. The use of the radio spectrum to obtain these observations is regulated and protected in accordance with national and international spectrum rules, but the relatively recent proliferation of wireless technology is challenging engineers' abilities to mitigate unwanted interference from the active services.

Complex rules govern the occupancy and use of the electromagnetic spectrum, both nationally and globally, but these rules have not adequately evolved with technology. Inefficiencies in spectrum use exist while demand increases, and most regulations are not aligned with or even cognizant of the special needs of passive scientific users. These issues are identified in this report, and addressing them presents the nation with an exceptional opportunity to adapt to the wireless revolution while protecting the passive users of the radio spectrum.

The radio spectrum is a finite resource that has been managed as such for the past 70 years by the federal government. This management enabled the growth of strong commercial and scientific communities. The endless pursuit of better techniques to leverage the unique characteristics of the radio spectrum has led to discoveries and innovations of enormous scientific and societal value. Over the past 20 years, rapid technological improvements have exponentially increased the capabilities of scientific, commercial, and government users. But today, the current regulatory regime is straining to enable the capabilities and meet the needs of the various communities of users. A new path is needed to preserve access to the radio spectrum, in which important scientific discoveries are made and civilian and government remote sensing operations are conducted, while allowing for growth that serves an increasingly mobile society. This Summary presents the report's key findings and recommendations.

Finding: Passive remote sensing observations are essential for monitoring Earth's natural systems and are therefore critical to human safety, the day-to-day operations of the government and the private sector, and the policy-making processes governing many sectors of the U.S. economy.

Finding: Radio astronomy has great potential for further fundamental discoveries, including the origins and evolution of the Universe, the nature of matter, and life in other solar systems, which will have an enormous impact on our understanding of fundamental physics and the place of humanity in the universe.

Recommendation: Recognizing that the national investment in passive radio astronomy and Earth remote sensing is dependent on access to the radio spectrum, the committee recommends that the Federal Communications Commission (FCC) and the National Telecommunications and Information Administration (NTIA) ensure that access to spectrum for passive radio and microwave observations of Earth environmental variables and radio astronomical observations of the sky is protected in the development of future spectrum policy.

Technological innovations continue to increase the utility of the radio spectrum. The advent of new technologies designed to exploit the diversity of the radio spectrum in space, frequency, polarization, and time will increase the efficiency of its use. However, the current means for managing spectrum use must be changed, as the current policies threaten to thwart scientific discovery, diminish the usefulness of critical environmental observations, and limit economic growth because of the inefficient use of finite spectral resources. Therefore, new spectrum management policies need to be explored for the sake of ensuring these critical national capabilities.

Finding: Radio wave bands (10 MHz to 3 THz) are indispensable for collecting information associated with specific astronomical and environmental phenomena. Often the same bands are equally indispensable for both passive Earth remote sensing and radio astronomy, and the passive nature of both services enables them to share the spectrum

productively. Currently, 2.07 percent of the spectrum below 3 GHz is allocated to the RAS and EESS on a primary basis, and 4.08 percent is allocated on a secondary basis (measured in Hertz).

Finding: Important scientific inquiry and applications enabled by the Earth Exploration Satellite Service and the Radio Astronomy Service are significantly impeded or precluded by radio frequency interference (RFI). Such RFI has reduced the societal and scientific return of EESS and RAS observatories and necessitates costly interference mitigation, which is often insufficient to prevent damage from RFI.

Finding: Better utilization of the spectrum and reduced RFI for scientific as well as commercial applications are possible with better knowledge of actual spectrum usage. Progress toward these goals would be made by gathering more information through improved and continuous spectral monitoring. This would be beneficial to both the commercial and the scientific communities.

Recommendation: The Department of Commerce/National Telecommunications and Information Administration (NTIA), in collaboration with the National Science Foundation (NSF), NASA, and the National Oceanic and Atmospheric Administration (NOAA), should spearhead the development of a national spectrum assessment system that measures the radio frequency (RF) environment with appropriately high resolution in time, space, and frequency for purposes of spectrum development and management, based on the spectral and spatial density of emitters.

The next generation of spectrum management policies must enable better sharing of the spectrum as well as diminishing the impact that users have on the RF spectrum. This can be done by exploiting currently available technologies and hastening the development of nascent technologies. New policies should encourage the following:

• The development of the means for direct interaction between active and passive spectrum users to protect current and future scientific uses of the spectrum. The nation needs to provide the policies that will make the spectrum more useful and productive for all users.

Recommendation: The EESS and RAS communities should be provided additional support through NSF, NASA, and NOAA to increase their participation in spectrum management forums within the International Telecommunication Union (ITU), FCC, NTIA, and other organizations. The goal of such participation is to foster outreach, advance the understanding of interference and regulation issues, and initiate mutual cooperation for interference mitigation.

• The development and implementation of technology to address RFI for current and future satellite systems to ensure that the national investment in scientific uses of the spectrum is preserved.

Recommendation: Investment in the development of mitigation technology should be increased so that it is commensurate with the costs of data denial that result from the use of systems without mitigation. To this end, NSF and NASA should support research and development for unilateral RFI mitigation technology in both EESS and RAS systems. NASA, NOAA, and the Department of Defense should require that appropriate RFI analyses and tests and practical RFI mitigation techniques be applied to all future satellite systems carrying passive microwave sensors.

• A regulatory environment that enables sharing the spectrum in both space and time. This is a "win-win" scenario that will enable additional scientific uses without impacting commercial development.

Recommendation: The NSF, NASA, and NTIA should jointly support research and development for cooperative RFI mitigation techniques and the associated forums As discussed in Chapter 4. and outreach necessary to enable the development of standards for greater spectral utilization and interference avoidance.

Recommendation: As cooperative spectrum-sharing techniques come into use, NSF and NASA spectrum managers should work with the regulatory agencies to enable observations that require an extremely wide spectral range. Such observations would provide a useful metric for the effectiveness of spectrum-sharing techniques for the passive services. These new initiatives are not easy, nor will they make success a certainty. It will take a national effort to understand clearly the needs of both communities, scientific and commercial, and to motivate each to make the choices necessary to enable greater access for each to the radio spectrum. The next generation of scientific users of the radio spectrum needs to be afforded the capacity to develop the technology to seek new horizons.

Recommendation: The Office of Science and Technology Policy should create a new, permanent, representative technology advisory body to identify technical and regulatory opportunities for improving spectrum sharing among all active and passive users, both government and nongovernment. In one sense, spectrum used for passive purposes, including Earth remote sensing and radio astronomy, can be likened to parkland preserved for public use. The true societal value of small parcels of land, especially in crowded urban areas, defies monetization, and proactive measures are required to ensure the preservation and shared use of such land. A small fraction of the radio spectrum allocated for passive purposes performs a similarly valuable societal function and requires proactive management to remain available—in this case for scientific purposes.

The passive services both offer a critical return to society through operations in support of environmental prediction and provide scientific intellectual value. Although the impacts of the passive services are difficult to quantify, they are valuable to society for providing vital information for climate and weather studies and in allowing astronomical studies of the heavens. The quiet radio bands, like public parks, deserve protection.

It would be in the strongest interests of the nation to ensure that access to spectrum for scientific purposes is maintained during the coming decades. The committee's recommendations provide a pathway for putting in place the regulatory mechanisms and associated supporting research activities necessary to accomplish this important task. The committee believes that such a pathway will also lead to greater efficiency in the active use of the spectrum, which should benefit all direct and indirect consumers of wireless telecommunications and data services.

References

[1] *Spectrum Management for Science in the 21st Century* http://www.nap.edu/catalog/12800.html pp. 1-5, Copyright © National Academy of Sciences, reprinted by permission.