RADIO RECEIVER SYSTEMS R&D INNOVATION NEEDS:

RECOMMENDATIONS OF THE WIRELESS SPECTRUM R&D INTERAGENCY WORKING GROUP

Prepared by the

WIRELESS SPECTRUM R&D INTERAGENCY WORKING GROUP

NETWORKING & INFORMATION TECHNOLOGY
RESEARCH & DEVELOPMENT SUBCOMMITTEE

COMMITTEE ON S&T ENTERPRISE

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About the Wireless Spectrum R&D Interagency Working Group

Federal agency members of the Wireless Spectrum R&D (WSRD) Interagency Working Group (IWG) work together to coordinate spectrum-related R&D activities both across the Federal government and with the private sector and academia under the auspices of the Networking and Information Technology Research and Development (NITRD) Subcommittee of the NSTC's Committee on Science and Technology Enterprise. The group's purpose is to facilitate efficient and effective investment in the advancement of spectrum-sharing technologies and systems, consistent with the WSRD IWG's guiding principles, which are transparency, smart investment, and solicitation of opportunities for technology transfer across and beyond the Federal government. More information is available at https://www.nitrd.gov/groups/wsrd.

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Background

The Wireless Spectrum R&D Interagency Working Group (WSRD IWG) of the Networking and Information Technology Research and Development (NITRD) Program brings together Federal agency experts to coordinate spectrum-related research and development activities both across the Federal government and with academia and the private sector, and to facilitate efficient and effective investment in spectrum sharing technologies and systems. Spectrum provides the “transmission lines” for communications between individuals and devices, and increasingly, between devices. It impacts almost every aspect of our daily lives, including technologies connecting family members or soldiers on the battlefield, drones delivering packages or collecting intelligence, satellites predicting snow, and spacecraft transmitting images of the surface of Mars. With the rapid expansion of wireless devices, many traditional spectrum use paradigms are being challenged and modified to accommodate the increasing demand. The WSRD IWG has examined nine different areas of R&D that could improve spectrum access and support innovation in both the Federal and commercial sectors. The set of recommendations contained in this report focus on what changes could be made in the radio receiver system to accomplish these goals. It includes recommendations that apply to five groups of stakeholders: receiver researchers, receiver system designers, manufacturers, regulators, and service providers.

Traditionally, spectrum was allocated to avoid interference of radio signals using frequency division (you transmit on this wave length, I’ll use a different one); time division (you can use it now, I will use it later); or geographic division (you can use it here, I will use it over there). But the explosion of wireless data service applications—from cellular networking to health, transportation, manufacturing, IoT, and drones—is driving innovation in modern radio systems. Many systems are moving to the use of wideband[1] spectrum to increase their capabilities and performance. This reliance on wideband requires radio systems with increased functionality in both transmitters and receivers. Improving overall system performance depends heavily on receivers that can handle increased spectrum congestion and interference.

Receiver design needs to be viewed from a systems approach, considering the full receiver processing chain to fully characterize and quantify receiver performance. The system elements include the antenna, filter, receiver circuits, analog-to-digital conversion, and digital signal processing components. Up-front system engineering is needed for more refined spectrum sharing approaches to reduce overall interference. In addition, receiver and transmitter designers must balance performance metrics (e.g., sensitivity, selectivity, and efficiency) and costs.

[1] Wideband is a transmission medium or channel that has a wider bandwidth than one voice channel (with a carrier wave of a certain modulated frequency). This term is usually contrasted with narrowband. http://searchnetworking.techtarget.com/definition/wideband

Recommendations of the WSRD IWG

To address the challenges of the rapidly changing landscape for radio receivers, the WSRD IWG developed recommendations for Federal R&D, standards development, and policy in radio receiver systems that imply coordination and collaboration with the private and academic sectors. WSRD held internal interagency discussions that included reviewing individual participant input from a May 2017 IWG workshop that included non-Federal experts from across the wireless research community.[2]

Based on the information gathered, the WSRD IWG recommends that research, whether public or private, focus on the following areas of radio receiver characteristics, technology standards development and adoption, and related policy issues:

1. **Receiver researchers and designers should address the full receiver processing chain and balance performance and costs while also considering energy efficiency, spectrum sharing, and interference impacts in sufficient detail:**
    a. Improve spectrum efficiency by developing full duplex-type designs.
    b. Improve channel prediction, using novel concepts such as big data analytics and real-time machine learning to increase receiver system performance and reduce policy burdens, and to enhance operations in high-interference environments for either narrowband or wideband systems.
    c. Advance research on phased arrays, smart antennas, and multiple-input/multiple-output (MIMO) techniques to form antenna beams dynamically and thereby reduce interference (spatially) and enhance data throughput.
    d. Continue to advance technology for low power consumption and reduced heat generation in receivers.
    e. Adapt and adopt appropriate spectrum sharing strategies and receiver implementation from the medical field.
2. **System designers and regulators should adopt standard approaches to capture and understand complex receiver system performance all the way from the antenna/front-end hardware physical layer to the application layer:**
    a. Improve methods for characterizing and testing receivers.
    b. Expand autonomous technologies toward multiband receiver access systems.
    c. Study spectrum convergence in receiver systems and their ability to adapt to various applications, including those related to the Internet of Things (IoT).
    d. Conduct research on monitoring and crowd-sourcing receiver data for situational awareness and for improving R&D efforts.
    e. Develop innovative methods to improve performance and assure secure and private information transfer across receiver systems.
    f. Study and consider the statistical dynamics of harmful interference, including risk-informed interference assessment techniques, and make those dynamics a key support component for enforcement policy development and receiver protection.

[2] More workshop information is available at https://nitrd.gov/nitrdgroups/index.php?title=WSRD_Workshop_IX .

3. **Manufacturers, service providers, and regulators should:**
    a. Develop processes to protect legacy systems and devices, including IoT in critical areas such as medical devices, cellular networks, and defense systems.
    b. Define key receiver design attributes and standards to improve receiver system performance in shared and congested spectrum environments.
    c. Define high-level receiver performance and "benchmark" goals for spectrum sharing and coexistence policies.
    d. Provide end users with quality metrics (or service performance measures) to inform their purchase decisions.
    e. Improve coordination and collaboration between receiver manufacturers to overcome intellectual property considerations for better receiver design and performance optimization.
    f. Advance large-scale and smaller testbeds to test and integrate receiver systems and to collaborate on innovations among the stakeholders.
4. **Service providers should address evolving and changing standards both during and after deployment of radio systems when the technology offers significant system capabilities and complex functionality.**