# The Importance of Spectrum Measurements

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Understanding actual usage of spectrum, versus spectrum allocations, has always been a challenge, even for regulatory agencies, such as the Federal Communications Commission (FCC) and the National Telecommunication and Information Administration (NTIA) in the U.S., and other national regulatory agencies worldwide. This is true for both federal and non-federal allocations. While there have been numerous past attempts to establish "spectrum observatories", such as in [1], there is still no scalable, pervasive methodology that measures spectrum usage in different frequency bands in close to real-time. Hence, every spectrum proceeding that proposes spectrum sharing inevitably faces the same hurdle: how does one share spectrum efficiently if there are almost no measurements of actual spectrum usage? On August 3, 2023, the FCC voted to adopt a Notice of Inquiry (NOI) [2] in an attempt to understand how the agency might obtain information on non-federal spectrum usage to better inform future proceedings. While this is a welcome first step, a similar effort towards understanding federal spectrum usage is also necessary, especially since many of the proposed bands for future sharing, for example in 7–24 GHz, have primarily federal incumbents.

## Spectrum Data Available Today

Most information on spectrum usage available today is through largely static databases, such as the Universal Licensing System (ULS) and Experimental Licensing System (ELS) databases of licensees maintained by the FCC. Shared spectrum systems, such as Television White Spaces and standard power unlicensed 6 GHz, derive protection contours for incumbents in these bands based on the information about location, frequency of operation, bandwidth, transmitted power, antenna gain, etc., contained in these databases, along with propagation models. There is no mechanism to supplement the static information with real-world measurements of spectrum usage. Hence, the efficiency of spectrum sharing using such data is limited by the accuracy of propagation models, many of which may not be band-specific and ignore the effects of clutter.

Internationally, the International Telecommunications Union (ITU) requires administrations to periodically monitor spectrum usage in their jurisdictions. Some countries, such as China, the U.K., Switzerland, and Canada have limited spectrum monitoring efforts underway to inform regulators as they frame spectrum policy. A common limitation of these measurement efforts is that they are usually spatially sparse and limited in the frequency range being measured. This is partly due to the cost of wide-band spectrum sensors and the infrastructure requirements for maintaining such a spectrum database and keeping it updated accurately.

## Defining and Measuring Spectrum Utilization

The NOI seeks comments on how to define spectrum utilization. This is a question that has vexed many in past efforts into spectrum measurements. Services such as public safety and radars may not occupy their allocated bands all the time or everywhere, whereas fixed links are often required to never turn off as part of their license agreement. Clearly, then, spectrum occupancy and utilization are functions of the service deployed in the band and measurements need to account for this. Such considerations add complexity and expense to any spectrum measurement method, but are essential to determining spectrum occupancy and if a particular band can be shared with another service. With the advent of smart antennas and access protocols that do not transit energy uniformly, in time and space, defining and measuring spectrum utilization can be even more difficult. For example, fixed microwave links are usually highly directional, with beamwidths of a few degrees. Spectrum measurements made off-axis to the main beam may not indicate that the band is occupied. However, a knowledge of allocations can help in ensuring that measurements are interpreted correctly. On the other hand, cellular and Wi-Fi signals broadcast known reference signals periodically: these can be detected reliably at fairly low signal levels even by consumer devices. When signal structure is known, such as in standards-based commercial wireless systems, a more accurate measurement can be derived by using correlation. In systems using proprietary signal structures, energy detection may be the only option, though one could reverse engineer the signal to determine the structure, as was recently presented in [3], where the Starlink signal structure is deduced from I/Q measurements made with a software-defined-radio (SDR).

## Options for Spectrum Measurements

The NOI seeks input on spectrum measurement methodologies, from low-cost, perhaps crowdsourced methods to high-cost, static sensors. Low-cost sensors, such as RadioHound [4], can be deployed in larger numbers, but the sensitivity of each sensor may be limited. Nevertheless, such methods can be instrumental in understanding spatial spectrum utilization at scale. Spectrum occupancy and utilization of all Wi-Fi (2.4 GHz, 5 GHz, and 6 GHz) and cellular bands (low, mid, and high bands) can be extracted from most Android phones using APIs [5 – 7] without the need for root access and offers another cost-effective way to crowdsource measurements on these bands. This approach was adopted by the FCC in a pilot project undertaken along with the US Postal Service in 2021 to understand cellular coverage [8]. At the higher end of cost and complexity, devices such as PRisM [9] also offer an option to crowdsource measurements using a smartphone interface, but can also provide general-purpose spectrum measurements in addition to specific cellular information. Platforms, such as those provided by thinkRF [10] and SDR-based sensors mounted in fixed locations, can also fill out the spectrum picture, especially in non-federal bands.

No matter how spectrum utilization and occupancy data is gathered, it is challenging to keep this data updated, curated, and available to researchers. Hence, attention needs to be paid to the data infrastructure requirements as well. There have been multiple federally funded projects that have attempted to create a single spectrum repository, but such a database has yet to be realized. Furthermore, many non-federal bands of interest are above 6 GHz, such as the satellite bands, and there are almost no spectrum databases that contain spectrum utilization and occupancy data for these bands since there are no cost-effective SDRs that operate above 6 GHz.

## Conclusions

Once again, the importance of measurements to sound spectrum policy is being emphasized by the FCC, creating an opportunity for researchers engaged in spectrum measurements to expand their efforts into new spectrum bands and developing standardized interfaces for crowdsourcing measurements from various sources. Future spectrum policy will, by necessity, have to consider sharing between federal and non-federal systems and hence understanding spectrum utilization and occupancy will becoming increasingly important not only for non-federal bands as specified in the NOI but federal bands as well.

## References


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## Biography


Monisha Ghosh (mghosh3@nd.edu) is a Professor of Electrical Engineering at the University of Notre Dame and a member of the Notre Dame Wireless Institute. She is also the Policy Outreach Director for SpectrumX (https://www.spectrumx.org/ ), the first NSF Center for Spectrum Innovation, and the co-chair of the FCC's Technological Advisory Council (TAC) Working Group on Advanced Spectrum Sharing. Her research interests are in the development of next generation wireless systems: cellular, Wi-Fi, and IoT, with an emphasis on spectrum sharing, coexistence, and applications of machine learning to improve network performance. Prior to joining the University of Notre Dame in 2022, she was the chief technology officer at the Federal Communications Commission, a Program Director at the National Science Foundation, Research Professor at the University of Chicago, and spent 24 years in industry research at Bell Labs, Philips Research and Interdigital working on a wide variety of wireless systems: HDTV, Wi-Fi, TV white spaces, and cellular. She obtained her B.Tech from IIT Kharagpur in 1986 and Ph.D. from USC in 1991.